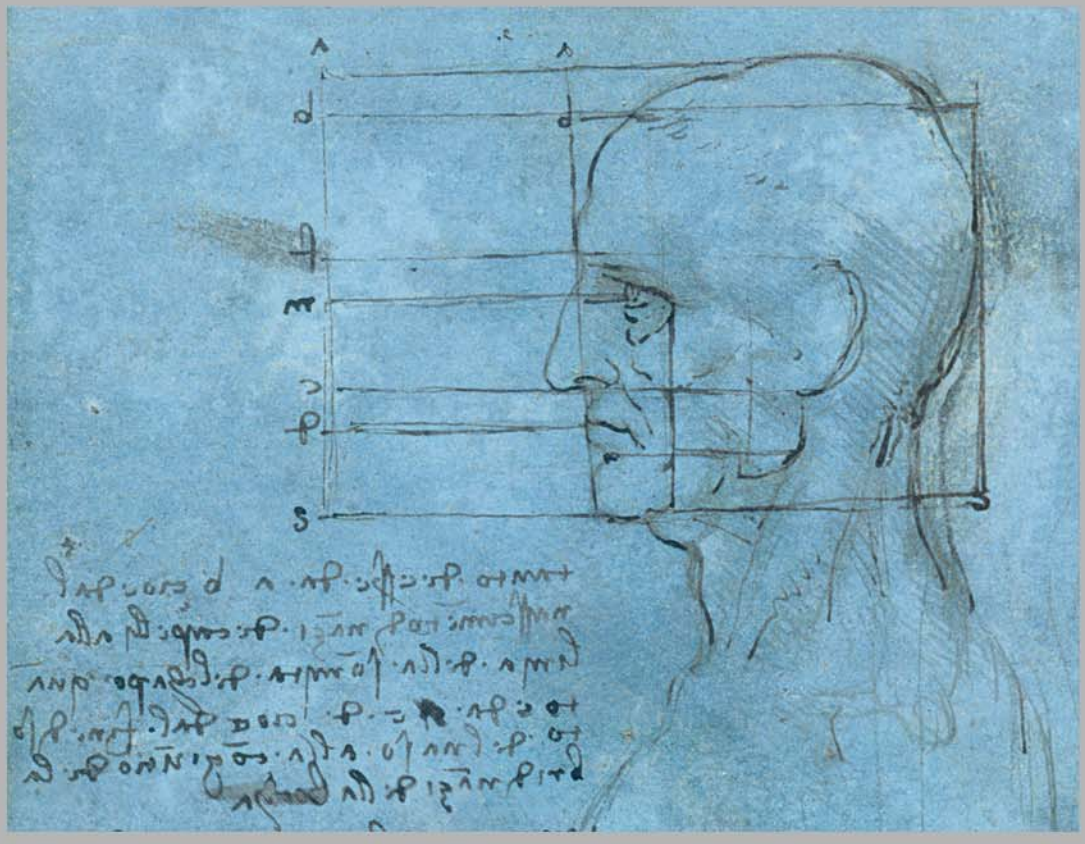
Facial Plastic and Reconstructive Surgery

second edition



Ira D. Paper

John Frodel
G. Richard Holt
Wayne F. Larrabee
Nathan Nachlas
Stephen S. Park
Jonathan M. Sykes
Dean Toriumi

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ЗНАНИЕ

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second edition

Edited by

Ira D. Papel, M.D.
Associate Professor
Division of Facial Plastic Surgery
Department of Otolaryngology–Head and Neck Surgery
The Johns Hopkins Hospital
Facial Plastic SurgiCenter
Owings Mills, Maryland

Associate Editors

John Frodel, M.D.
Associate Professor
Division of Otolaryngology–Plastic
and Reconstructive surgery
University of Mexico Health Sciences Center
Albuquerque, New Mexico

G. Richard Holt, M.D., M.S.E., M.P.H.
Lecturer in Facial Plastic and Reconstructive Surgery
Department of Otolaryngology–Head and Neck Surgery
Johns Hopkins School of Medicine
Baltimore, Maryland

Wayne F. Larrabee, M.D., M. P. H.
Clinical Professor
Department of Otolaryngolgy–Head and Neck Surgery
University of Washington
Seattle, Washington

Nathan Nachlas, M.D.
Boca Raton Center for Facial Plastic Surgery
Boca Raton, Florida

Stephen S. Park, M.D.
Director, Division of Facial Plastic Surgery
Department of Otolaryngology–Head and
Neck Surgery
University of Virginia
Charlottesville, Virginia

Jonathan M. Sykes, M.D., F.A.C.S.
Professor of Otolaryngology
Director, Facial Plastic and Reconstructive Surgery
University of California at Davis Medical Center
Sacramento, California

Dean Toriumi, M.D.
Division of Facial Plastic and Reconstructive Surgery
Department of Otolaryngology–Head and
Neck Surgery
Eye and Ear Infirmary
University of Illinois at Chicago
Chicago, Illinois

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Editorial Assistant: Diane Sardini
Director, Production and Manufacturing: Anne Vinnicombe
Production Editor: Becky Dille
Marketing Director: Phyllis Gold
Sales Manager: Ross Lumpkin
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Contributors

Peter A. Adamson, M.D., F.R.C.S.C., F.A.C.S.
Professor of Otolaryngology
Department of Otolaryngology
Toronto General Hospital
University of Toronto
Toronto, Ontario
Canada

Min Ahn, M.D.
Oakland, California

Donald J. Annino, M.D., D.M.D.
Assistant Professor
Department of Otolaryngology–Head and Neck Surgery
New England Medical Center
Tufts University School of Medicine
Boston, Massachusetts

Richard Arden, M.D.
Farmington Hills, Michigan

Shan R. Baker, M.D.
Professor and Chief
Facial Plastic and Reconstructive Surgery
Department of Otolaryngology–Head and Neck Surgery
and
Director
Center for Facial Cosmetic Surgery
University of Michigan
Livonia, Michigan

Daniel G. Becker, M.D., F.A.C.S.
Associate Professor and Director
Division of Facial Plastic and Reconstructive Surgery
Department of Otolaryngology–Head and Neck Surgery
University of Pennsylvania Hospital
Philadelphia, Pennsylvania

Richard G. Bennett, M.D.
Clinical Professor of Medicine (Dermatology)
Department of Medicine, Dermatology Division
University of California at Los Angeles
Santa Monica, California

William J. Binder, M.D.
Assistant Clinical Professor
Department of Head and Neck Surgery
University of California at
Los Angeles Medical Center
Los Angeles, California

Andrew Blitzer, M.D., D.D.S.
Professor of Clinical Otolaryngology
Columbia University
New York, New York

Mitchell F. Brin, M.D.
Bachman–Strauss Associate Professor
Department of Neurology
Mount Sinai Medical Center
New York, New York

Daniel Buchbinder, D.M.D.
Professor
Oral and Maxillofacial Surgery
and Otolaryngology
Mount Sinai School of Medicine
New York, New York

Alan J.C. Burke, MD
Fellow, Facial Plastic Surgery
Department of Otolaryngology–Head and Neck Surgery
University of Oregon Health Sciences Center
Portland, Oregon

Brian B. Burkey, M.D.
Associate Professor
Department of Otolaryngology
Vanderbilt University School of Medicine
Nashville, Tennessee

Paul J. Carniol, M.D.
Clinical Associate Professor
Department of Surgery
University of Medicine and Denistry
Summit, New Jersey

Benjamin S. Carson, Sr., M.D.
Director
Division of Pediatric Neurosurgery
and
Professor
Neurosurgery, Plastic Surgery, Oncology, and Pediatrics
The Johns Hopkins School of Medicine
Baltimore, Maryland

Maria S. Chand, M.D., F.A.C.S.
Assistant Professor
Department of Otolaryngology–Head and Neck Surgery
Indiana University
Indianapolis, Indiana

Donn R. Chatham, M.D.
Clinical Instructor
Department of Otolaryngology
University of Louisville
Louisville, Kentucky

Ted A. Cook, M.D., F.A.C.S.
Professor
Department of Otolaryngology–Head and Neck Surgery
Oregon Health and Science University
Portland, Oregon

Peter D. Costantino, M.D.
Associate Professor of Clinical Otolaryngology–Head and Neck Surgery
Department of Otolaryngology–Head and Neck Surgery
St. Luke's–Roosevelt Medical Center
New York, New York

J. Madison Clark, M.D.
Assistant Professor, Director
Division of Facial Plastic and Reconstructive Surgery
Department of Otolaryngology–Head and Neck Surgery
Medical University of South Carolina
Charleston, South Carolina

John R. Coleman, Jr., M.D.
Atlanta Center for Ear, Nose, and Throat and Facial Plastic Surgery
Atlanta, Georgia

Roger L. Crumley, M.D.
Professor and Chair
Department of Otolaryngology–Head and Neck Surgery
University of California, Irvine
Orange, California

Steven H. Dayan, M.D.
Clincial Assistant Professor
Department of Otolaryngology
University of Illinois
Chicago, Illinois

Timothy D. Doerr, M.D.
Asistant Professor of Surgery
Division of Otolaryngology–Head and Neck Surgery
University of Rochester School of Medicine and Dentistry
Rochester, New York

David W. Eisele, M.D.
Professor and Chairman
Division of Otolaryngology–Head and Neck Surgery
University of California at San Francisco
San Francisco, California

Moshe Ephrat, M.D., F.A.C.S.
Assistant Clinical Instructor
Department of Otolaryngology
Mount Sinai Medical School
New York, New York

George W. Facer, M.D.
Professor
Department of Otorhinolaryngology
Mayo Clinic
Scottsdale, Arizona

Edmund Fisher, M.D.
Attending Physician
Department of Head and Neck Surgery
Kaiser Foundation Hospital
Woodland Hills, California

Hossam M.T. Foda, M.D.
Instructor
Division of Facial Plastic Surgery
Department of Otolaryngology–Head and Neck Surgery
Alexandria Medical School
El-Mesallah, Alexandria
Egypt

Craig D. Friedman, M.D., F.A.C.S.
Visiting Surgeon
Section of Otolaryngology
Yale New Haven Hospital
New Haven, Connecticutt
and
Director
Craniofacial Tissue Engineering
Face-md.com
Westport, Connecticutt

Jaime R. Garza, M.D., D.D.S.
Associate Professor of Plastic Surgery
Department of Surgery
and
Associate Vice President
The President's Office
University of Texas Health Science Center at San Antonio
San Antonio, Texas

Eric M. Genden, M.D.
Assistant Professor
Department of Otolaryngology
Mount Sinai School of Medicine
New York, New York

George S. Goding, Jr., M.D.
Associate Professor
Division of Otolaryngology
Hennepin County Medical Center
University of Minnesota
Minneapolis, Minnesota

H. Devon Graham, III, M.D.
Private Practice
Ochsner Clinic Foundation
Department of Otolaryngology–Head and Neck Surgery
Department of Plastic and Reconstructive Surgery
and
Clinical Assistant Professor
Department of Otolaryngology–Head and Neck Surgery
Tulane University Medical School
New Orleans, Louisiana

Steven D. Gray, M.D.
Professor
Division of Otolaryngology–Head and Neck Surgery
University of Utah School of Medicne
Salt Lake City, Utah

Michael Guarnieri, Ph.D., M.P.H.
Senior Staff
Department of Neurological Surgery
Johns Hopkins University
Baltimore, Maryland

Robert A. Guida, M.D., F.A.C.S.
Clinical Professor of Otolaryngology and Plastic Surgery
New York Presbyterian Hospital and
Cornell Weill School of Medicine
New York, New York

Matthew M. Hanasono, M.D.
Resident
Department of Otolaryngology
Stanford University Medical Center
Stanford, California

Christopher B. Harmon, M.D.

David A. Hecht, M.D.
Phoenix, Arizona

John D. Hendrix, M.D.
Dermatologic Surgery of
Central Virginia, PLC
Martha Jefferson Hospital
Charlottesville, Virginia

Peter A. Hilger, M.D., M.S.
Associate Professor
Division of Facial Plastic Surgery
Department of Otolaryngology
University of Minnesota
Edina, Minnesota

John F. Hoffman, M.D.
Associate Professor
Department of Otolaryngology–Head and Neck Surgery
University of Utah
Salt Lake City, Utah

G. Richard Holt, M.D., M.S.E., M.P.H.
Lecturer in Facial Plastic and Reconstructive Surgery
Department of Otolaryngology–Head and Neck Surgery
Johns Hopkins School of Medicine
Baltimore, Maryland

David B. Hom, M.D., F.A.C.S.
Associate Professor
Division of Facial Plastic and
Reconstructive Surgery
Department of Otolaryngology
University of Minnesota
Minneapolis, Minnesota

Henry Huang, M.D.
Fellow
Department of Facial Plastic Surgery
University of Toronto
Toronto, Ontario
Canada

Henry Huank, M.D.
Rouge Valley Health System
Ajax, Ontario
Canada

Sara A. Kaltreider, M.D.
Associate Professor of Ophthalmology
Department of Ophthalmology
University of Virginia
Charlottesville, Virginia

Jan L. Kasperbauer, M.D.
Consultant
Department of Otorhinolaryngolgy
Mayo Medical Center
Rochester, Minnesota

Robert M. Kellman, M.D.
Professor and Chairman
Department of Otolaryngology
Upstate Medical University
State University of New York
Syracuse, New York

Paul E. Kelly, M.D.
ENT and Facial Plastic Surgery
Dover, Deleware

Eugene B. Kern, M.D., M.S.
Professor of Otorhinolaryngology, Retired
Mayo Clinic
Rochester, Minnesota

R. James Koch, M.D.
Assistant Professor of Surgery
Department of Otolaryngology
Stanford University Medical Center
Stanford, California

Mimi S. Kokoska, M.D.
Assistant Professor
Department of Otolaryngology–Head and Neck Surgery
Indiana University School of Medicine
Indianapolis, Indiana

Theda C. Kontis, M.D., F.A.C.S.
Assistant Professor
Department of Otolaryngology–Head and Neck Surgery
Division of Facial Plastic and Reconstructive Surgery
Johns Hopkins Medical Institutions
Owings Mills, Maryland

Russell W.H. Kridel, M.D.
Associate Clinical Professor
Division of Facial Plastic Surgery
Department of Otolaryngology–Head and Neck Surgery
University of Texas Health Science Center
Houston, Texas

Roger P. Levin, D.D.S., M.B.A.
President
The Levin Group
Owings Mills, Maryland

Timothy S. Lian, M.D.
Assistant Professor
Department of Otolaryngology–Head and Neck Surgery
Louisiana State University Health Sciences Center–Shreveport
Shreveport, Louisiana

Garrett B. Lyons, Jr., D.D.S.

Corey S. Maas, M.D.
Associate Professor
Division of Facial Plastic Surgery
University of California at San Francisco
San Francisco, California

Brian P. Maloney, M.D.
President
The Maloney Center
Atlanta, Georgia

Stephen H. Mandy, M.D.
Clinical Professor of Dermatology
Department of Dermatology
University of Miami
Miami, Florida

Robert H. Mathog, M.D.
Professor and Chair
Department of Otolaryngology
Wayne State University School of Medicine
Detroit, Michigan

John A. McCurdy, Jr. M.D.
Assistant Clinical Professor
Department of Surgery
John A. Burns School of Medicine
University of Hawaii
Honolulu, Hawaii

Harry Mittelman, M.D.
Clinical Professor
Division of Facial Plastic Surgery
Department of Otolaryngology
Stanford University
Stanford, California

Brent Moelleken, M.D., F.A.C.S.
Attending Physician
Department of Plastic Surgery
University of California at Los Angeles Medical Center
Los Angeles, California

Nathan Monhaim, M.D.
Department of Otolaryngology–Head and Neck Surgery
University of California at San Francisco
San Francisco, California

Gary D. Monheit, M.D.
Associate Professor
Department of Dermatology
University of Alabama at Birmingham
Birmingham, Alabama

Craig S. Murakami, M.D., F.A.C.S.
Virginia Mason Medical Center
Seattle, Washington

James Newman, M.D.
Clinical Instructor
Department of Surgery
Stanford University
San Mateo, California

Gilbert J. Nolst Trenité, M.D., Ph. D.
Professor of Otorhinolaryngology
Department of Otorhinolaryngology
Acadamie Medical Center of the University of Amsterdam
Amsterdam, The Netherlands

Steven S. Orten, M.D.
Tulsa, Oklahoma

Norman J. Pastorek, M.D., F.A.C.S.
Clinical Professor and Director of Facial Plastic Surgery
Department of Otorhinolarynogology
New York Presbyterian Hospital—Cornell Campus
New York, New York

Stephen Perkins, M.D.
Clinical Associate Professor
Department of Otolaryngology–Head and Neck Surgery
Indiana University School of Medicine
Indianapolis, Indiana

Judith Pinborough-Zimmerman, Ph.D., S.L.P.
Program Manager
Utah Department of Health
Salt Lake City, Utah

Eric S. Powitzky, M.D.
Department of Otolaryngology–Head and Neck Surgery
Vanderbilt University
Nashville, Tennessee

Vito C. Quatela, M.D.
Clinical Associate Professor of Otolaryngology
Department of Surgery
Rochester, New York

Brett S. Rankin, M.D.
York, Maine

Marion B. Ridley, M.D., F.A.C.S.
Associate Professor of Otolaryngology–Head and Neck Surgery
Department of Otolaryngology–Head and Neck Surgery
University of South Florida College of Medicine
Tampa, Florida

Robert O. Ruder, M.D.
Assistant Clinical Professor
University of California at Los Angeles Medical Center
and
Instructor
University of Southern California School of Medicine
Department of Head and Neck Surgery
Cedars Sinai Medical Center
Los Angeles, California

William Russell Ries, M.D.
Associate Professor
Department of Otolaryngology
Vanderbilt University Medical Center
Nashville, Tennessee

Paul Sabini, M.D.
Rochester, New York

Gary Shaw, M.D., F.A.C.S.
Kansas City, Missouri

William W. Shockley, M.D.
Professor of Otolaryngology–Head and Neck Surgery
Department of Otolaryngology–Head and Neck Surgery
University of North Carolina
Chapel Hill, North Carolina

Russell S. Shu, M.D.
Assistant Clinical Professor
Department of Otolaryngology–Head and Neck Surgery
New England Medical Center
Tufts University School of Medicine
Boston, Massachusetts

Craig. L. Slingluff, M.D.
Professor of Surgery
Chief, Division of Surgical Oncology
Department of Surgery
University of Virginia
Charlottesville, Virginia

Marshall E. Smith, M.D.
Associate Professor
Division of Otolaryngology–Head and Neck Surgery
University of Utah School of Medicine
Salt Lake City, Utah

Robert B. Stanley, Jr., M.D., D.D.S.
Professor
Department of Otolaryngology–Head and Neck Surgery
University of Washington
Seattle, Washington

Dow Stough, M.D.
Clinical Professor
Department of Dermatology
Medical Science Campus
University of Arkansas
Little Rock, Arkansas

Fred J. Stucker, M.D.
Chairman and Professor
Department of Otolaryngology–Head and Neck Surgery
Louisiana State University Health Sciences Center–Shreveport
Shreveport, Louisiana

M. Eugene Tardy, Jr., M.D., F.A.C.S.
Professor of Clinical Otolaryngology
University of Illinois at Chicago
Chicago, Illinois

J. Regan Thomas, M.D.
Professor and Department Head
Department of Otolaryngology–Head and Neck Surgery
University of Illinois at Chicago
Chicago, Illinois

Geoffrey W. Tobias, M.D.
Assistant Clinical Professor
Department of Otolaryngology–Head and Neck Surgery
Mount Sinai Hospital
New York, New York

Whitney D. Tope, M. Phil., M.D.
Associate Professor
Department of Dermatology
University of Minnesota
Minneapolis, Minnesota

Rudy J. Triana, M.D.
Assistant Professor
Department of Otolaryngology–Head and Neck Surgery
University of North Carolina School of Medicine
Chapel Hill, North Carolina

Mark Urken, MD
Professor and Chairman
Department of Otolaryngology-Head and Neck Surgery
Mount Sinai Medical Center
New York, New York

Craig A. Vander Kolk, M.D., F.A.C.S.
Associate Professor of Plastic Surgery
and
Assistant Professor of Pediatrics
The Johns Hopkins School of Medicine
Baltimore, Maryland

Steven M. VanHook, M.D.
Resident
Internal Medicine
Vanderbilt University
Nashville, Tennessee

Karin Vargervik, D.D.S.
Professor
Department of Growth and Development
University of San Francisco
San Francisco, California

Tom D. Wang, M.D.
Associate Professor of Facial Plastic Surgery
Department of Otolaryngology–Head
and Neck Surgery
Oregon Health and Science University
Protland, Oregon

Deborah Watson, M.D.
Assistant Professor
Division of Head and Neck Surgery
San Diego School of Medicine
University of California
San Diego, California

Jeffrey M. Whitworth, M.D.
Assistant Clinical Professor
Department of Dermatology
The New Jersy Medical School
Newark, New Jersey

Edwin F. Williams, III, M.D.
Clinical Associate Professor of Surgery
Division of Otolaryngology–Head and Neck Surgery
Albany Medical Center
Albany, New York

Matthew Wolpoe, M.D.
Resident
Department of Otolaryngology–Head and Neck Surgery
Johns Hopkins University School of Medicine

Foreword from the First Edition

As president of the American Academy of Facial Plastic and Reconstructive Surgery it is my privilege to have contributed to this textbook project and to have been asked to write its foreword.

Drs. Ira Papel and Nathan Nachlas are to be congratulated on this comprehensive text on facial plastic and reconstructive surgery, covering the entire spectrum of the specialty. The goal of this book is to provide source material for both the resident surgeon and the experienced practitioner. With more than 1,600 illustrations and 900 pages authored by some the most respected facial plastic surgeons in Europe and the United States, this goal has been achieved. I would like to thank Dr. Papel and Dr. Nachlas for their effort, which has made this book a work of love. All proceeds and royalties have been dedicated to the Educational Foundation of the American Academy of Facial Plastic and Reconstructive Surgery.

Norman J. Pastorek, M.D., F.A.C.S.
New York, New York

Foreword to the Second Edition

Drs. Papel and Nachlas identified the need for a comprehensive but compact textbook to cover the broad and exciting specialty of facial plastic surgery. Their first edition of *Facial Plastic and Reconstructive Surgery* successfully answered this need and has become a classic among residents, fellows, and practicing facial plastic surgeons. The second edition expands and improves on the first edition with sections on basic principles, aesthetic facial surgery, nasal surgery, reconstructive surgery, trauma, and congenital deformities.

I would like to thank Dr. Papel, the section editors and all the contributing authors for their contributions. As editor of the *Archives of Facial Plastic Surgery* I very much appreciate their efforts to organize so many authors' work in a coherent and readable fashion. Dr. Papel is donating the proceeds and royalties to the Educational Foundation of the American Academy of Facial Plastic and Reconstructive Surgery and stands in the best tradition of educators in our field. *Facial Plastic and Reconstructive Surgery* is an essential book for the library of all facial plastic surgeons and others interested in the specialty.

Wayne F. Larrabee, Jr., M.D.
President, American Board of Facial Plastic
and Reconstructive Surgery

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Preface from the First Edition

During our respective residencies, fellowships, and clinical practices it became apparent that no single text or volume served as a source of reference for facial plastic and reconstructive problems. Although many excellent texts existed for subjects such as facial trauma, rhinoplasty, congenital abnormalities, reconstruction, and facial aesthetic surgery, no single core textbook was available to provide the essential background information on each subject area.

Facial Plastic and Reconstructive Surgery has been designed to serve as an affordable, yet comprehensive, reference for surgeons in clinical practice and training. The text has been organized into divisions representing principles, reconstructive techniques, aesthetic surgery and congenital abnormalities. In each of these areas the surgeon will find chapters devoted to the core knowledge of each specific problem or technique. The goal of this text was not to create a surgical atlas but to provide the essential background knowledge for more detailed research or clinical practice. We intended to produce a balance of relevant basic science material and clinically oriented presentations.

The authors invited to prepare chapters for this text represent many years of clinical practice and basic research in facial plastic and reconstructive surgery. These surgeons practice several medical specialties and arise from a spectrum of training experiences. Most have been leaders in developing the techniques and procedures that they describe. We appreciate the hard work and diligence of the contributing authors in preparing manuscripts for this textbook.

We would also like to thank Anne Patterson, Maura Leib, and Diana Laulainen of Mosby-Year Book. Their efforts have guided us skillfully through each tedious stage of production and helped us maintain the quality for which all facial plastic surgeons strive.

Ira D. Papel
Nathan E. Nachlas

Preface to the Second Edition

When the first edition of *Facial Plastic and Reconstructive Surgery* was published 10 years ago we knew that many of the chapters would need updating. The rapid development of new technologies and techniques has made this update even more essential. In this new edition we have included information on the applications of new endoscopic, laser, and microvascular techniques. New biomaterials are analyzed with regard to basic science and clinical use. Because of its growing importance in the modern medicolegal world, a chapter on ethics in facial plastic surgery has been included. The aesthetic surgery, rhinoplasty, and congenital deformities sections have been expanded due to the rapid development of information in these areas. Many more options for reconstructive techniques have also been included.

As in the first edition the mission of this text is to provide the core information necessary for a surgeon to research a specific problem or technique in facial plastic surgery. Each chapter provides a general overview, basic science essentials, clinical applications, and appropriate references. This text is not intended to be a surgical atlas or a comprehensive text on each subject. We strive to present the critical core information for practicing surgeons, fellows, and residents.

I would like to thank the associate editors: Drs. Frodel, Holt, Larrabee, Nachlas, Park, Sykes, and Toriumi who each provided invaluable advice and contributions in the development of this text. These gentlemen have greatly expanded the scope and quality of the final work.

The staff at Thieme Medical Publishers in New York have believed in our mission and worked hard to bring this text to fruition. Our heartfelt thanks for the countless hours required to produce such a textbook.

All royalties and proceeds generated by sales of *Facial Plastic and Reconstructive Surgery*, second edition are donated to the Education and Research Foundation of the American Academy of Facial Plastic Surgery. Our goal is to provide future surgeons with the ability to enhance and improve the practice of facial plastic and reconstructive surgery.

Ira D. Papel, M.D., F.A.C.S.
Owings Mills, Maryland

Acknowledgments

To our ever patient families.

To our parents, who made the opportunities possible.

To the many contributors of facial plastic surgery, who have demonstrated a commitment to excellence in education, patient care, and the advancement of the specialty.

Principles of Facial Plastic and Reconstructive Surgery

Section

I

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Chapter 1

Anatomy and Physiology of the Skin

Richard G. Bennett

The skin is a complex tissue that is transected, manipulated, and rearranged during cosmetic and reconstructive surgery. Yet most surgeons view the skin as a simple barrier to be cut through rather than a complicated organ structure. This viewpoint has led to a paucity of cutaneous research within surgical programs and a general lack of understanding of basic cutaneous anatomy and physiology. This chapter focuses on the surgically relevant features of cutaneous anatomy and physiology. For more detailed descriptions of cutaneous anatomy and physiology, refer to several books listed in the references.[1–3]

THE SURFACE CHARACTERISTICS OF SKIN

If the skin is considered an organ, it is the heaviest organ, whereas the lung is the largest organ in surface area. However, if the skin is considered a tissue, it is not the heaviest tissue. Goldsmith[4] states that the weight of skin is approximately 3.79 kg, which ranks it the fourth heaviest tissue after fat, bone, and muscle.

The skin invests the body and is draped over the bony prominences. It is an important component of outward beauty. Because the skin is the initial structure seen by others, it takes on extreme importance. At the orifices, the skin changes texture and its composition changes from dry to moist. In the very young, the skin is smooth and lacks surface growths and irregularities. Modifications occur with aging; in childhood nevi appear, in middle age the skin starts to sag, and in old age wrinkles appear. With aging the skin may be marred by areas of hyperpigmentation, scars, areas of atrophy, and a variety of cutaneous lesions. These events are the result of physiologic changes that occur over time, and many patients wish to reverse the effects rather than grow old gracefully.

The skin is not a uniform organ macroscopically, microscopically, physiologically, or when viewed in the fourth dimension, time. There are regional and temporal variations in the epidermal thickness, dermal thickness, elastic fiber content, presence and number of hair follicles, sebaceous glands, apocrine glands, and eccrine glands. Parts of the skin are hair bearing and others are not. The skin may be dry as on the trunk or arms, moist as in the groin or axillae, or oily as on the face. In addition, there are individual differences with regard to these cutaneous differences. For instance, some individuals have small pores and smooth skin on the cheeks (Fig. 1–1A), whereas other individuals have patulous pores and oily skin on the face and are prone to acne (Fig. 1–1B). Some individuals with unusually dry skin are prone to xerosis and atopic dermatitis.

Before performing surgery on the skin, the patient's skin should be assessed for clues that will influence the outcome of surgery (Table 1–1). For instance, hypertrophic scars, keloids, hyperpigmentation, and double joints should be noted. An important phenomenon to take into account is the Köbner phenomenon. This phenomenon is the predisposition of certain cutaneous diseases to localize in areas of scars regardless of how carefully the surgery is performed. Important common skin diseases that will localize in scars include psoriasis, lichen planus, and discoid lupus erythematosus (Fig. 1–2).

Aging skin is extremely important to the cosmetic surgeon. Aged skin has changes that are either endogenous or exogenous in origin. The endogenous changes include fine wrinkling, dermal atrophy, and a decrease in subdermal adipose tissue. This atrophy is particularly marked on the face and dorsum of the hands. In addition, there is a loss of elastic fibers and laxity of the skin. The exogenous changes occur largely because of chronic sun exposure and are characterized by coarse folds and a leathery appearance to the skin. The term *photoaging* has been used to describe these changes.[5,6] The leathery appearance results from a buildup of elastotic material in the papillary portion of the dermis. Also, there is a homogenization of collagen fibers that become

TABLE 1–1 Cutaneous Lesions Directly or Indirectly Influencing Appearance of Future Cutaneous Scars

Lesion	Influence
Hypertrophic scars	Hypertrophic scars
Keloids	Keloids
Dupuytren's contracture	
Hyperpigmentation	Hyperpigmentation
Lichen planus	Köbner phenomenon resulting in lichen planus or psoriasis or discoid lupus erythematosus in scars
Psoriasis	
Discoid lupus erythematosus	
Spread scars	Spread scars
Double-jointed	
Ruddy complexion	Telangiectasia around scars

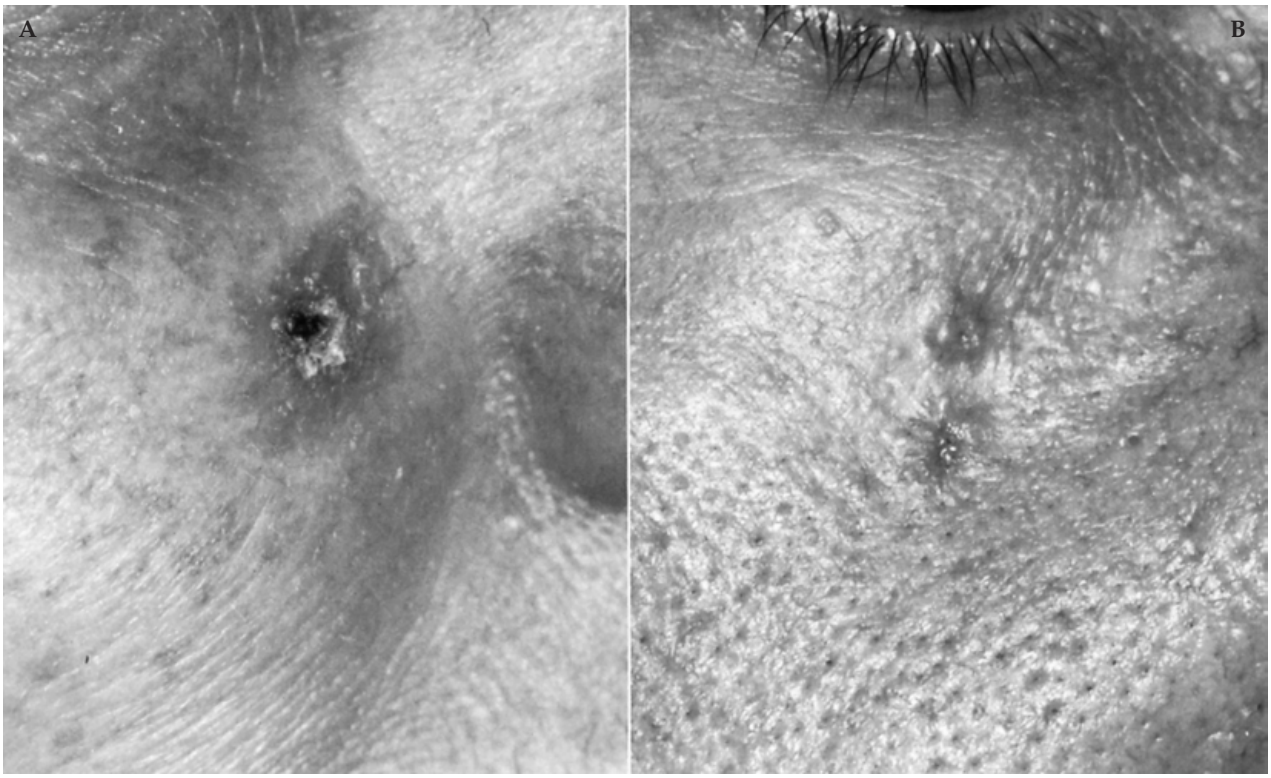

Figure 1–1 **(A)** An individual with smooth cheek skin with small inconspicuous pores. **(B)** An individual with cheek skin with large patulous conspicuous pores.

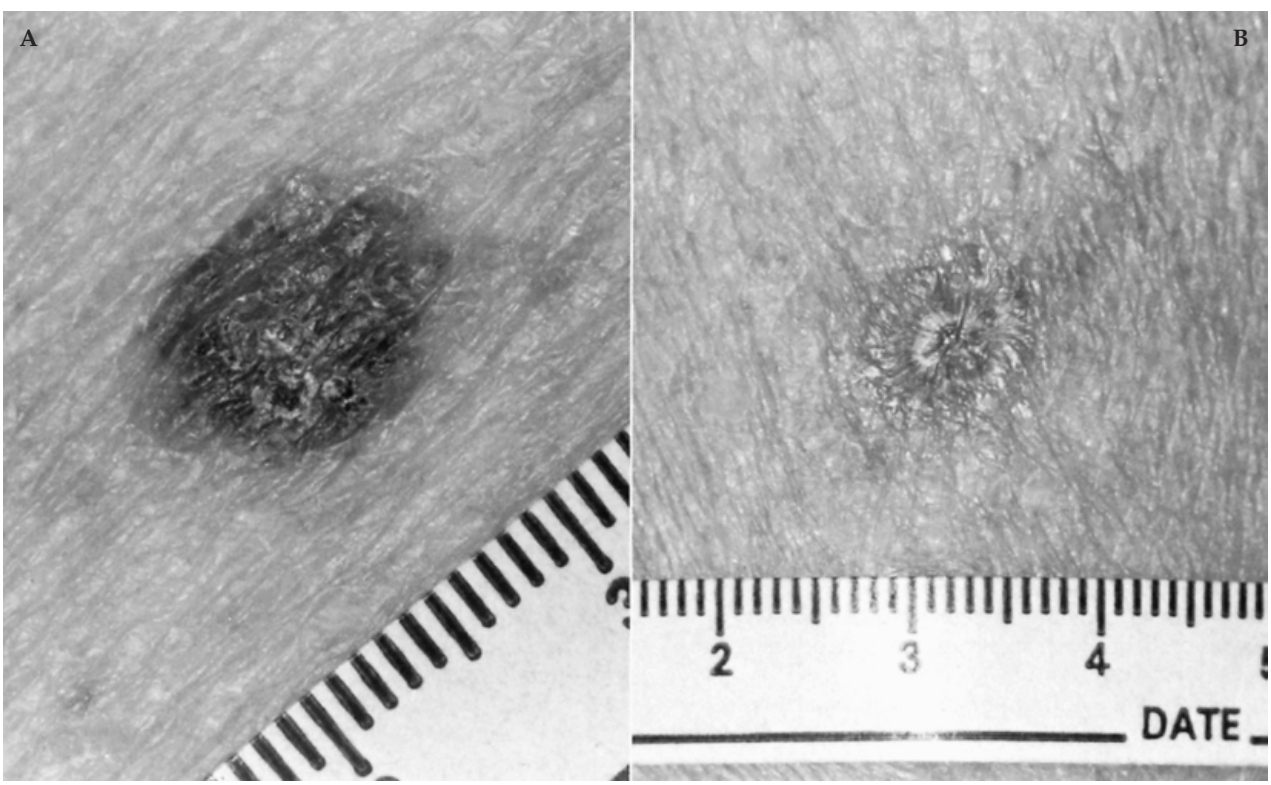

Figure 1–2 Psoriasis localized to skin biopsy site. **(A)** Prebiopsy superficial melanoma. **(B)** Post-biopsy; note scaly area around biopsy. Patient had extensive psoriasis elsewhere.

basophilic and an accumulation of glycosaminoglycan and proteoglycan complexes within the dermis.[7] Recent interest has focused on topical creams, such as tretinoin (Retin-A), that help reverse some of the changes associated with aging.[8]

ANATOMY OF THE SKIN

The skin is divided into three layers—the epidermis, the dermis, and the superficial fascia (Fig. 1–3). Like the surface epidermis, which appears differently in separate body areas, each of these three parts of the skin is different in separate areas of the body.

The Epidermis

The epidermis is the top layer of the skin. It contains four distinct cell types—keratinocytes, melanocytes, Langerhans' cells, and Merkel's cells. About 80% of the cells in the epidermis are keratinocytes. Keratinocytes are subclassified by their location within the epidermis and their degree of keratinization. The epidermis is divided into five layers. The basal cell layer, the stratum germinativum, is the bottom layer of the epidermis. It is composed of a single layer of cuboidal cells, the basal cells. Basal cells have a slightly basophilic cytoplasm and divide to give rise to the next layer above, the prickle cell layer. The basal cells rest on the basement membrane and are connected to each other through desmosomes and to the basement membrane by hemidesmosomes. Between some of the basal cells are melanocytes, the pigment-producing cells of the body. For every 10 basal cells there exists about one or two melanocytes. However, this ratio varies in different areas of the body.

The next layer above the basal cell layer is the prickle cell layer, the stratum spinosum. This layer is usually three to four cells thick and is composed of polygonal cells with preformed keratin. This keratin gives these cells a definite cytoplasmic eosinophilia. Even under light microscopy, the desmosomal attachments between the prickle cells are evident. The attachments appear as small spines emanating from the cells and give rise to the name prickle cells.

The next layer above the prickle cell layer is the granular cell layer, the stratum granulosum. This layer is one to four cells thick; the cells contain coarse cytoplasmic granules that are deeply basophilic and represent preformed keratin granules, keratohyalin granules, that will coalesce to help form the next layer, the cornified layer, the stratum corneum. The stratum corneum is the outermost part of the epidermis and is formed from the extremely flattened, anucleated keratinocytes and compacted keratin granules.[9] The cell borders and nuclei are lost as the keratin granules fuse, and this layer often is described as having a basket-weave pattern. The stratum corneum is usually a number of cell layers thick and may reach enormous proportions in the palms and soles.

On the palms and soles a fifth layer of epidermis is often identified, the stratum lucidum. This clear area appears between the stratum corneum and the stratum granulosum.

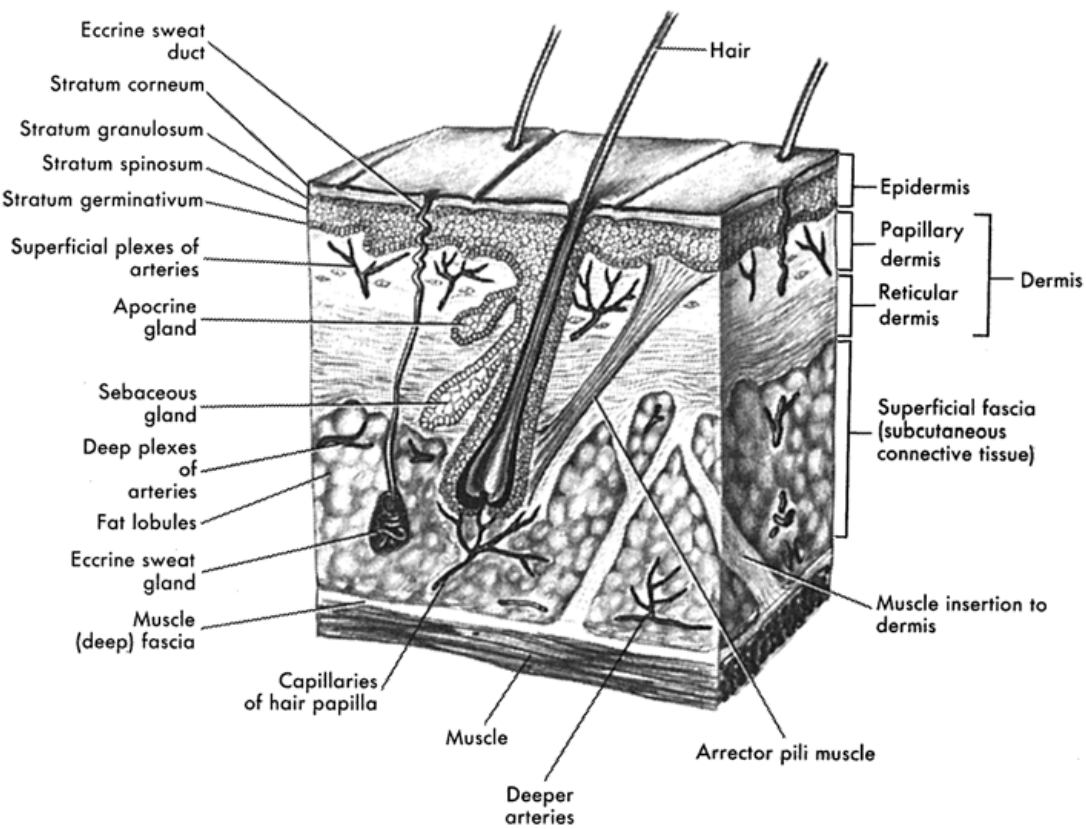

Figure 1–3 The three layers of the skin: epidermis, dermis, and superficial fascia. (From Bennett RG. *Fundamentals of cutaneous surgery*. St Louis: CV Mosby Co., 1988, with permission.)

Cell Types

Keratinocytes

Of great importance in epidermal cells is keratin. Within the stratum corneum, 60% of its mass and 85% of its cellular proteins are made up of keratin filament. Keratin filaments are complex tubular structures formed first by three keratin polypeptide chains coiling together to form a coiled coil, and then nine coils coming together to form a tubular structure.[10]

Keratin filaments become aggregated between the granular and cornified layers of the skin. This aggregation occurs because of a protein component of the keratohyalin granules known as profilaggrin. Profilaggrin undergoes dephosphorylation and proteolysis to form filaggrin. It is filaggrin that catalyzes the aggregation of keratin filaments. The complex of keratin filaments within the filaggrin matrix is known as macrofibril.

The cornified cells of the stratum corneum contain a cell envelope deep to the plasma membrane. The cell envelope is about 12 μm wide and acts as an impermeable barrier. The major precursor proteins found in the cell membrane are keratolinin and involucrin. When cornified cells pass through the outer half of the stratum corneum, the cell plasma membrane becomes discontinuous and the cell envelope becomes the outermost barrier of the outermost cornified cells.

Certain keratin filaments are also known as tonofilaments and connect the desmosomes at the cell surface with the nuclear membrane of the cell. Keratin filaments thus provide a cytoskeleton to the cell and may also serve as a communication system between the cell surface and the nucleus.

Keratin filaments are intermediate filaments that are 10 μm in diameter and are used as a marker for the epithelial cells. There are 19 antigenetic different keratins. Monoclonal antibodies to all 19 keratins have been developed and are used to identify the origin of neoplasms or specific dermatologic disorders.

Langerhans' Cells

Within the epidermis are a few additional cells that are important. Langerhans' cells are clear cells found mainly within the prickle cell layer. Under light microscopy these cells resemble melanocytes. These cells are difficult to see unless a special stain, the gold-chloride stain, or electron microscopy is used. With the gold-chloride stain, Langerhans' cells appear dendritic. Langerhans' cells contain cytoplasmic organelles, Birbeck's granules, seen under electron microscopy. Langerhans' cells have many features of monocytes and macrophages and are thought to migrate to the skin from the bone marrow. These cells are probably the mediators of immunologic responses within the skin.[11,12] The dendritic processes of the Langerhans' cells efficiently capture and process antigens within the skin. The Langerhans' cells then present the antigen to the skin-specific lymphocytes. The number of Langerhans' cells is greatly enhanced during allergic reactions such as contact dermatitis. With aging or exposure to ultraviolet light the number of Langerhans' cells decreases. Thiers et al[13] found a 15% decrease in Langerhans' cells on buttock skin on subjects older than 65 compared to subjects under age 24.

Merkel's Cells

Merkel's cell is found in the basal cell layer and, like Langerhans' cell, is difficult to visualize under light microscopy. Under electron microscopy, Merkel's cell has membrane-bound granules similar to those found in neuroendocrine tissue cells. Therefore, this cell is probably part of the amine precursor uptake decarboxylation (APUD) system of the body[14] and may be associated with the terminal nerves within the skin. The function of Merkel's cells is currently unknown. However, Merkel's cell tumors occasionally arise from these cells.

Melanocytes

Melanocytes are found within the basal cell layer and are specialized to produce melanin pigment. Melanocytes may be variable in appearance but appear with routine hematoxylin-eosin (H&E)–stained sections as cuboidal cells with a clear cytoplasm and eccentrically placed, crescent-shaped nuclei. Under special stains, such as the Dopa stain, melanocytes appear as stellate cells. The melanin granules produced by these cells are donated to adjacent keratinocytes via their stellate projections. In blacks, these melanocytes are particularly active. In those with vitiligo, melanocytes are absent altogether. In those with albinism, the melanocytes are present but lack the enzyme tyrosinase so that tyrosine cannot be transformed into melanin. The ratio of melanocytes to basal cells is 1:4 to 1:10 and varies with anatomical location but not with race. With aging, the melanocytic density decreases with each decade by 6% to 8%.[15] In addition, the melanocytic enzyme tyrosine declines in activity with age.[16] Therefore, the elderly do not tan as easily as when they were young. Melanocytes in older skin also are somewhat pleomorphic as are the keratinocytes.[1] Melanocytes in the elderly may show some nuclear atypia and variations in size, shape, and staining quality.

Dermal–Epidermal Junction

Basement Membrane

The area between the epidermis and the dermis is a well-defined area known as the basement membrane zone. On H&E–stained sections this zone appears as a thin (i.e., 1 to 2 mm), poorly defined band of eosinophilic material. The basement membrane actually functions in the following three ways: it attaches the epidermis to the dermis, provides mechanical support to the epidermis, and provides a barrier to chemicals or cells. The basement membrane is actually a complex structure, consisting of a number of layers seen on electron microscopy[17] (Fig. 1–4). The hemidesmosome is within the basal cell plasma membrane and consists of tonofilaments from within the basal cell that condense and attach to an electron dense thickening, identified as the attachment plaque. Plasmalemmal vesicles are part of the intracellular basal cell structure; these vesicles participate in endocytosis and exocytosis of low molecular weight solutes, soluble macromolecules, and small colloidal particles. The lamina lucida rests on top of the lamina densa. Within the lamina lucida are the subbasal dense plate and anchoring filaments. Attached to the undersurface of the lamina densa are anchoring dermal microfibril bundles and anchoring fibrils. Dermal microfibril bundles represent terminations of the dermal elas-

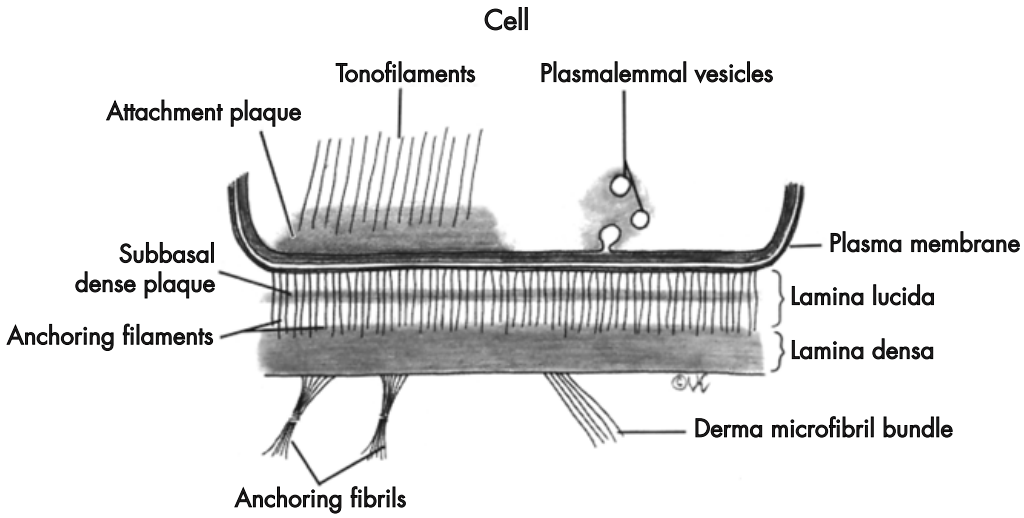

Figure 1–4 Basement membrane anatomy.

tic system and contribute somewhat to the anchorage of the basement membrane. Anchoring fibrils are specialized collagen fibrils that consist of type VII collagen and have been described as wheat stack–shaped structures.[18] Their function is to anchor the epidermis and the epidermal–dermal junction to the dermis. Anchoring fibrils are absent in early scars and are less numerous in sun-exposed areas compared with sun-protected areas.[19] The basement membrane zone continues around hair follicles and sweat ducts.

Anchoring Fibrils

The anchoring fibrils in skin, like other types of collagen, are susceptible to degradation by collagenase. Collagenase may be stimulated by the cytokinin interleukin-1. Interleukin-1 in turn may be produced by keratinocytes that are stimulated by ultraviolet light.[20,21] Collagenase may also be inhibited by topically applied tretinoin, which may explain the improved stability of tretinoin-treated skin. Woodley et al[22] showed that topical tretinoin, when applied to the forearm, increased the anchoring fibril density. They speculated that this increased density was due to the drug's property of inhibiting collagenase. On electron microscopy, the number of anchoring fibrils appeared to increase with tretinoin applications.[23]

Rete Ridges

The contour of the bottom of the epidermis is irregular with numerous projections, the rete pegs. These projections help to anchor the epidermis into the dermis. When viewed in three dimensions, the rete pegs form a netlike pattern and are more properly referred to as rete ridges (Fig. 1–5A). The corresponding upward elevations of the dermis that interdigitate with the rete ridges are the dermal papillae. In scars the rete pegs are lost (Fig. 1–5C), and the epidermis has a smooth bottom. The lack of rete pegs in scar tissue is one reason why scar epidermis may shear off more easily than normal epidermis. With aging there is a decrease in the length of the dermal papillae and rete pegs and the dermal-epidermal junction appears flattened[24,25] (Fig. 1–5B). The relative decrease in interface allows dermal–epidermal separation to occur more readily in the elderly and probably leads to a propensity for

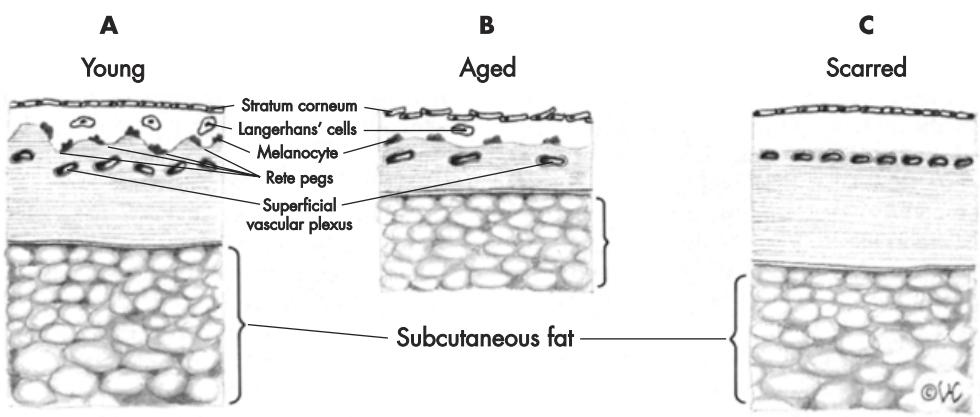

Figure 1–5 The changes in the skin with time and scarring. **(A)** Young skin. **(B)** Aged skin. **(C)** Scarred skin.

torn skin after minor trauma. The decreased length of the dermal–epidermal junction also leads to a decrease in the quantity of available keratinized cells because of a decrease in the number of basal cells per unit area. This promotes dry skin.[25] The decline in surface area of the dermal–epidermal interface also lessens communication and nutrient transfer between the dermis and epidermis.

Hair Shafts

Piercing the epidermis at intervals are hair shafts. Hair shafts are complex structures that arise within hair follicles. The hair follicle is composed of a number of cell layers. It is important to understand that the outer cell layer, the external root sheath, is really an extension of the surface epidermis. As such, some diseases in the epidermis tend to involve the outermost sheath of the hair follicle. For instance, Bowen's disease carcinoma and lentigo maligna melanoma can be seen not only within interfollicular epidermis but also within the external root sheath of hair follicles. The fact that these skin cancers extend down hair follicles has certain implications regarding cure rates by various treatment methods. The remainder of the hair anatomy is discussed later in this chapter.

Effects of Aging

With aging the normal and neat epidermal architecture is lost. Epidermal cells vary in size, shape, and staining qualities.[26] There is some loss of polarity, and the orderly progression from basal cell layer to granular cell layer is not so pronounced. Cellular heterogenicity is seen.

With aging the epidermis appears thinner under the microscope. It is believed that the thin epidermis in the elderly is actually a misconception; in the young the epidermis appears thicker because the dermis is more contractile.[27]

The time progression from the basal cell layer to the stratum granulosum is about 2 weeks; from the lowest layer of the stratum corneum to the surface of the skin takes an additional 2 weeks. In the elderly the epidermal replacement is decreased by 30 to 50% and may account for slower wound healing.[28] Cellular proliferation within the epidermis may also be under control of various stimulatory substances that include nerve growth factor and epidermal growth factor (EGF). EGF is predominantly located in the basal cell layer with lesser amounts in the more differentiated cell layers.[29] With increasing degrees of differentiation, EGF binding decreases.[30] EGF has been found to be increased in transitional cell carcinoma of the bladder where it was associated. with poor differentiation and invasion.[31]

The Dermis

The dermis is divided into two parts, the papillary dermis and the reticular dermis (see Fig. 1–3). The papillary dermis is relatively thin and is located just below the dermal–epidermal junction and is composed of loose collagen, blood vessels, and fibrocytes. The reticular dermis is below the papillary dermis, is relatively thick, and makes up the rest of the dermis. The reticular dermis is composed of compact collagen with few fibrocytes. Cutting across the dermis are peripheral branches of the vascular and nervous systems and epidermal appendages (i.e., pilosebaceous, apocrine, and eccrine units). The papillary dermis surrounds the adnexal structures and is called the adventitial dermis.

Structural Components

The main structural components of the dermis are collagen, reticulin, and elastic fibers embedded in a matrix of glycoproteins. This matrix is referred to as the ground substance. The collagen is made up of collagen fibers that are synthesized by fibrocytes. The collagen bundles are easily seen on H&E-stained sections as eosinophilic fibers that are bundled together. Because the collagen bundles are oriented in various directions, normal dermal collagen is birefringent in polarized light. In scars the collagen is often not so randomly directed but is laid down instead in the direction of wound stress. When scar collagen is polarized, it is thus not birefringent.

Collagen

Collagen is continuously turning over in the skin. The rate of turnover depends on the rate of synthesis and the rate of degradation. The latter is controlled by collagenase that is located largely in the papillary dermis and synthesized by fibroblasts.[32–34]

With aging skin, collagen synthesis decreases and the skin collagen content decreases.[35] Skin collagen decreases by 1% per year throughout adult life.[36] In addition, collagen fibers change their appearance. In infancy, collagen bundles are small and oriented parallel to the skin surface. In young adulthood, collagen bundles appear randomly arranged in the papillary dermis, but in the reticular dermis the collagen bundles are large, loosely interwoven, and tightly packed. In the elderly, collagen is more compact perhaps because of the loss of ground substance that normally is found between individual collagen bundles. Collagen in the elderly is arranged in thick, coarse bundles or as loose-woven, straight fibers.[37] Some of the enzymes (i.e., galactosyltransferase and glucosyltransferase) that modify collagen within the cell are decreased with aging.[38]

Reticulin and Elastic Fibers

Reticulin fibers are also found in the dermis. These fibers are thin, small fibers that are probably early collagen fibers soon after extrusion from fibrocytes. Elastic fibers are wavy eosinophilic fibers that vary in length and width. Elastin is the functional protein component of the elastic fiber.[39] Surrounding the elastin is a microfibrillar component that can be seen on electron microscopy. Elastic fibers extend from the dermal–epidermal basement membrane into the reticular dermis, but only in the deeper portion of the dermis are they invested with elastin and thus can be seen under the microscope as elastic fibers.[40] In sun-damaged skin the elastic fibers are usually thick and abundant in the papillary dermis. These thickened elastic fibers are referred to as elastotic fibers. Their origin from elastic fibers is shown by the fact that they stain positively with an antielastin antibody (HB8) and disappear with elastase.[41] With age, elastic fibers in the reticular dermis increase in number and become thicker, more branched, and haphazardly arranged. There are areas of focal loss and focal proliferation of elastic fibers.[42] In the papillary dermis, however, elastic fibers disappear with age. There is a decrease in the diameter and number of elastic fibers and the fibers are often fragmented.[43] Thus with aging there is a lack of func-

tional elastic fibers, and the skin becomes loose, pendulous, and devoid of recoil. Striae cutis distensae are linear flat or atrophic areas in the skin, which has been subjected to stress. Striae cutis distensae are probably the result of attenuation or rupture of elastic fibers.[44]

Within the dermis are also microfibrillar fibers that can be seen on electron microscopy. These fibers appear as linear bundles containing many individual microfibrils. The microfibrils are very small and have an average diameter of 10 to 12 μm. One component of microfibrils, fibrillin, is a glycoprotein that was recently characterized.[45] These fibers serve as a scaffolding for the deposition of elastin during elastogenesis. Recently, Hollister et al[46] found a deficiency of the microfibrillar–fiber system in the skin and cultured fibroblasts of patients with Marfan's syndrome.

Fibrocytes

The main cell in the dermis is the fibrocyte. These cells are abundant in the papillary dermis but sparse in the reticular dermis. The fibrocyte may become modulated during wound healing to become an active collagen-producing cell with abundant endoplasmic reticulum. The fibrocyte may also become a contractile cell during wound contraction. The contractile fibrocyte has intracytoplasmic filaments that resemble actin on special stains. Therefore, the fibrocyte is a versatile cell, responding to wound injury and stress.

Fibrocytes decrease with age and perhaps this accounts for slower healing in the elderly. Andrew, Behnke, and Sato[47] counted the number of dermal nuclei and found that the abdomen at 80 years of age had less than half the number of nuclei present at 1 year of age.

Mast cells may also be found within the dermis, mostly around blood vessels in the papillary dermis. In scars, mast cells can be abundant.

The ground substance is also made by fibrocytes and is composed of glycoproteins and glycosaminoglycans. The ground substance is fluid and can be displaced by pressure. For instance, sleeping with an arm on a sharp object may produce a depression in the skin resulting from displacement of the ground substance. However, within a few hours this displaced fluid returns to its normal position as the arm is used. Hypertrophic scars and keloids also contain considerable ground substance. Therefore pressure massage of hypertrophic scars will reduce their swelling resulting from a reduction of the ground substance.

The Superficial Fascia

Below the dermis but above the underlying muscle is the superficial fascia. Although this layer has been called the subcutis, the panniculus adiposis, or simply the subcutaneous fat layer, all of these terms are either poor or misleading, and the term *superficial fascia* is preferred. This structure is composed of both a fatty component, fat cells, and a fibrous component, the fibrous septae (Fig. 1–6). In some areas of the body, such as the scalp, the fibrous component predominates, and it is therefore impossible to undermine the skin. On the trunk and extremities, the fat component predominates, making undermining relatively easy. On the face, there is a mixture of fibrous septae and fat. Here the fibrous septae actually run from the underlying deep (muscle) fascia investing muscles to insert into the overlying dermis. On the lateral face the fibrous septae of the superficial fascia may become organized between the adjoining fibrous septae giving rise to a structure known as the superficial musculoaponeurotic system (SMAS).

The thickness of the superficial fascia varies from one region of the body to another, from one gender to another, and from one individual to another. Because it contains abundant fat, this layer obviously reflects the nutritional status of the individual.

The Vascular Network

The blood vessels of the skin consist of a superficial network and a deep network (Fig. 1–7). The deep network, the deep plexus, lies in the superficial portion of the superficial fascia. From this deep network, small arteries pass vertically upward to the papillary dermis where they give rise to small arteries that interconnect to form a superficial arteriolar network, the superficial plexus. The superficial plexus gives rise to capillary loops that ascend into the dermal papillae and descend into the papillary dermis where they connect with venules that form the superficial venular network, the superficial venular plexus. The latter connects with veins in the superficial fascia.

On the face the arteriolar portion of the capillary loops may be dilated, whereas on the extremities the venular side of the capillary loop may be distended. Because of the difference in the portion of the capillary loop dilated in these two areas, the response to sclerosing agents or laser is not the

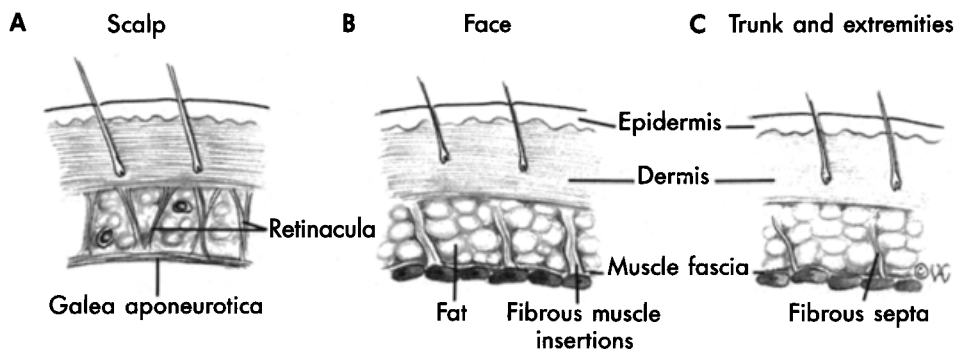

Figure 1–6 The superficial fascia in certain anatomic areas. **(A)** The scalp. **(B)** The face. **(C)** The trunk and extremities.

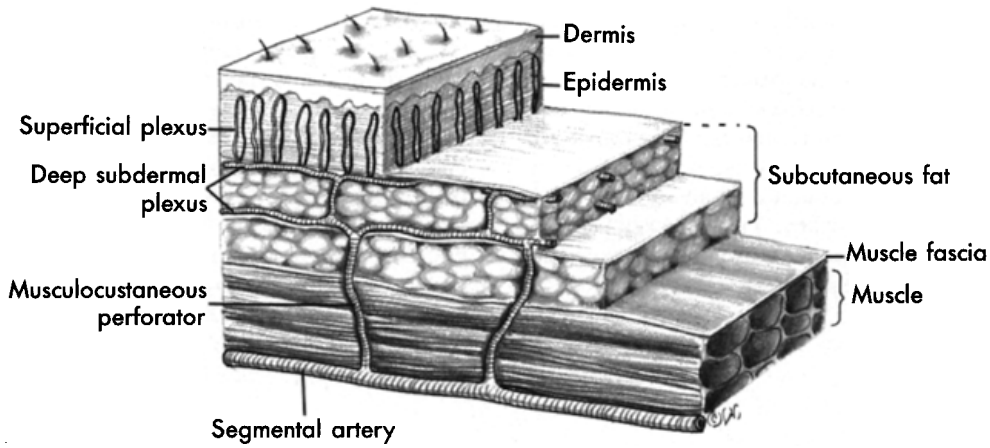

Figure 1–7 The vascular network of the skin.

same. The telangiectatic vessels on the face are arteriolar, red, and respond well to lasers emitting wavelengths in the yellow portion of the electromagnetic spectrum but respond poorly to sclerosing agents. In contrast, the telangiectatic vessels on the legs are venular, bluish, and respond well to sclerosing agents but poorly to lasers.

On the distal extremities there are shunts between the arterioles and venules in the superficial plexuses. These shunts are controlled by glomus cells that are innervated by adrenergic fibers. Glomus cells are polygonal in shape and group around vessels.

The microscopic appearance of cutaneous vessels is similar to that of vessels elsewhere in the body. The vascular lumen is surrounded by endothelial cells that sit on a basement membrane, which is surrounded by smooth muscle cells, pericytes, and connective tissues. With aging the pericytes surrounding the vessels decrease in number and synthetic activity.[48] These changes parallel the thinning of vascular walls with aging and, along with the decrease in stromal support, explain the susceptibility of bruising in the elderly.

Dermal blood vessels normally do not have a surrounding infiltrate. However, within photodamaged skin, a lymphohistiocytic perivenular infiltrate with numerous mast cells is present. Skin with this infiltrate has been labeled chronic heliodermatitis.[49] In the elderly, dermal blood vessels may be collapsed, disorganized, or absent.[25]

The skin also contains lymphatics. The lymphatics begin in the superficial papillary dermis as blind-ended vessels that are lined by endothelial cells without a basal lamina. The more proximal portion of the lymphatic system within the superficial fascia contains thicker walls and valves.

Nerves

The nerves in the skin are distributed in a network that resembles the vascular network previously described. Cutaneous nerves are either sensory or autonomic. Nerves in the skin appear as nerves elsewhere in the peripheral nervous system. With routine H&E stains, the sensory nerves cannot be distinguished from the autonomic nerves. The sensory nerves are afferent nerves that carry the sensations of pain, itching, temperature, pressure, and proprioception. The sensory impulses begin in nonencapsulated receptors or encapsulated receptors. The nonencapsulated receptors include the end organs, which reside in the dermal papillae and wrap around the hair follicles, and the neural–Merkel's cell complexes. The encapsulated receptors include the Meissner's and Vater-Pacini corpuscles. The Meissner's corpuscles that mediate the sensation of touch are located in the dermal papillae and appear as a string wound around a spindle. The Vater-Pacini corpuscles that mediate the sensation of pressure are located in the superficial fascia, most abundantly in the palms and soles, and appear as oval bodies with internal concentric lamellae.

The efferent nerves in the skin are mainly autonomic and originate in the sympathetic system. These nerves innervate the glomus bodies, the smooth muscles of blood vessels, the smooth muscles, the arrector pili (i.e., smooth muscles connected to hair follicles), and the apocrine and eccrine glands. Innervation of these nerves thus causes the blood vessels to constrict, hair to stand, goose bumps to appear, and sweating to occur.

Pilosebaceous Unit

The pilosebaceous unit consists of the hair, hair follicle, sebaceous gland, sensory end organ, and arrector pili muscle. This unit makes hair and an oily fatty emollient; it also has a sensory and motor function. In many of the areas of the skin, such as the scalp, the hair is dense and thick. This hair is referred to as the terminal hair. In other areas of the body, such as the temples, the hair is thin and almost imperceptible. This fine hair is vellus hair. In some areas of the body, such as the nose, the sebaceous portion of the pilosebaceous unit is enlarged and is the predominant part of the unit; in other areas, the hair portion of the pilosebaceous unit is prominent and the sebaceous portion minimal. Only on the palms, soles, and mucous membranes is the pilosebaceous unit absent.

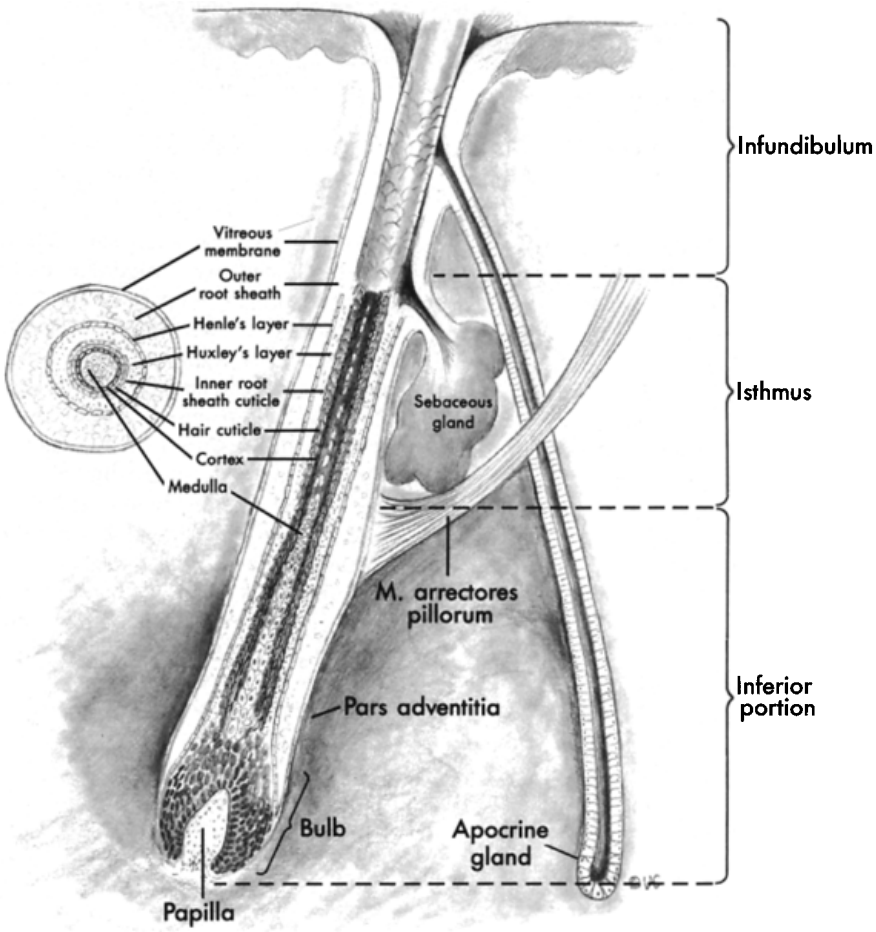

Figure 1–8 Hair shaft and hair follicle.

Hair and Hair Follicle

The hair follicle is a structure composed of three portions from which a hair arises (Fig. 1–8). The topmost portion is the infundibulum, which extends from the surface of the skin to the level of the opening of the sebaceous gland duct into the follicle. When apocrine glands are also present, these may empty into the infundibulum. The isthmus connects the infundibulum with the area at which the arrector pili muscle inserts into the follicle. The inferior portion is the portion of the follicle below the insertion of the arrector pili muscle.

Hair arises from the hair bulb, the lowest portion of the hair follicle. The hair bulb is a rounded structure that contains the hair matrix. The hair matrix consists of cells with vesicular nuclei and basophilic cytoplasm that give rise to the hair. Also found within the hair bulb are melanocytes that are incorporated into growing hairs. The hair bulb surrounds as a cap the papilla that contains specialized mesenchymal cells and is a dermal structure. The hair papilla influences the activity within the hair matrix from which the hair shaft and inner and outer root sheaths arise. The hair shaft is formed by keratinization of the cells within the hair matrix.

The mature hair shaft has a complicated structure with several distinct layers. The innermost portion is the medulla, which is absent in vellus hair but present in nonvellus hair. The next layer is a cortex and a hair cuticle, which consists of shingles of overlapping cells. Above the matrix, more layers appear. The inner and the outer root sheaths are keratinized layers that form support for the growing hair. Surrounding the outer root sheath is the vitreous, an eosinophilic band that is continuous but thicker than the epidermal basement zone. The final two layers are the fibrous root sheath and the peri-adventitia dermis.

Hair growth occurs in cycles with anagen, catagen, and telogen stages. The anagen stage is the growth stage. During this stage the inferior portion of the hair elongates and forms a bulb that contains the matrix within which is the dermal papilla. The catagen stage is an involutional stage in which the inferior portion of the hair ascends to the level of the attachment of the arrector pili muscle. In its path of retreat, a band of collagen can be distinguished. The telogen phase is the resting phase. During this stage, the inferior portion of the follicle is absent.

With aging, the number, rate of growth, and diameter of hair shafts declines. Gray hair is also seen with advanced age and results from decreased amounts of pigment within hair shafts. On electron microscopy, gray hair contains melanocytes but with large vacuoles in their cytoplasms. The melanosomes are not fully melanized.[15]

Arrector Pili Muscles

Associated with hair follicles are the arrector pili muscles. These small muscles insert onto the hair follicles below the sebaceous gland duct and extend obliquely upward into the papillary dermis where they are anchored. Contraction of the arrector pili muscles is caused by sympathetic nerves and causes the hair to be pulled from an oblique position to a more vertical position. Clinically, this contraction results in slight elevations of the skin, known as cutis anserina or goosebumps.

Sensory Nerves

Also associated with hair follicles are the sensory nerves (the end organs) that ramify in a netlike fashion around the isthmus and inferior portions of the follicle. As the hairs are brushed, these sensory nerves are activated.

Sebaceous Gland

The sebaceous gland is associated with the hair follicle, and its duct empties into the hair follicle. In some areas of the body, the hair follicle is so small that the sebaceous glands appear to empty directly onto the skin. Sebaceous glands produce a fatty secretion, sebum, that provides emollients for the hair and skin. Sebum production peaks in late adolescence and is associated with acne. Thereafter, sebum production declines by about 23% per decade in men and 32% per decade in women.[50] This decrease is associated with a decreased androgen production. However, the decreased glandular production in the elderly does not parallel the sebaceous gland size, which actually increases with age.[51] A common lesion in middle-age adults and the elderly is sebaceous hyperplasia. Sebaceous glands are present in most areas of the body except the palms and soles. There is a high density of sebaceous glands on the face, chest, and back. In some anatomic areas, sebaceous glands have special names (e.g., Fordyce's spots on the lips, Tyson's glands on the prepuce and labia minora, Montgomery's tubercles on the areola, and meibomian glands on the eyelid).

The sebaceous gland is unilobular or multilobular and empties into the hair follicle via a short duct. This duct is composed of squamous epithelium and ends in the infundibulum of the hair follicle. The cells on the periphery of the sebaceous gland are cuboidal with basophilic cytoplasm. These cells differentiate into larger lipid-filled cells whose borders disintegrate as the cells approach the sebaceous duct. The secretion of the sebaceous glands are holocrine and are under the influence of male and female sex hormones.

Eccrine Glands

The eccrine glands produce sweat. Eccrine glands are found everywhere on the skin surface except at the mucocutaneous junctions and the nailbeds. Eccrine glands are particularly numerous on the palms, soles, and forehead. With aging the number and function of eccrine glands decreases.

The eccrine unit is composed of the following three parts: a secretory gland, an intradermal duct, and an intraepidermal duct. The secretory gland is coiled and is situated in the deep dermis or subdermal fat. The lumen of the gland is surrounded by two types of secretory cells—clear cells that contain glycogen and dark cells that contain mucopolysaccharides. These secretory cells lie on a basal lamina that is surrounded by myoepithelial cells and periadnexal dermis. The gland itself is innervated by nonmyelinated cholinergic and adrenergenic fibers. The intradermal duct ascends through the dermis with a relatively straight course. The duct is lined by an eosinophilic cuticle produced by basophilic duct cells. Like the gland portion of the eccrine unit, the intradermal duct is surrounded by myoepithelial cells and periadnexal dermis. The intraepidermal duct spirals through the epidermis to the surface. The lumen of the intraepidermal duct is lined by cells that are keratinized.

Apocrine Glands

Apocrine glands produce a secretion that is odorless but when acted on by bacteria becomes odoriferous. Apocrine glands, unlike sweat glands, are found only in certain locations on the body. They are most numerous in the axillae and groin. In some areas of the body apocrine glands have special names, e.g., Moll's glands on the eyelids, mammary glands on the breast, and ceruminous glands of the external auditory canal.

The apocrine unit also consists of a secretory coil, an intradermal duct, and an intraepidermal duct. The secretory coil is located within the subdermal fat and has a large lumen. The secretory cells surrounding the lumen are cuboidal cells with eosinophilic cytoplasm. These cells show apical budding. The secretory cells rest on a basal lamina and are surrounded by elongated myoepithelial cells and periadnexal dermis. These glands are under both cholinergic and adrenergic stimulation. The intradermal portion of the duct ascends relatively straight and usually empties into the hair follicle above the sebaceous duct orifice. The duct may also open directly onto the skin surface. The intradermal portion of the duct has a double layer of basophilic cells resting on a basal lamina. The basal lamina is in turn surrounded by myoepithelial cells and periadnexal dermis.

SUMMARY

The skin is a complex structure both anatomically and physiologically. Understanding this organ will enhance a surgeon's ability to predict its response to injury and to achieve the optimal cosmetic and functional result for the patient.

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Chapter 2

Wound Healing

Edmund Fisher and John L. Frodel Jr.

Cutaneous wound repair involves a complex yet coordinated series of biologic events. Although complete understanding of all biochemical steps is probably unnecessary, it is essential for the facial plastic surgeon to know the basic stages of wound healing to achieve the best result. Virtually all wounds produce visible scars; even when the healing process is normal, functionally disabling scars may occur. Abnormal wound healing may involve hypertrophic scarring and keloid formation, which further compromise appearance and function. Accordingly, the surgeon must approach an acquired or iatrogenic wound carefully, considering the factors involved in wound repair. In this chapter, basic cutaneous anatomy and the phases of wound healing are reviewed pursuant to a discussion of factors affecting wound repair and scar formation.

HISTORY

Wound healing has been a concern throughout recorded history. The Edwin Smith Papyrus (1600 BC) represents the first documentation of wound care and healing.[1] War and the treatment of its casualties accounts for most of the information recorded in other ancient literature. Nearly 150 descriptions of wounds are included in Homer's account on the siege of Troy by the Greeks (*The Iliad*, 1000 BC). The use of so-called sovereign medicines was noted in the treatment of these wounds, along with a high mortality rate. By the time of Hippocrates (460 to 370 BC), established wound management included removal of foreign bodies, cleansing and drying of the wound, suturing (with crude techniques), and application of clean, dry dressings. Celsus (25 BC to AD 50) appears to be the first to discuss inflammation, but Galen (AD 130 to 200) in his treatment of Roman gladiators and soldiers developed the doctrine of laudable pus (suppuration) as an important aspect of wound healing. Unfortunately, this notion was generally accepted until the fourteenth century when Henry de Mondeville (1260 to 1320) advised that wounds be cleaned and suppuration avoided. His doctrines were considered unacceptable by many but eventually prevailed. With the advent of gunpowder in the fourteenth century, a new type of wound was established. Cauterization with hot oil was the treatment of choice, with little reverence for cleanliness. Only when French surgeon Pare (1520 to 1590) found his oil supply exhausted and was forced to apply milder compounds (e.g., egg yolk, oil of roses, and turpentine) did this inhumane, ineffective treatment end.[1]

Wound treatment has continued to evolve since the sixteenth century, although subsequent advances have been related primarily to the creation of optimal conditions for wound repair. Advances include debridement of necrotic tissues and foreign bodies, wound edge apposition, and use of aseptic technique (the Lister principle). Of comparable validity are the following tenets of Halsted that should be known and respected: gentle handling of tissue, aseptic technique, sharp anatomic dissection of tissue, careful hemostasis, obliteration of dead space, avoidance of tension, and reliance on rest.[2] Although the biologic processes of wound healing have been more thoroughly described in this century, control over the healing process and thus the final outcome remains the goal.

ANATOMIC CONSIDERATIONS

Knowledge of the basic anatomic components of skin is essential to understanding wound healing.[3] Skin has two layers—the epidermis and the dermis—that contribute to wound healing (Fig. 2–1).

The epidermis is a protective, waterproof layer characterized by color, texture, and, unfortunately, scar tissue. The basal, or germinal, layer continually replicates, pushing dying keratin to the surface. Destruction of this superficial layer by an abrasion or burn allows tissue fluid weeping and exposes the wound to outside substances, such as bacteria or medications. Because the basal layers remain intact in such injuries, healing generally occurs without scarring. However, as melanocytes are found in the epidermis, these injuries may result in discoloration. Because the epidermis contains no collagen fibers, wound strength is minimal. It does, however, have considerable growth potential, enabling rapid epithelial cell migration to seal fresh wounds within a few hours.

The epidermis rests on the dermis in an irregular papillary surface interface (papillary ridges) that makes the two parts difficult to separate. Collagen, the most important component of this layer, is produced as a fibrous protein and, through extensive cross-linking, provides intrinsic strength to this layer. The process of laying down the collagen requires much more time than the rapid process of epithelial closure. The dermis also contains the blood supply to the skin and various epithelial-lined skin appendages, such as sweat and sebaceuous glands. Sebaceous glands are epidermal-lined structures and the principal source of epithelial regeneration in dermal injuries.

WOUND HEALING PHASES

Wound healing is accomplished in multiple phases that occur over time (Fig. 2–2). Whether an injury is secondary to an abrasion, a burn, a contusion, or a laceration, an immediate

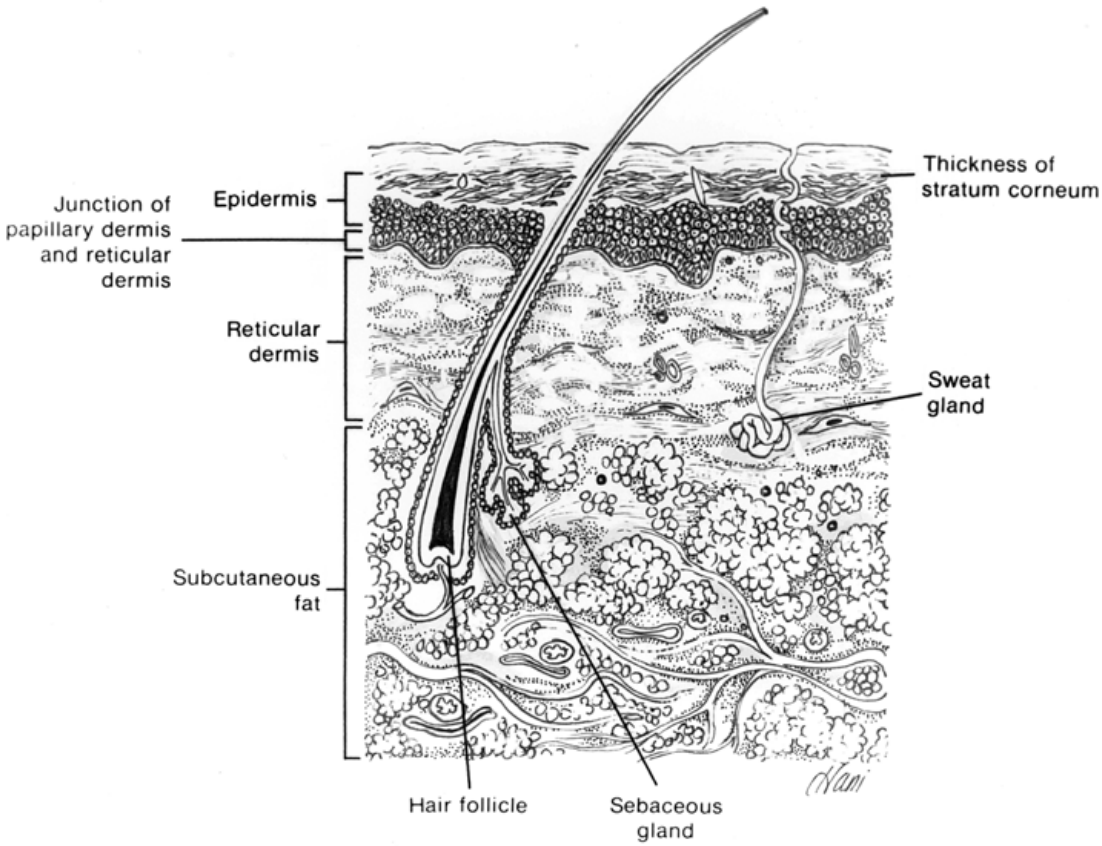

Figure 2–1 Diagram of normal skin and appendages. (Modified from Koranda FC. Dermabrasion. In: Thomas JR, Holt GR (eds). *Facial scars: incision, revision, and camouflage*. St. Louis: CV Mosby, 1989. With permission.)

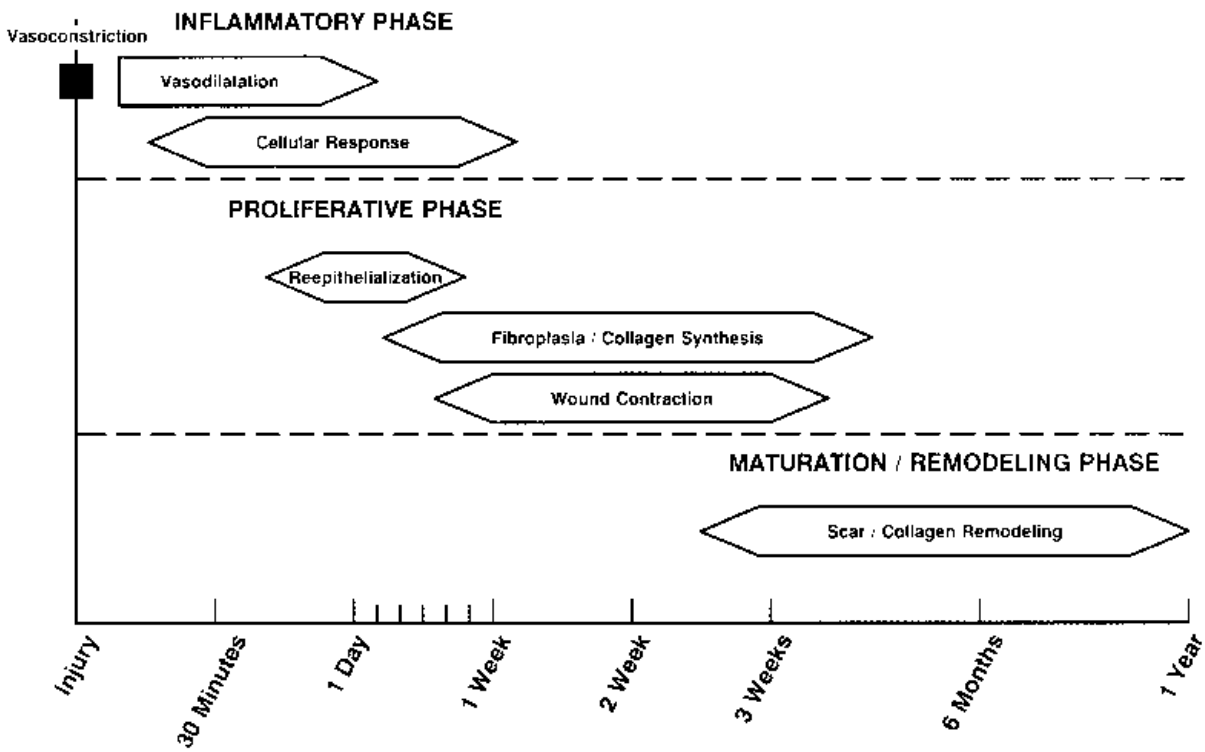

Figure 2–2 Phases of wound healing.

vascular and inflammatory response occurs. Local vasoconstriction is the initial event and lasts 5 to 10 minutes. With endothelial cell injury, the coagulation cascade is activated, resulting in platelet adhesion and aggregation into clots or plugs. Activated platelets release a variety of biologically active substances, including prostaglandins and vasoactive materials (i.e., serotonin, histamine, proteases, thromboxane) that further affect vascular tone. Various chemotactic and proliferative factors are also released, including platelet-derived growth factor (PDGF), epidermal growth factor (EGF), insulin-like growth factor (IGF-1), transforming growth factor–β (TGF–β) and fibroblast growth factor (FGF), which activate their target epithelial, endothelial, and fibroblast cells.[3–5] Table 2–1 is a list of cytokines in wound healing.

After the initial vasoconstriction, active vasodilation takes place, probably secondary to histamine release from mast cells, and circulates serotonin. These factors, along with enzymes that affect norepinephrine and proteolytic enzymes that activate kallikrein, which in turn activate the kinins, significantly increase vascular permeability by allowing endothelial cell separation. Microvascular permeability changes increase for the first 48 to 72 hours, allowing the inflammatory phase to persist.[3]

The cellular response in the inflammatory phase lags slightly behind the vascular changes. Fibronectin appears to be a major component of granulation tissue as it promotes the migration of neutrophils, monocytes, fibroblasts, and endothelial cells into the region. Cross-linking between the clot and fibronectin provides a temporary matrix by which epithelial cells and fibroblasts may proliferate in the wound.[5,6]

Polymorphonuclear leukocytes (granulocytes) and monocytes appear shortly after injury. The granulocytes are

TABLE 2–1 Cytokines Involved in Wound Healing

Cytokine	Abbreviation	Source	Function
Human growth hormone	GH	Pituitary gland	Fibroblast proliferation; increases collagen content and tensile strength; anabolism; stimulates IGF-1
Epidermal growth factor	EGF	Platelets, bodily fluids (including saliva, urine, milk, and plasma)	Epithelial cell and fibroblast proliferation and migration; activates fibroblasts; angiogenic
Platelet-derived growth factor	PDGF	Platelets, macrophages, fibroblasts, endothelial cells, smooth-muscle cells	Mitogenic for fibroblasts and smooth muscle cells; chemoattractant for neutrophils and macrophages; angiogenic
Fibroblast growth factor	FGF	Macrophages, brain, pituitary gland	Proliferation and migration of vascular endothelial cells; mitogenic and chemotactic for keratinocytes and fibroblasts
Transforming growth factors	TGF	Platelets, fibroblasts, neutrophils, macrophages, lymphocytes	Epithelial cell and fibroblast proliferation
Nerve growth factor	NGF	Schwann cell, muscle cells	Motoneurons, Schwann cells, muscle cells
Brain-derived neurotrophic factor	BDNF	Central nervous system, skeletal muscle, heart, lung	Support cranial and spinal motoneurons after axotomy
Ciliary neurotrophic factor	CNTF	Schwann cells	Promote survival and differentiation of neural and glial cells within the nervous system
Insulin-like growth factor–1	IGF-1	Fibroblasts, liver, plasma	Fibroblast proliferation, synthesis of proteoglycans and collagen
Tumor necrosis factor	TNF	Macrophages, mast cells, lymphocytes, other tissues and cells	Fibroblast proliferation
Interleukins	IL	Macrophages, lymphocytes, other tissues and cells	Fibroblast proliferation, neutrophil chemotaxis
Interferons	IFN	Fibroblasts, lymphocytes	Inhibition of fibroblast proliferation and collagen synthesis
Keratinocyte growth factors	KGF	Fibroblasts	Epithelial cell proliferation

Source: Terris DJ. Dynamics of wound healing. In: Bailey BJ (ed). *Head and neck surgery–otolaryngology.* Philadelphia: Lippincott-Raven Publishers, 1998. With permission.

stimulated by chemotactic factors and act primarily to remove bacteria and debris from the wound. These short-lived cells disappear rapidly in the noncontaminated wound. In the contaminated wound, however, granulocytes persist and prolong the inflammatory phase. This important extended inflammation may account for more severe end-stage scarring. Accordingly, it is important to progress from this stage as quickly as possible, so that the wound may close and subsequent collagen deposit may begin.[3] In contrast, healing will proceed in the clean wound without the presence of granulocytes if there is normal macrophage, fibroblast, and endothelial cell function.[7]

Perhaps the most important component of the cellular response of the inflammatory phase is the macrophage.[8] This becomes the predominant cell type by day 3 or 4.[3] Although phagocytosis and tissue debridement are an important function of macrophages, release of chemotactic and growth factors, including TGF–β, basic FGF, EGF, TGF–α, and PDGF, for endothelial cell and fibroblast proliferation may be the most significant functions.[9–11] In the context of poor macrophage function, granulation tissue formation, fibroplasia, and collagen production are impaired, as well as overall wound healing.[12] Lymphocytes produce TGF–β, interferons, interleukins, and tumor necrosis factor, which also interact with the macrophage during the inflammatory process, linking the immune response to wound repair.[13]

The transition from inflammation to subsequent conditions illustrates the complexity and overlap of the concept of successive stages in wound healing. Interaction of the vascular and cellular responses prepares the wound for formation of granulation tissue, epithelial repair, and collagen deposition. In the first few days after injury, wound strength is minimal and relies primarily on fibrin clot and early epithelialization.[2,3] Only when inflammation subsides does collagen deposition begin, with subsequent increases in tensile wound strength.

The next major aspect of wound healing is the proliferative phase, which includes epithelial regeneration, fibroplasia and collagen formation, wound contraction, and neovascularization.

Epithelial regeneration plays a critical role in the wound repair process. With the completion of this process there is reestablishment of a barrier to protect underlying tissues from bacteria and foreign material. The process of reepithelialization begins within 24 hours of injury as a migration of epithelial cells from surrounding wound margins or from deeper adnexal structures, such as hair follicles or sebaceous glands, begins. The precise initiating stimulus for this event is uncertain, but the process begins with basal epithelial cell differentiation and separation from the underlying basement membrane and dermis.[3,9,14–15] This cell differentiation begins a complex process by which active mitosis of basal cells leads to migration across the wound (Fig. 2–3). The advancing front of epithelial cells continues until it comes into contact with similar epithelial cells. A contact inhibition of migration occurs, followed by further mitotic differentiation leading to epithelial stratification. Simultaneously, basal cells next to the wound and in the injured skin appendages begin mitotic activity, thus assisting in thickening the new epithelial layer.[14] This extended epithelial growth is maximal at 48 to 72 hours. The stimulus for epithelial proliferation is unknown, but it

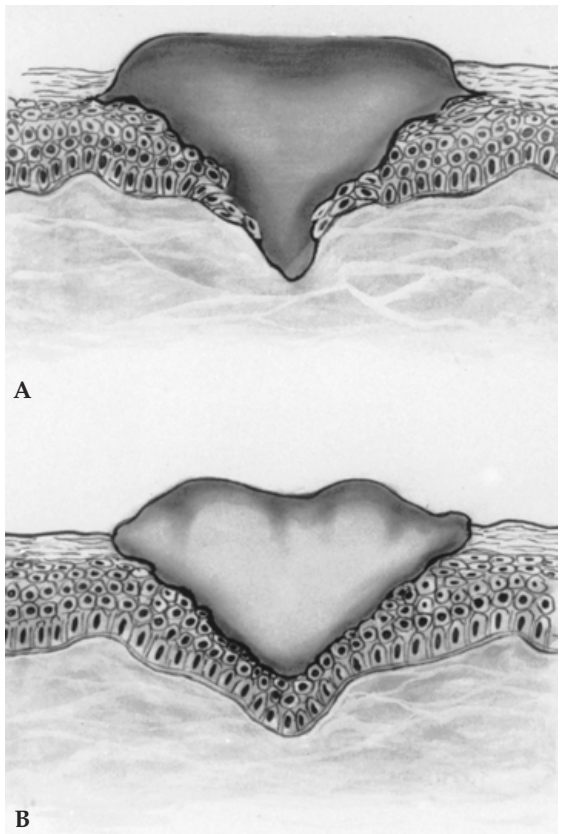

Figure 2–3 **(A)** Differentiated and dividing basal epithelial cells migrating beneath dried clot. **(B)** Contact inhibition and further differentiation with epithelial stratification.

appears that EGF and its close relative TGF–α[13] are involved. These polypeptides have been shown to function as mitogens for epithelium and stimulants for fibroplasia and granulation tissue.[9,16,17] Research also suggests that EGF enhances early wound healing, particularly in partial-thickness wounds.[18] Chalones, which are glycoproteins that inhibit epidermal replication, may also be involved in increasing epidermal proliferation in an open wound when they are temporarily lost until the epidermis regenerates.[19]

In wounds closed primarily, epithelialization may be completed in 24 to 28 hours, but secondary intention wounds take considerably longer, especially if the wound is full thickness. In these cases, minimal epithelial migration usually continues for 3 to 5 days until a granulation bed has been established.[3]

It has long been understood that a moist wound surface enhances normal wound healing. Conversely, wound desiccation significantly impairs normal wound healing (Fig. 2–4).[20] When a crust or scab forms, the underlying dermis becomes desiccated and partially necrotic. Accordingly, the migrating epidermis takes a longer, less efficient route, thus delaying epithelialization. In occluded moist wounds, migration is direct and unimpeded, providing more rapid wound coverage.[5,21]

As reepithelialization proceeds, granulation tissue forms beginning 3 to 4 days after injury. It consists of inflammatory

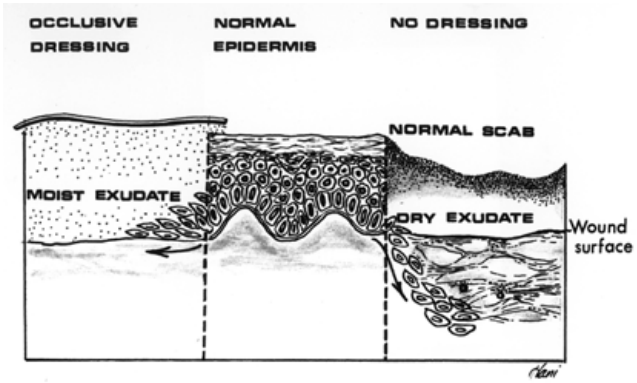

Figure 2–4 Effects of moist occlusion on promoting more rapid epithelialization than when under dried clot. (Modified from Winter GD. Epidermal regeneration studied in the domestic pig. In: Maibach HI, Rovee DT (eds). *Epidermal wound healing*. Chicago: Year Book Medical Publishers, 1972. With permission.)

cells, new blood vessels, and fibroblasts in a bed containing fibrin, glycoproteins, newly formed collagen, and glycosaminoglycans.[5] Granulation tissue persists until reepithelialization is completed.

Fibroblasts appear in the wound as early as day 2 or 3 and play an important role in healing. Fibroblasts migrate and replicate in response to mediators (C5a, fibronectin, PDGF, FGF, and TGF–β).[22] Besides producing collagen, fibroblasts are important in the production of elastin, fibronectin, glycosaminoglycans, and collagenase, which is important in the later maturation and remodeling phase.[23] Fibroblasts, along with perivascular mesenchymal cells, differentiate into myofibroblasts, which are important for wound contraction.[5,24] Glycosaminoglycans are complex polysaccharides that are important to the early granulation tissue response. Hyaluronic acid initially predominates but is replaced by chondroitin 4-sulfate, dermatan sulfate, and other proteoglycans.[5] Together these make up the ground substance that is important for subsequent collagen formation.[14]

Although collagen is present in the wound as early as day 3, the rate of synthesis increases dramatically by day 4. It is commonly believed that the fibroblastic aspect of the proliferative phase begins at this time.[25] Collagen molecules, or tropocollagen, are aggregated into filaments, which in turn are woven into fibrils via complex intermolecular bonding. Finally, the fibrils combine in a ropelike fashion to form the collagen fiber[14] (Fig. 2–5).

In the early period of fibroplasia, type III collagen predominates. As the scar matures, however, type I collagen is the major component of scar tissue.[9] Although wound tensile strength is minimal in the first few days, there is a gradual increase in strength corresponding to the amount of collagen in the wound. At the end of the inflammatory phase, approximately 5 to 7 days, the wound has only about 10% of its final tensile strength. Collagen synthesis and degradation reach a maximum about 3 weeks after injury.[3] A period of maturation follows, during which collagen formation subsides and fibroblasts decrease in the scar.

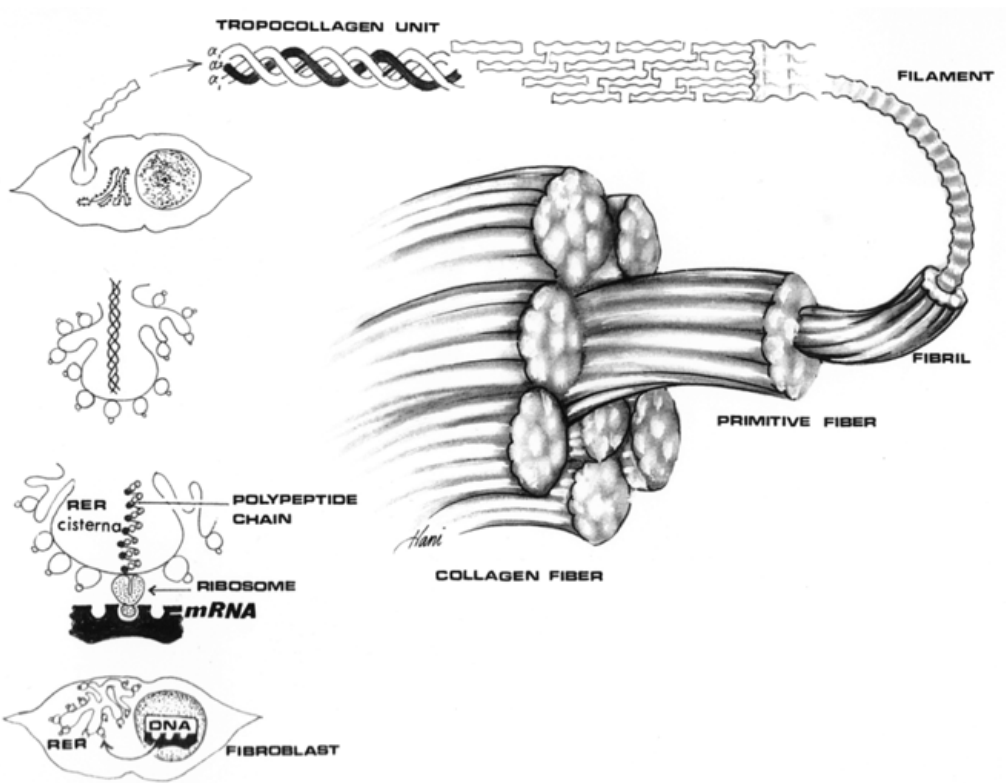

Figure 2–5 Summary of collagen formation.

Discussion of the proliferative phase is not complete without a discussion of wound contraction neovascularization. Because the wound must be essentially closed before other long-term healing phases will progress, an attempt to contract the wound is begun in full-thickness wounds. This contraction is centripetal, mediated by the myofibroblast, and maximal at 10 to 15 days. If a wound is left open for a long time, contraction may become severe, especially if significant inflammation is present.[3] In the presence of skin grafts, wound contraction is less severe but still a significant factor. Even with full-thickness skin grafts, 20% contraction will generally occur.[26]

Neovascularization is obviously important to the healing wound. Early endothelial cell migration through the basement membrane is followed by angiogenesis, which is stimulated by macrophages, platelets, lymphocytes, and mast cells. These cells release numerous growth factors, including FGF, PDGF, TGF–α and β, and vascular endothelial growth factor. Low oxygen tension in the wound may stimulate an angiogenesis factor from macrophages, leading to the formation of new vascular channels.[27] As oxygenated blood reaches the wound, this factor decreases stimulation of neovascularization, leading to an eventual decrease in vascularization of the scar.[9]

The final stage of wound healing is the maturation or remodeling phase. During this period, the scar becomes stronger and shows a decrease in its dimensions and erythema. It is pale in color, softer, and less protruding. These changes are all secondary to the remodeling and reorganization that occurs. As mentioned, type III collagen is gradually replaced by type I collagen. Water resorption around the scar allows further organization of the collagen fibers.[5] Although these fibers are initially in disarray, they gradually line up in a more parallel fashion, increasing tensile strength and improving appearance. Likewise, neovasculature regresses and the final scar is relatively avascular.

Completion of the remodeling phase may take 12 to 18 months. At this time, the scar has approximately 70 to 80% of the tensile strength of unwounded normal skin (Fig. 2–6).

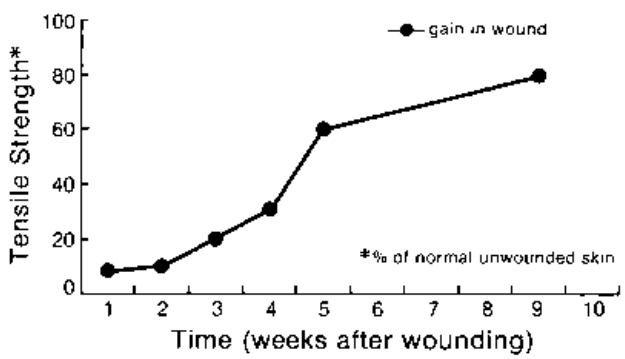

Figure 2–6 Increase in wound tensile strength with time after injury. (Modified from Goslin JB. Wound healing for the dermatologic surgeon. *J Dermatol Surg Oncol* 1988;14(a):965. With permission.)

TABLE 2–2 Factors That Impede Wound Healing

Disease states	Local factors
Hereditary	Ischemia
Coagulation disorders	Infection
Ehlers–Danlos/Marfan's	Tissue trauma
Prolidase deficiency	Retained foreign body
Werner's syndrome	Desiccation
Vascular disorders	Medications
Congestive heart failure	Glucocorticoids
Atherosclerosis	Anticoagulants
Hypertension	Antineoplastic agents
Vasculitis	Colchicine
Venous stasis	Penicillamine
Lymphedema	Vitamin E
Metabolic	Salicylates (high dose)
Chronic renal failure	Nonsteroidals (high dose)
Diabetes mellitus	Zinc sulfate (high dose)
Malnutrition	Vitamin A (high dose)
Cushing's syndrome	
Hyperthyroidism	
Immunologic deficiency states	
Others	
Chronic pulmonary disease	
Liver failure	
Malignancy	

Source: Terris DJ. Dynamics of wound healing. In: Bailey BJ (ed). *Head and neck surgery–otolaryngology.* 2nd ed. Philadelphia: Lippincott-Raven Publishers, 1998. With permission.

CLINICAL CONSIDERATIONS IN WOUND HEALING

Although wound healing proceeds in a systematic fashion, local factors and systemic considerations may affect healing. Attempts have been made for hundreds of years to hasten the healing process, but no condition or substance has been shown unequivocally to achieve this goal. More importantly, certain local wound conditions and systemic deficiencies that impair optimal wound healing have been noted (Table 2–2).

LOCAL WOUND HEALING FACTORS

Of absolute importance to normal wound healing is the local wound environment. Factors in this environment that may be affected by the clinician are reviewed in the following section.

Wound Closure Techniques

Good surgical technique is essential for normal wound repair. Crushing skin edges with inappropriately large forceps, tying sutures too tightly, and cauterizing too excessively

may result in local tissue inflammation, necrosis, and, potentially, infection. If improper suture material is used, similar events may occur. The surgeon must always take into account basic surgical principles as a major factor in the wound healing process.

Wound Desiccation

Adequate wound humidity is essential for proper healing. Studies suggest that epithelial cells migrate if there is adequate surface moisture.[20,28] Desiccated, crusted (i.e., scab) wounds heal much more slowly than those that are kept moist. As shown in Fig. 2–4, epithelial cells will select a pathway of migration at a proper moisture or humidity level deep to the crusted scab area in a desiccated wound. Not only is this often a longer route for epithelial closure, but it is also one that requires increased energy expenditure by the cell. If the wound is kept moist, particularly with an occlusive dressing, migration proceeds more directly and efficiently.[5,28] Accordingly, numerous semiocclusive or occlusive dressings have been developed. Studies suggest that minimal atmospheric oxygen is directly absorbed through an open wound; thus, even totally occlusive dressings allow normal wound healing.[21,29] With either type of dressing, epithelialization is enhanced, thus decreasing epithelial closure time by up to 50%.[21,28,30,31] Occlusive dressings have the added advantage of promoting fibroblast, keratinocyte, and endothelial cell proliferation because of the fluid that collects under these impermeable membranes, which contains PDGF.[32–34] However, bacteria may have the opportunity to proliferate under such dressings. Table 2–3 presents some of the commonly used biosynthetic occlusive or semiocclusive dressings.[9,21,35] Clinical evidence supports the use of such dressings after CO_2 laser skin resurfacing.[36,37] Topical medications are commonly utilized for abraded wounds and after wound closures. Eaglestein and Mertz noted the effect of various medications on the relative rate of healing.[38] For example, triamcinolone ointment hindered the relative rate of healing by 34% and petroleum jelly by 8%. On the other hand, polymyxin B sulfate (Neosporin ointment) and silver sulfadiazine (Silvadene cream) increased the healing rate by 28%.

Wound Tissue Ischemia

Local tissue ischemia caused by infection, hematoma, foreign bodies, anemia, or poor surgical technique may slow wound healing. Oxygen is consumed in higher quantities in a healing wound.[39] However, even under optimal wound healing conditions, tissue injury results in reduced oxygen when it is most needed. It should be noted that not all wound healing phases are affected by low oxygen tensions; chemotactic and growth factors, angiogenesis, and epithelial cell migration are promoted by hypoxia.[9] However, for fibroblasts to proliferate and collagen synthesis to occur, a P_{O_2} of 30 to 40 mmHg is necessary.[40]

Oxygen supplementation, via hyperbaric oxygen administration, may improve the rate of epithelialization, but it appears not to have an impact on long-term wound healing results.[41]

Infection

Ischemic, contaminated states may lead to local bacterial wound infection. If this occurs, wound healing will be prolonged.[9] Bacteria delay normal healing phases by directly damaging cells of wound repair, by prolonging the inflammatory phase, and by competing for oxygen and nutrients within the wound.[9,42]

SYSTEMIC WOUND HEALING FACTORS

Congenital Alterations

Genetic disorders affecting wound healing, rarely seen clinically, include Ehlers–Danlos syndrome, pseudoxanthoma elasticum, cutis laxa, osteogenesis imperfecta, progeria, and many others. Different types of the wound healing process causing pathologic wound healing or defective collagen production result from congenital errors in metabolism.[42]

Although diabetes mellitus may also be acquired, it is more commonly an inherited condition that affects wound healing in multiple ways. Microangiopathy diminishes oxygen delivery, whereas insulin deficiency is particularly significant in early wound healing phases when leukocyte function is defective. This combination of factors creates the potential for an increased incidence of wound infections.[39,42,43] Low insulin states also lead to defective collagen synthesis.[43] Early insulin therapy and supplemental vitamin A (25,000 units/day) appear to improve wound healing in patients with diabetes.[42,44]

Hypertrophic scars and keloids represent genetic pathologic "overhealing" states. The lesions are caused by excessive production and deposition of collagen and glycoprotein without equivalent degradation. Although a thorough discussion of hypertrophic scars and keloids is beyond the scope of this chapter, differences between the two are important for clinicians. Hypertrophic scars (Fig. 2–7) are elevated and remain within the original tissue injury site; they tend to regress with time. In contrast, keloids (Fig. 2–8) overgrow the boundaries of the original injury and invade the surrounding normal tissue.[42,45] Treatment of both hypertrophic scars and keloids is directed toward inhibiting collagen overproduction by a combination of intralesional corticosteroids and, occasionally, excision with postoperative pressure devices, silicon gel sheeting, interferon-α2b, or radiation.[46] However, recurrence is usually frequent, although one study reported only an 8% recurrence rate when surgery excision of keloids was combined with radiation or intralesional steroids and interferon-α2b.[47] Finally, TGF–β1 has been shown to induce keloid collagen growth. Future therapy may be aimed at blocking the action of this growth factor in wounds prone to keloid formation.[22]

Acquired Alterations

Although no agent or process has been shown to improve wound healing unequivocally, certain deficiency and disease states are known to impair wound healing.

TABLE 2–3 Types of Newer Surgical Dressings

Name	Types of composition	Transparent	Adherent	Absorbent	Gas-permeable	Fluid-permeable	Clinical uses
Opsite	Polyurethane	Yes	Yes	No	Yes	No	Sutured wounds, cutaneous ulcers, skin graft sites, laser wounds
Tegaderm	Polyurethane	Yes	Yes	No	Yes	No	Same as for Opsite
Bioclusive	Polyurethane	Yes	Yes	No	Yes	No	Same as for Opsite
Ensure	Polyurethane	Yes	Yes	No	Yes	No	Same as for Opsite
Flexan	Two-layer polyurethane	No	Yes	Yes	Yes	No	Laser wounds
RevitaDerm	Three-layer polyurethane	No	Yes	Yes	Yes	No	Laser wounds
Vigilon	Polyurethane oxide/water	Partially	No	Yes	Yes	Yes	Dermabrasion, laser wounds
Second Skin	Polyurethane oxide/water	Partially	No	Yes	Yes	Yes	Dermabrasion, laser wounds, friction blisters
Duoderm	Hydrocolloid	No	Yes	Yes	No	No	Cutaneous ulcers, sutured wounds, dermabrasion, friction blisters
Comfeel Ulcus	Hydrocolloid	No	Yes	Yes	No	No	Same as for Duoderm
Biobrane	Silicone/nylon with collagen peptides	No	No	No	Yes	Yes	Thermal burns, dermabrasion
Silon-TSR	Silicone polymers	Yes	No	No	Yes	Yes	Laser wounds, dermabrasion
N-terface	Monofilament plastic	No	No	No	Yes	Yes	Skin grafts, dermabrasion, laser wounds

Source: Expanded and modified from Wheeland RG. The Miller surgical dressings and wound healing. *Dermatol Clin North Am* 1987;5(2):400.

Figure 2–7 Hypertrophic scar.

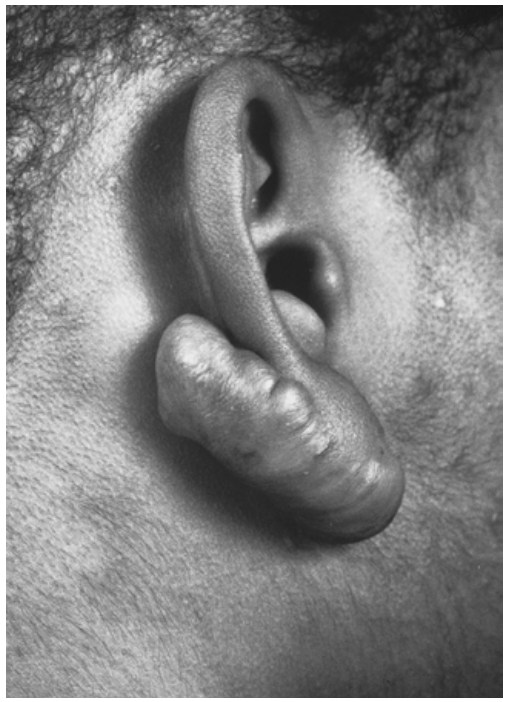

Figure 2–8 Keloid.

Nutritional deficiencies rarely cause poor wound healing unless they are extremely severe, which may be the case in patients with cancer or alcoholism. Severe protein deficiency affects healing, and, in this circumstance, an effort to correct the nutritional state with administration of essential amino acids must be made to ensure normal wound healing.[9,25]

Several vitamins play supportive substrate roles, and deficiencies may affect wound healing. Vitamin A deficiency inhibits epithelialization and wound closure, decreases collagen synthesis rates, and retards cross-linking of the collagen molecule.[3,5] As an important cofactor providing the hydroxylation of lysine and proline during collagen synthesis, vitamin C has long been known to be an important factor in wound healing. Because humans cannot synthesize vitamin C, bodily stores will only last 4 to 5 months before scurvy, with impaired wound healing, develops. Vitamin C is important in neutrophil function, serving as a reducing agent in superoxide radical formation. Thus, deficiencies may increase wound infection and inhibit healing.[3,21] Because the production of clotting factors II, VII, IX, and X depend on cofactor vitamin K, prolonged bleeding and hematoma may occur in deficiency states; moreover, when the clot forms, it is similarly deficient in clotting factors and cannot develop a normal collagen matrix.[9,21,25] Vitamin E inhibits wound healing by decreasing collagen production and tensile strength but appears to have minimal impact on the healing process.

Zinc and iron represent the most important trace elements involved in wound healing. Zinc is also an important component of enzymes in RNA and DNA synthesis and of collagenase.[5,21]

Many diseases that are beyond the scope of this discussion also may impair wound healing. This group includes hereditary conditions, vascular diseases (e.g., congestive heart failure, atherosclerosis, venous stasis, lymphedema), metabolic disorders (e.g., chronic renal failure, diabetes, Cushing's syndrome, hyperthyroidism), immune deficiency states, chronic liver disease, malignancies, and thrombocytopenic conditions.[5] Abnormal wound repair is commonly a result of poor nutrition or immunologic dysfunction in these medical conditions.

Other aspects of wound healing are affected by the aging process. With age, healing proceeds more slowly, and thus there is decreased tensile strength.[21,48,49]

Patients who have undergone radiation therapy are known to be at high risk for poor wound healing. Obliterative endarteritis may result in a wound with decreased collagen and poor tensile strength. In addition, other biochemical alterations at the molecular level probably play an important role.[25,50,51]

Numerous systemic medications have an impact on wound healing, although only a few are clinically significant. Most important are the corticosteroids that inhibit aspects of the inflammatory phase and eventually affect collagen synthesis and wound contraction.[52,53] Similarly, cellular defense mechanisms are affected, and the incidence of infection increases. Oral administration of vitamin A seems to reverse many of these adverse effects,[54] although routine administration of vitamins (e.g., vitamins C, A, E) or minerals (e.g., zinc) does not promote wound healing.[9]

Various chemotherapeutic agents affect wound healing via their relationship to the inflammatory phase or by initiating collagen synthesis and wound contraction. Although early phases of wound repair may be inhibited by these agents, normal healing usually results.[55]

FUTURE CONSIDERATIONS

Although a basic understanding of wound healing is evident in the literature, research in a variety of areas is needed, including the use of cutaneous growth factors and biologic dressings. EGF along with polypeptides that stimulate RNA and DNA

and protein synthesis have been shown to enhance the rate of healing of partial-thickness wounds.[18] Without question, further wound-enhancing modalities should be studied.

Biologic dressings and the use of cultured keratinocyte grafts merit watching in the future.[56] Large quantities of cultured autologous grafts can be grown and have been useful in the treatment of superficial wounds and as biologic dressings.

SUMMARY

The goal in management of cutaneous wounds is timely healing with an acceptable scar. Knowledge of the biology of tissue injury and repair is necessary to create optimal conditions for wound healing.

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Chapter 3

Soft Tissue Techniques

Ted A. Cook, Robert A. Guida, and Alan J. C. Burke

Expertise in facial plastic and reconstructive surgery requires knowledge and skills of basic soft tissue surgery. The face, with its excellent blood supply, variety of relaxed skin tension lines, and numerous anatomic boundary markers, offers great flexibility and challenge for rewarding cosmetic and reconstructive procedures. Superb results can only be obtained if certain rudimentary principles are practiced. It is the purpose of this chapter to discuss equipment, techniques, and surgical principles that we consider necessary to achieve optimal results.

Best soft tissue technique requires a detailed understanding of our working substrate. Throughout the head and neck, the skin has widely different thicknesses (e.g., scalp versus eyelid), sebaceous content (alar versus cervical skin), vascularity, and other attributes, such as skin appendages like hair. Different areas require different handling. Care must be taken not to advance tissue from one anatomic unit to another because the quality of skin will often change, resulting in a disfiguring scar.

The requirement for large or pedicled flaps and the need for tension applied to wound closure begs for an intimate knowledge of facial vascularity. Skin undermining and dissection should be done in the immediate subdermal layers to protect the dermal plexus of vessels in skin zones that receive watershed or random vascular supply. The random vascular supply refers to a blood supply from the musculocutaneous perforators that arborize in the subdermis. Axial flaps trace along the path of arterial vessels; therefore, they are more robust and can be more easily pedicled and transferred to areas of marginal vascular supply. Fortunately, the really excellent blood supply of the face provides for great resistance to infection and higher rates of wound healing in comparison with other tissues. At this juncture, it is important to note that smokers compromise their cutaneous circulation by causing prolonged vasoconstriction of the subdermal vascular plexus. Soft tissue viability following surgical manipulation can thus be seriously attenuated by smoking, affecting healing, scarring, and local flap viability.

EQUIPMENT

Soft Tissue Instrument Set

To obtain good soft tissue handling, proper instrumentation is mandatory. The basic soft tissue instrument set should include the 10 items listed in the box and depicted in Figure 3–1. Brown-Adson forceps are toothed to provide a firm grasp of

Basic Soft Tissue Instrument Set

1. Brown-Adson tissue forceps
2. Bishop-Harman tissue forceps
3. Single and double skin hooks
4. Webster needle holder
5. Castroviejo needle holder
6. Stevens tenotomy scissors
7. Castroviejo calipers
8. Small suture scissors
9. No. 15 knife blades
10. Moist sponges

Figure 3–1 Soft tissue instrument set.

deep soft tissue. For finer, less traumatic manipulation, as in skin closure, the delicate, single-toothed Bishop-Harman forceps are used. Skin hooks inflict less tissue crushing than forceps and are essential for skin edge eversion and retraction needed in skin undermining or placement of subcuticular sutures. Two varieties of needle holders are used to effectively manage the smaller needles used for facial surgery. The Webster needle holder easily grasps smaller needles and is used for subcuticular or deep suturing of the head and neck. The delicate Castroviejo needle holder allows accurate placement of finer sutures for skin closure, nerve grafting, or other precise work. A variety of Stevens tenotomy scissors are used for undermining or cutting through soft tissues or skin. The tips are curved and blunted and should be used with the points directed upward when undermining and in the direction of the incision when cutting through skin. Smaller suture scissors are necessary to achieve more accurate cutting of the fine sutures used in facial work. Precision work and flap design frequently require measurement with Castroviejo calipers because of the easy maneuverability, 0- to 20-mm scale, and sharp tips that can be used for skin markings. Knife handles on the set include no. 3, no. 9, and the Beaver handle. The nos. 15 and 11 knife blades are the most frequently used in facial plastic surgery. The larger no. 10 blade is rarely required on facial skin. Finally, moist sponges are always used in soft tissue work on the face. A wet sponge causes less pulling and trauma to the soft tissue and blood vessels than a dry sponge.

Local Anesthesia Set

The majority of work done on the face can be accomplished with local anesthesia only (Fig. 3–2). The local set should consist of a 10-mL three-ringed syringe. The three-ringed holder offers control for injecting small amounts of anesthesia. A 30-gauge 1.5-in. needle minimizes the pain of injection. A sealed, packaged anesthetic agent, often 1% lidocaine with 1:100,000 epinephrine, is used in conjunction with sodium bicarbonate in a 9:1 mixture. Preservatives in the packaged anesthetic bottle lower the pH, causing increased pain on injection. This can be minimized by the buffering effect of the sodium bicarbonate. We most commonly use a 50:50 combination of 1% lidocaine, a short-acting amide, and 0.5% bupivacaine, a longer-acting amide, to provide more lasting local anesthesia. The addition of epinephrine reduces intraoperative bleeding by causing vasoconstriction and also prolongs anesthetic action by preventing leeching of anesthetic solution from the soft tissues.

TABLE 3–1 Lidocaine vs. Bupivicaine: Onset, Dose, and Duration of Action

	Onset	Dose (mg/kg)	Duration(h)
Lidocaine	Rapid	3–5 5–7 with epi	1–2
Bupivacaine	Delayed	3	2–4

Photographic Equipment

A camera is an absolute necessity in the practice of facial plastic surgery. Not only is it helpful for insurance documentation and liability coverage, but it is most significant in maintaining good patient rapport. Important features include a 35mm camera body, a macro lens with a focal length of 105 mm that allows for portrait shots, an off-centered metered flash, and a sturdy carrying case capable of carrying extra miscellaneous equipment. Modern digital film technology now has an image fidelity that closely matches that of conventional 35mm film. The latter is still regarded as the gold standard for image documentation, though the ease of use, image manipulation, and archiving is making digital photoprocessing a more popular option.

EXCISIONS

Planning of Excisions and Incisions

Proper planning is necessary for achieving good results when excising lesions on the head and neck.[1] The face has several unique features that must be recognized before any surgical

Figure 3–2 Local anesthesia set.

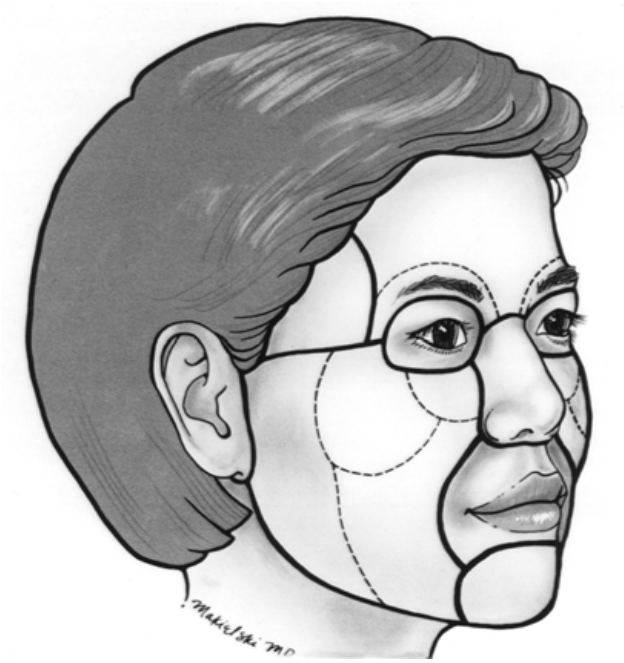

Figure 3–3 Anatomic subunits of the face.

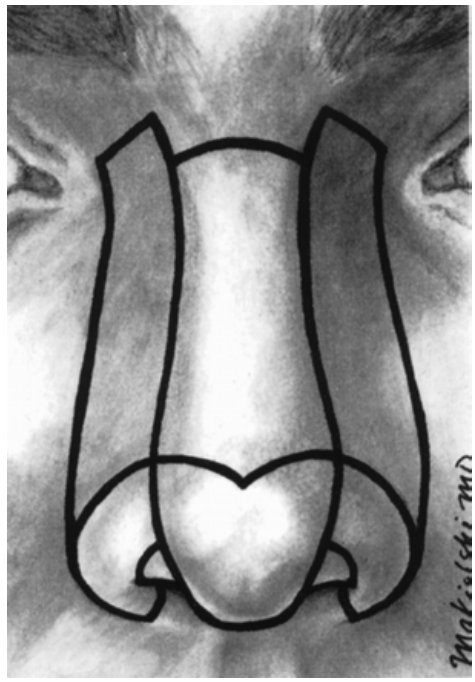

Figure 3–4 Nasal subunits.

maneuvers can be planned. An abundance of anatomic boundary markers between aesthetic units can be found on the face (e.g., the sublabial crease, the nasolabial fold, and the preauricular crease) that are ideal for incision placement (Figs. 3–3 to 3–5). The relaxed skin tension lines (RSTL) and a lack of tension-loaded facial movements enables one to hide and minimize most facial incisions (Figs. 3–6 and 3–7). The RSTLs are equivalent to the lines observed originally by Langer when he excised circular punches of skin in cadavers and observed their resultant linear configuration. These RSTLs can be predicted based on the underlying facial mus-

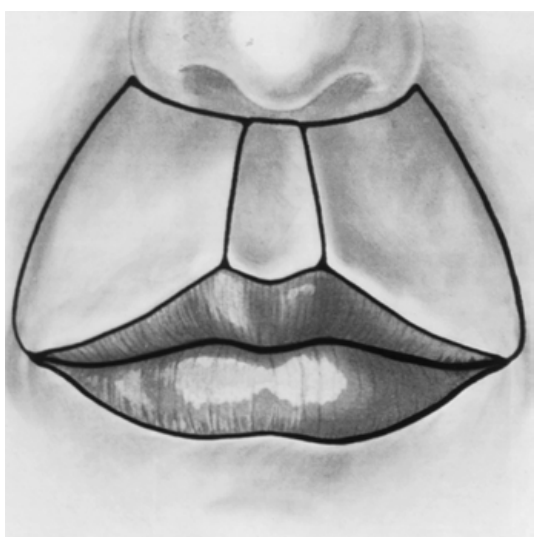

Figure 3–5 Lip subunits.

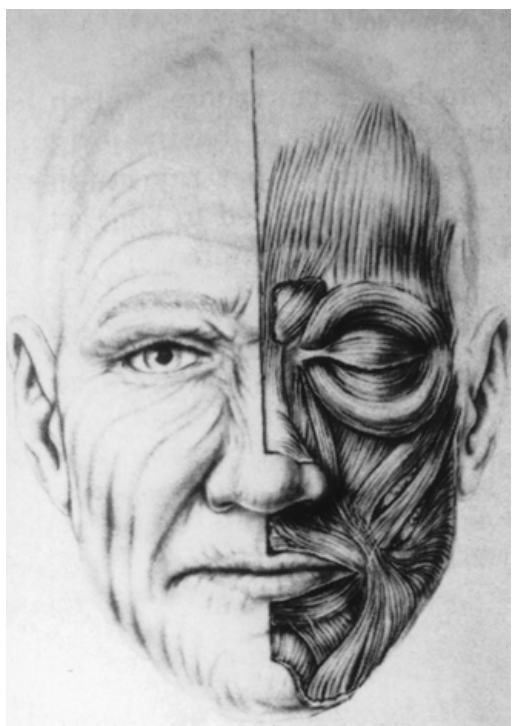

Figure 3–6 Facial rhytids and relationship to underlying facial musculature. (From Larrabee WF, Makielski KH. Surgical anatomy of the face. New York: Raven Press; 1993, with permission.)

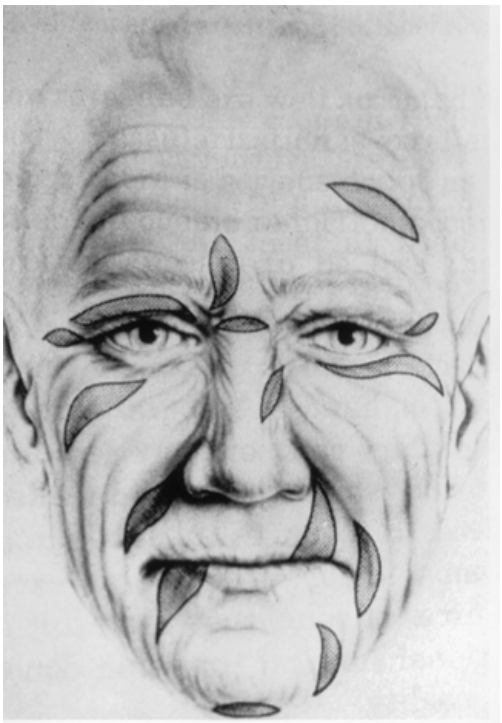

Figure 3–7 Fusiform excisions along facial relaxed skin tension lines.

culature; they will always be perpendicular to the orientation of muscle fibers. The only exception is around the eye where the RSTLs parallel the musculus orbicularis oculi fibers, owing to the rigid scaffold provided by the tarsal plate. All incisions, especially in the face, must be made so that the long axis of the incision is in one of the RSTLs even if it curves or, in some instances, double curves. Incisions made in the RSTL will close with minimal tension and without widening the scar; however, incisions made across the lines will close under significant tension and the scar will spread as it heals.

Anatomical subunits distract visually from the perception of scars along the borders because of facial geometry, angulation, and shadowing. Many different access incisions can be hidden in orifices, such as endonasal or transconjunctival incisions. Utilizing anatomical structures as fence-like barriers works in select circumstances, such as placement of bilobe flaps around the ear or within the alar crease. The hairline or the hair itself provides excellent camouflage. Scars that are the result of endoscopic techniques are similarly camouflaged by the tunneling of access incisions to the site of interest.

Certain areas require exacting tissue handling and reconstitution. The mucocutaneous borders of the lip's vermilion and the eyelid's gray line are such examples. In these areas not only must the precise depth and alignment of the mucocutaneous junctions be restored but the exact structural integrity of the underlying supporting structures—the musculus orbicularis oris in the lip and the tarsal plate in the lid—must be meticulously reconstructed.

Often structural or tension-bearing elements are required. The superficial musculo-aponeurotic system (SMAS) layer provides an underlying supporting, tension-bearing trapeze in the subcutaneous layer of the skin. This can be utilized to place tension on structures and appose the epidermis in a tension-free manner. Examples include the deep temporalis fascia or the canthal tendons both of which can support great tension loads.

The simplest type of excision is a fusiform design commonly referred to as an ellipse. The fusiform excision involves wide undermining of all sides and bilateral advancement of tissue for closure. As mentioned previously, the fusiform must always be designed in an RSTL and with a length-to-width ratio of 2.5:1 to 3:1, thus helping to avoid the standing cone or dog-ear deformity at the ends of the wound on closure (Fig. 3–7). The dog-ear or standing cone deformity results from the rotation of skin around a pivot point. The excess skin and advancement collects in the shape of a cone. The formation of these dog ears can be predicted and prevented by the excision of excess tissue that permits the standing cone to lay flat. Burow's triangle is a simple example of this execution and should ideally be designed to parallel the excision lines in the RSTLs for best camouflage. To flatten a standing cone, an inferiorly based triangle is excised, akin to the door flap of a tee-pee.

Methods of altering the size of the fusiform excision can be usefully employed (Fig. 3–8). An M-plasty created at the ends of the fusiform will shorten the final length of the wound and decrease the volume of healthy skin excised.[2] However, the trade-off for shortening the overall incision length is to create an additional small incision on each side and a wound that is a bit more complex to close. The limbs of an M-plasty should be less than 30 degrees to help avoid the creation of standing cone deformities. The closure is actually a V-to-Y maneuver that shortens the scar along its central axis. This technique is used when large defects may be closed as an ellipse and when avoiding extension of an ellipse across a normal anatomic border, such as the vermilion. Serial excisions at 2- to 3-month intervals will allow excision of larger defects with a final straight-line closure. Serial excisions are performed by excising and discarding scar tissue until a point is reached where the minimized scar can be excised from healthy tissue boundaries.

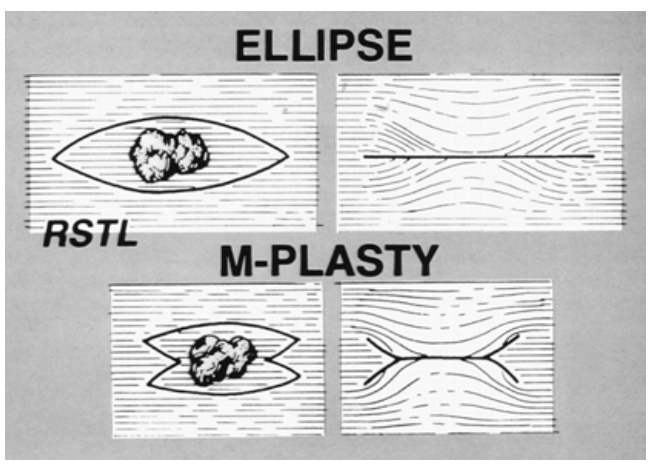

Figure 3–8 Upper: Planning and creating a fusiform excision. Lower: M-plasty for a shorter scar.

This technique has a similar background to tissue expansion where the dermis is stimulated to hypertrophy, increasing its surface area and thus affording larger flap expansion and the ability to excise a lesion in single or fewer stages. Tissue expanders have gained some popularity for large wound closures and in scalp excisions. Saline-filled expanders are sized and placed in subgaleal pockets to permit their fixation. Expansion takes place over the course of 3 to 6 weeks during which different regimens are used to inflate the expander with injected saline. Reexcision may be prevented in some areas, such as scalp or forehead, by the use of tissue expanders at the sides of the defect before final closure.

Execution of Incisions

Most incisions in the facial region can be made with either a no. 15 or a no. 11 blade using a no. 9 knife handle. The no. 11 blade is most useful for straight cuts made perpendicular to the skin with a sawing-type motion (e.g., creating small cuts in a running W-plasty incision). The initial knife position is perpendicular to the skin edge, and the tip of the blade should be used to begin the incision. Then the handle of the knife should be arched downward so that the midportion of the incision is made with the belly of the blade. At the end of the incision, the handle should be arched upward again so that the end of the incision is made with the tip of the blade. The blade should always be perpendicular to the skin surface, and the incision should be made completely through skin and subcutaneous tissue for the entire length of the cut. When making an incision to excise a lesion, instead of creating the cut at right angles to the skin surface, bevel the incision outward (Fig. 3–9). This accomplishes the following: it aids in skin edge eversion, which is helpful in preventing depressed scars; it helps to create the plane for undermining; and it gives better assurance of completely excising around the lesion. A skin hook should then be placed into the starting end of the first-side incision providing traction and stabilization for the second-side incision. Without this stabilization of the end of the wound it is difficult to make the second incision precise.

The final step in executing an excision before closure is undermining. This is performed in proportion to the amount of skin tension and to optimize suturing techniques. Undermining should be done in the immediate subdermal plane (Fig. 3–10). Around the central face, this plane avoids emerging motor nerves. The facial nerve branches pass deep to all of the mimetic musculature except those branches that emerge superficially to innervate the lateral fibers of the orbicularis oris, approximately 1 to 2 cm from the lateral commissure. Undermining should be used in virtually all surgical procedures in the skin of the head and neck and should be done completely around the incision, the ends as well as the sides, for a distance of about 2 cm from the wound edges. Studies have shown that undermining beyond 2 cm is probably counterproductive in removing tension from the wound edges.[4] However, for advancement and rotation flaps, useful undermining should be performed 3 to 4 times the length of the arc of rotation, or size of the defect to be closed. The scalp requires special consideration. Despite extensive undermining in the scalp, little advancement can be achieved because of the tensile strength of the galea aponeurosis. This can be overcome by placing multiple galeotomies perpendicular to the line of scalp advancement to facilitate mobilization of scalp tissue.

Although undermining has traditionally been performed with curved scissors and tissue forceps, the use of a skin hook and a no. 15 scalpel blade is more advantageous. The skin edge should be everted outward with the skin hook and middle finger, and the belly of the no. 15 blade beveled upward to scrape the undersurface of the skin to be undermined. This technique provides more effective skin eversion, less crushing of the skin edges tissue, and more accurate and less traumatic undermining. Undermining allows for movement of wound edges toward the center of a defect and decreases the tension on the wound edges. Also, with differential undermining one can move the center of the excision to a desirable spot. This principle is especially important when closing cheek defects arising from meilolabial flaps. The skin and soft tissue of the upper lip are not undermined to prevent upward distortion of this aesthetically important anatomical unit. The undermining is borne by the upper malar tissue, allowing its mobilization to the lip.

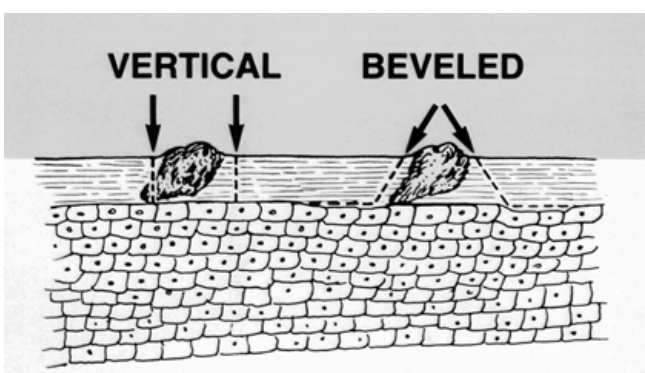

Figure 3–9 Beveling outward from lesion when creating skin incision.

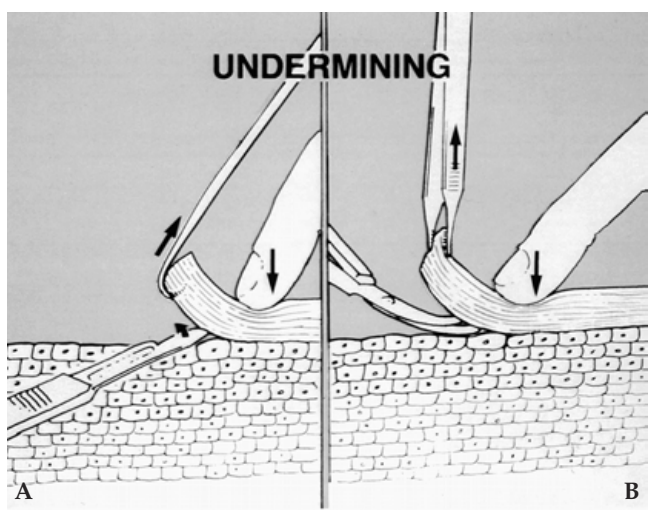

Figure 3–10 Undermining skin with skin hook and no. 15 blade (**A**) versus forceps and scissors (**B**).

Closure of Excisions

By wound closure, we generally refer to the active process of primary-intention, suture-assisted healing. The goal of secondary-intention healing is not to appose the skin edges but to allow the wound to heal by the collection of granulation tissue from the base to the superficial layers of a wound over which epithelium migrates. Secondary intention healing is always an option, but rarely is it the best cosmetic option. The canthal areas of the eyes are particularly amenable to secondary-intention healing with a good cosmetic outcome. In these areas, the skin is thin, contoured in three dimensions, and subject to constant motion secondary to lid closure—all issues that might favor secondary-intention healing.

Depending on the size and location of the defect, closure of an excision can be done primarily (e.g., in a fusiform defect), with a flap, or using a graft. Regardless of the technique chosen, the following three principles for achievement of better wound healing should be remembered: minimize trauma to the wound edges, place minimal tension on the wound edges, and provide eversion of the skin closure.

When closing a defect, especially a fusiform excision, it is important to equalize the sides of the incision to avoid bunching at the ends of the wound. The best way to avoid this problem is to use the principle of halving (Fig. 3–11). This is done by placing the first suture in the center of the defect. The next suture should bisect the two remaining halves, and, by continuation of this halving, the wound will be closed with equal tension and eversion throughout, even if one side of the incision is initially longer than the other. Another technique to equalize the length of both sides of an excision is to remove a triangle of skin (Burow's triangle) from the longer side of the wound (Fig. 3–12). Often, if adequate undermining is performed, this step can be avoided.

There are several methods for closing a wound (Fig. 3–13). The standard simple suture should be inserted with the needle angled slightly outward to achieve slight eversion of the wound edge with the knot tied as far as possible from the wound edge (Fig. 3–10A). The simple suture provides little wound edge eversion and hardly any relief of wound edge tension; therefore, it is not the best approach to closure of facial skin. Vertical mattress suturing involves placing the small intracuticular portion of the suture first, holding up the wound edges with the suture, and causing eversion of the wound for placement of the wide portion of the suture (Fig. 3–10B). This suture provides both eversion and tension relief, and for this reason it can be useful in closing skin edges that will be under tension despite subcutaneous closure.

Tacking of wound corners can be accomplished either by placement of simple interrupted corner sutures or by use of the Gillies half-buried corner stitch. Here the corner tissue is tacked into place by a suture that begins in a transcutaneous position, passes through the dermal plane of the advancing tissue corner, and finishes with a transcutaneous suture. This has the theoretical advantage of providing strength to a tissue closure without disrupting the skin. It often works best in narrow-based tissue remnants where passing a needle transcutaneously through the apex would otherwise be technically difficult and result in unnecessary tissue trauma.

The most useful suture technique for accomplishing both eversion of wound edges and relief of tension of the edges is the subcuticular buried everting technique (Fig. 3–13B). In placing the suture in the head and neck region, a small, one-half curved, reverse cutting needle (such as the Ethicon P-2 needle) is most helpful. The subcuticular suture is placed while everting the wound edge outward between a skin hook and the middle finger. The surgeon should reach back with the needle under the dermis and insert the suture 2 to 3mm back from the wound edge, tying the knot in a buried fashion. The monofilament absorbable synthetic material polydioxinone (PDS) is preferred for the buried subcuticular suture because there is less chance of cutting the tissue in a cheese-wire fashion. The skin is then closed with fine monofilament or fast-absorbing gut to align the depth of the two sides of the wound. Stainless steel staples provide for wound eversion and ride above the level of the skin surface when in place (Fig. 3–10F). Because of this and the low tissue reaction from stainless steel there is very little incidence of skin marking from staples themselves. They are particularly useful for enclosing neck and scalp defects, providing full-thickness closure.

Simple interrupted sutures are most commonly used to reapproximate skin edges once the subcuticular layer has been placed. Because placement of such sutures can be time consuming, some clinicians prefer using simple running sutures or a running locking suture technique. The advantage of the running suture is that it is quicker to place and provides even tension throughout the length of the wound.

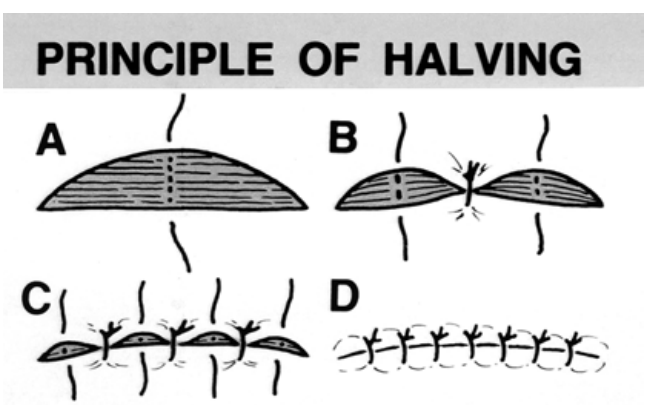

Figure 3–11 Principle of halving.

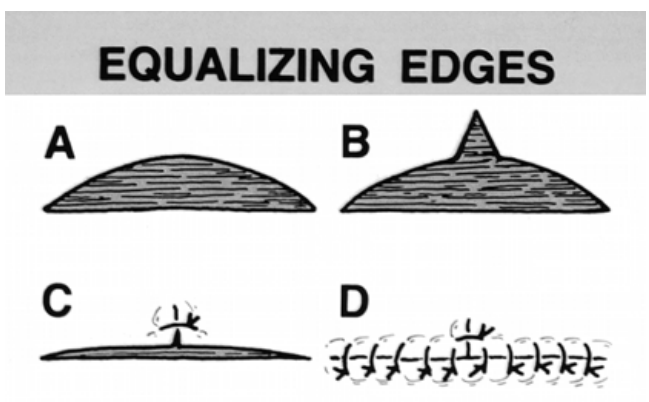

Figure 3–12 Equalizing length of edges with a Burow's triangle.

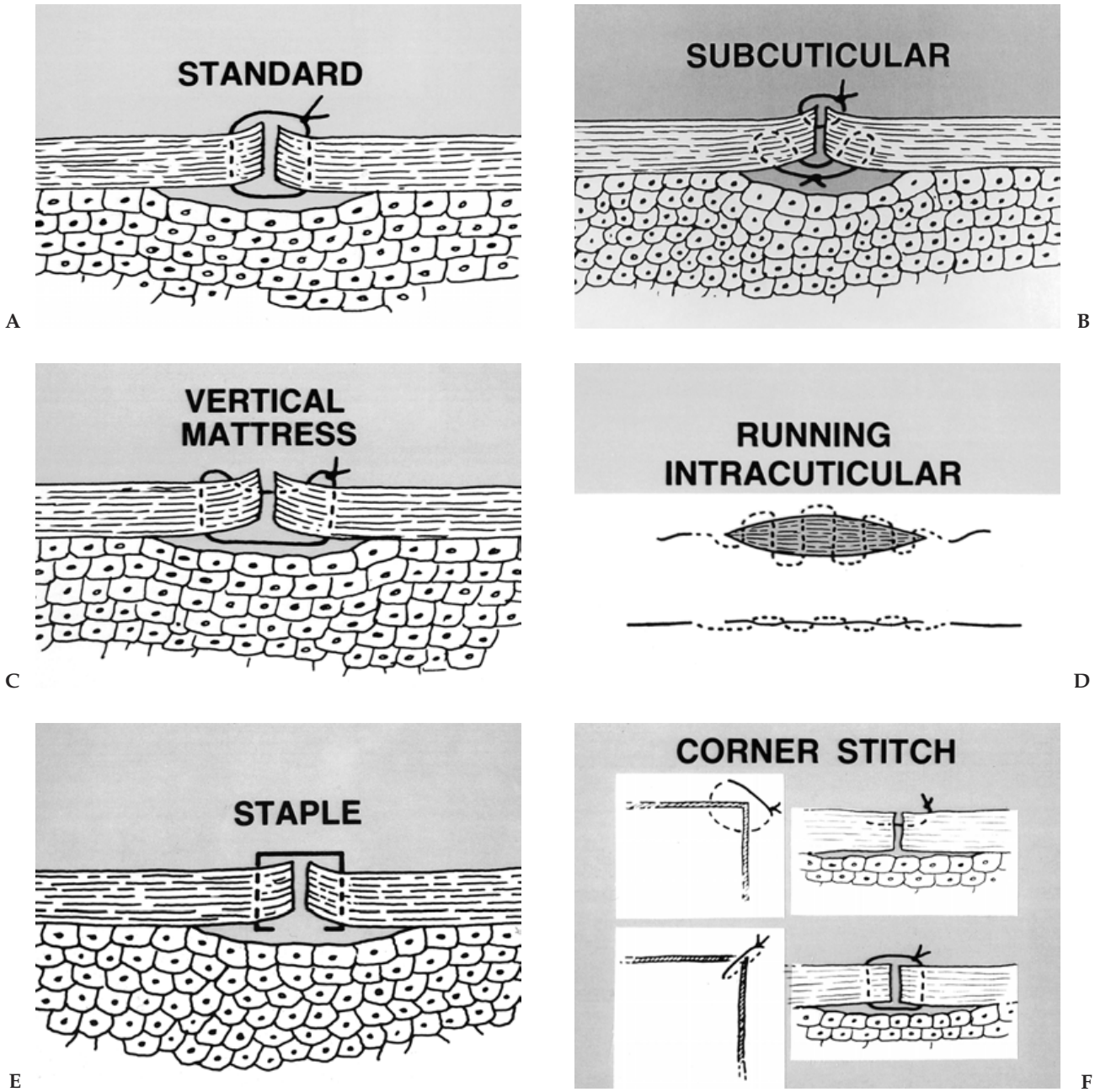

Figure 3–13 Excision closure techniques. **(A)** Standard simple suture. **(B)** Subcuticular buried everting suture. **(C)** Vertical mattress suture. **(D)** Running intracuticular suture. **(E)** Stainless steel staple. **(F)** Corner stitch.

However, if pulled too tightly, the running suture may compromise vascularity to the skin edge. The running intracuticular suture provides good closure of straight wounds, especially in children, but does not relieve tension from the wound edges. Although more time consuming and difficult to use, it can provide an excellent result once the technique is mastered.

When proper subcuticular closure of a facial wound has been done, there should be eversion of the skin edges, with the edges approximating each other under minimal tension. The skin can then be properly closed using a 6-0 fast-absorbing gut that has minimal tissue reaction and will dissolve spontaneously in 3 to 5 days. The repair is then reinforced with sterile strips to relieve wound edge tension further. For minimizing scar widening, wound taping for 4 to 6 weeks or more has been advocated (even though this can occur for up to 6 months) and is usually satisfactory in cosmetic-sensitive areas or in areas where the dynamic stretching of underlying musculature would otherwise put the wound under adverse tension, e.g., lip wounds.

Interest in the use of cyanoacrylate tissue adhesives for the closure of wounds, both traumatic and surgical, has grown rapidly.[5] Many authors feel that these adhesives will gain a significant role in wound care because of their ease of application, simplification of wound care, and good performance in comparison with that of traditional sutures. Their use has been limited by the histotoxicity of their degradation products, cyanoacetate and formaldehyde, though now products with lowered histotoxicity have been introduced. The use of cyanoacrylates has been particularly favorable in the emergency room due to ease of use and with pediatric patients because of the ability to avoid the emotional and physical pain of needles. Some authors believe that there is no cosmetic difference between standard suture and cyanoacrylate closure. We believe that for selected wounds cyanoacrylate tissue adhesives hold great promise but that the wound characteristics are of key importance; superficial wounds without deep tissue penetration appear most suitable for this type of adhesive.

The final aspect of closing an excisional wound involves adequate dressing to provide protection and pressure to the site. This prevents collection of fluid or blood underneath the wound edges. The dressing usually involves antibiotic ointment, a nonadhesive gauze, and cotton or gauze sponge followed by tape. A tissue adhesive on the surrounding skin is used to prevent the tape from losing its firm attachment to the skin. Drains can be used if there is a risk of hematoma development, with the aim of removing these when less than 10 cm^3 has been collected in a 24-hour period in the face, or 30 cm^3 in the neck.

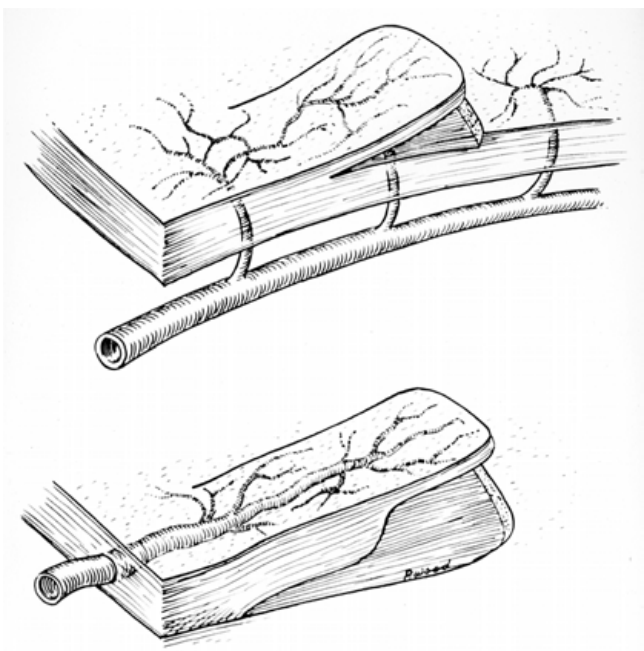

Figure 3–14 Upper: Random-pattern flap. Lower: Axial-pattern flap.

LOCAL FLAPS

The simplest local flap is the fusiform excision (discussed previously). As a general rule, one should favor the simplest repair and avoid more complex closures. Because the skin of the head and neck has a superb subdermal vasculature, almost all local flaps in this area can be designed as random-pattern flaps rather than axial-pattern flaps based on specific arteries (Fig. 3–14).[6] The flaps are almost always elevated in the immediate subdermal plane; and sharp undermining is necessary on all sides of the flap and receptor site in this same plane. The principles of soft tissue surgery previously mentioned should be strictly adhered to when executing these flaps.

Unilateral Advancement Flap

The classic, single-pedicled advancement flap moves entirely in one direction, advancing over the defect (Fig. 3–15). It has limited value in the head and neck because of its somewhat restricted flexibility. The forehead and lip, especially the upper lip, are the two areas where this flap may occasionally be useful. In the face, these flaps are rarely designed in a straight line but commonly follow the natural skin lines. The length-to-width ratio may be as high as 4:1 and seldom requires excision of Burow's triangles for closure if adequate undermining is performed. For smaller defects, a variation of the single advancement flap is the V to Y flap. This design recedes the flap away from the defect and can be used to bulk up an area slightly widened and lengthen an axis of an area (Fig. 3–16).

Bilateral Advancement Flap

The bilateral advancement flap is more flexible in terms of planning, although the same principles of design utilized for the single advancement flap also apply here. A flap is

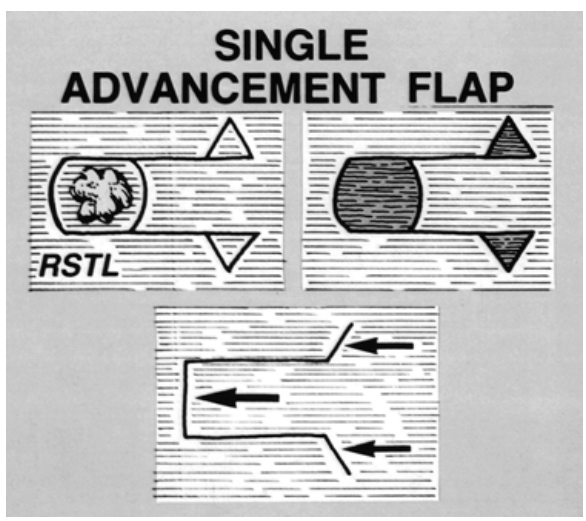

Figure 3–15 Unilateral advancement flap.

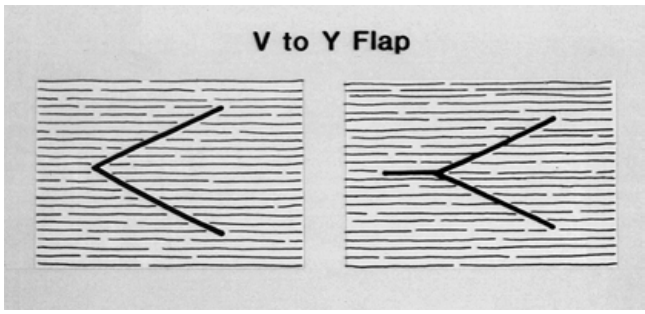

Figure 3–16 V to Y advancement flap.

advanced from both sides of a defect that is too large to be closed with a single advancement flap (Fig. 3–17). The two flaps need not be of equal length. The flap should be designed so that closure of the final line where the two flaps meet is placed in an optimal location, such as the philtrum of the upper lip. The bilateral advancement flap requires extensive undermining and long incision lines. With adequate undermining, closure without Burow's triangles can be accomplished. Although limited in its use in the head and neck, it can close some forehead defects and, less often, dorsal nasal defects quite nicely.

Rotation Flap

The classic rotation flap covers a triangular defect by rotating a semicircular flap around the pivotal point (Fig. 3–18). It is a versatile, broad-based flap capable of closing large defects in the head and neck. The length of the perimeter of the flap should be at least four times the width of the defect itself to allow easy closure with no donor site defect. The relaxing-side incision should be placed in an RSTL or an anatomic borderline (i.e., nasolabial groove or preauricular crease). Rarely is there a need for an equalizing Burow's triangle at the distal end of the flap if the surrounding tissue is undermined appropriately.

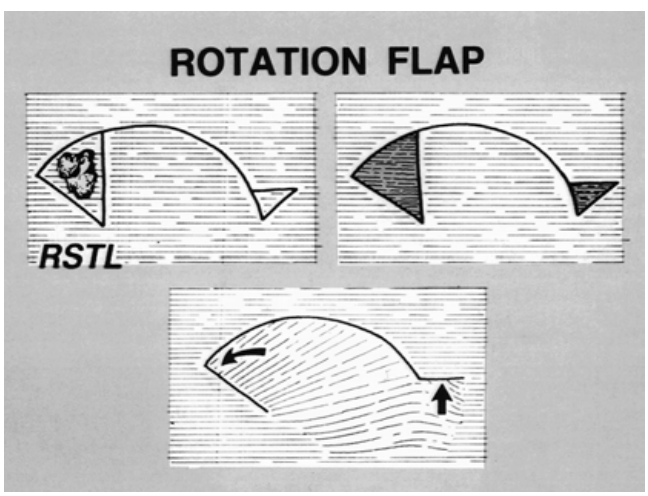

Figure 3–18 Classic rotation flap.

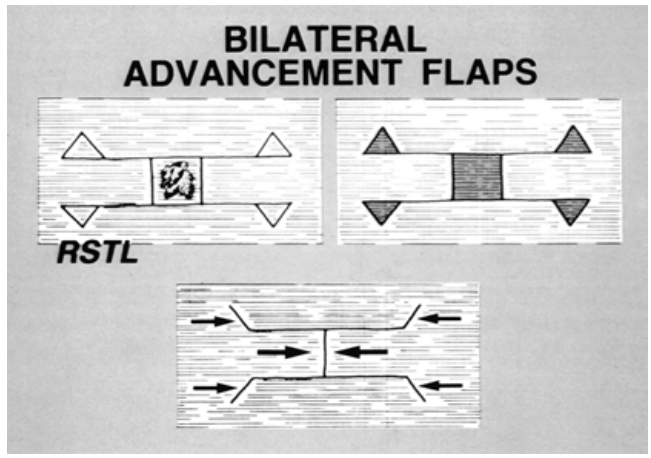

Figure 3–17 Bilateral advancement flap.

Interposition Flaps

Interposition flaps, sometimes called transposition flaps, are flaps that are raised from their donor site and rotated over adjacent tissue to be placed in the defect site.[7] This usually requires a combination of rotation and advancement of tissue. The interposition of flaps in such a manner provides great flexibility for closure of a variety of large and small defects in the head and neck. The bilobed flap is actually two transposition flaps. When a defect is too large to close primarily, a smaller flap is used to close the defect using a second, smaller flap to close the first donor site (Fig. 3–19). As a general rule, the first flap (A) should be slightly smaller than the original defect, and the second flap (B) should be half the diameter of the first. However, the combined length of both flaps, must equal the length of the original defect. The flaps should be created as half-ellipses, with the direction of the final closure planned along the orientation of the RSTL. Flap A should be 90 degrees to the long axis of the original defect and flap B 180 degrees to that axis. Care must

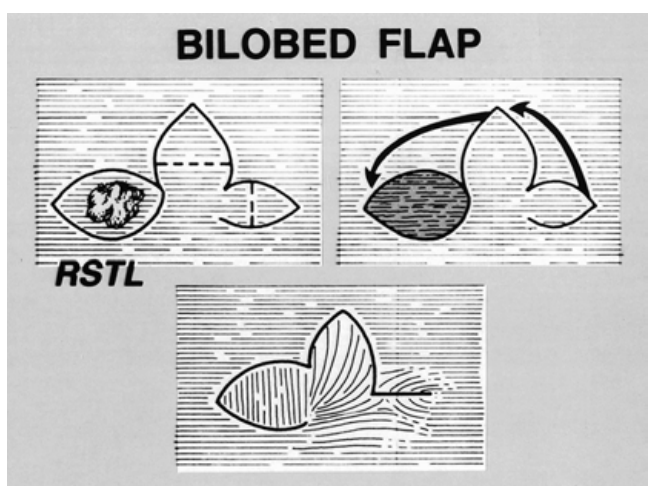

Figure 3–19 Bilobed interposition flap.

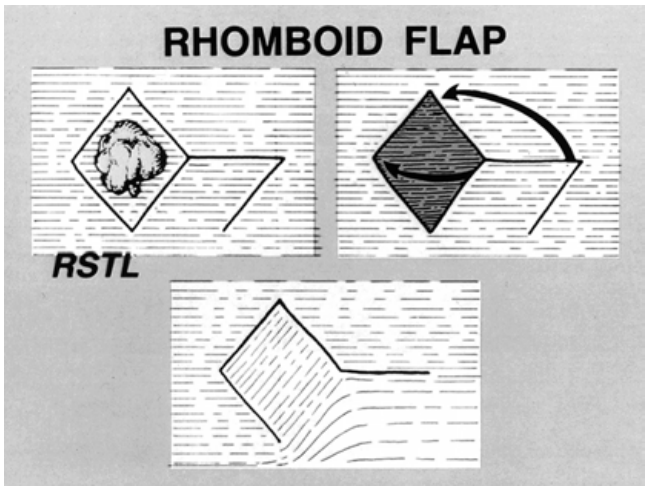

Figure 3–20 Rhombic interposition flap.

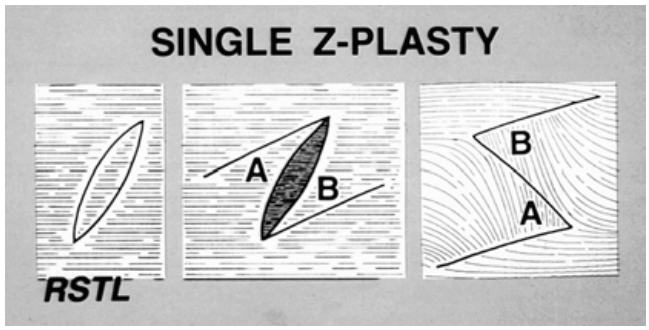

Figure 3–21 Single Z-plasty.

be taken so that the base of flap A, which becomes the common base of both flaps at final closure, is not made too narrow by extending the second side of flap B too far back for the defect. The rhombic (Limberg) interposition flap[2] is a reliable alternative for closure of many smaller defects of the head and neck (Fig. 3–20).[8] This flap takes advantage of the elasticity of the skin adjacent to the defect by rotating and advancing that skin over the recipient site. The tension across the secondary defect is perpendicular to that of the original defect. After the flap is interposed into the defect, the secondary defect can be easily closed primarily. The flap can be designed from virtually any angle around a given defect so that the final closure can almost always be in the direction of the RSTL. All four sides of the basic defect and both legs of the flap must be of equal length. The outer edge of the flap must be parallel to the sides of the rhombic defect. The Webster 30-degree angle flap and the Duformental flap are other frequently used variations of the original flap design by Limberg.

Z-plasty

Z-plasty is an interposition technique whereby two equal and opposing flaps are raised and interposed around a shared axis. The best way to visualize the basic concept of this "double triangular flap" construction is to draw out a parallelogram with a short axis and a long axis. The result of interposing the flaps is to exchange the long axis with the short axis, borrowing tissue from one dimension and essentially donating it to the dimension at right angles. Thus, the surgeon can lengthen a contracting scar (Fig. 3–21).[9] Z-plasty has the following three basic functions:

1. rotate the long axis of a scar from an unfavorable to a favorable position,
2. lengthen a contracted scar line, and
3. align anatomic lines that have been misaligned.

By achieving the desired result when doing a Z-plasty, one accepts a new scar that is three times the length of the original. The amount of lengthening achieved by Z-plasty is related to the length of the central and lateral limbs, as well as the angle of the Z-plasty. In general, a 30-degree Z-plasty achieves a 25% increase in length of the axis to the central limb, a 45-degree Z-plasty achieves a 50% increase, and a 60-degree Z-plasty achieves a 75% increase (Figs. 3–22 to 3–23).[10] Our general rule is to use no Z-plasty with arms greater than 1 cm in the face or 1.5 cm in the neck. When a greater length gain is needed, the scar is broken up with two or more nonadjoining Z-plasties. Most often, we use a 60-degree angled Z-plasty, although we will work with angles from 45 degrees to 70 degrees adjusting to the individual case. For longer scars, a multiple Z-plasty can be used (Fig. 3–24).

All Z-plasties are planned, marked out with Castroviejo calipers, scratched out with the tip of an 18-gauge needle, and created with a no. 11 scalpel. Wide undermining is necessary

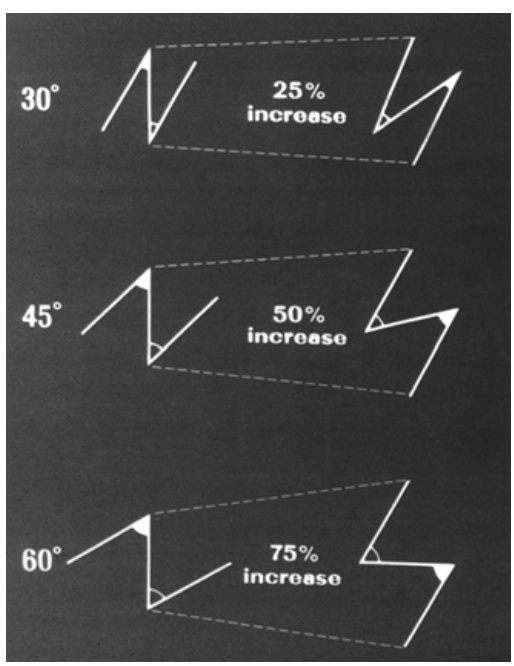

Figure 3–22 Z-plasty angles.

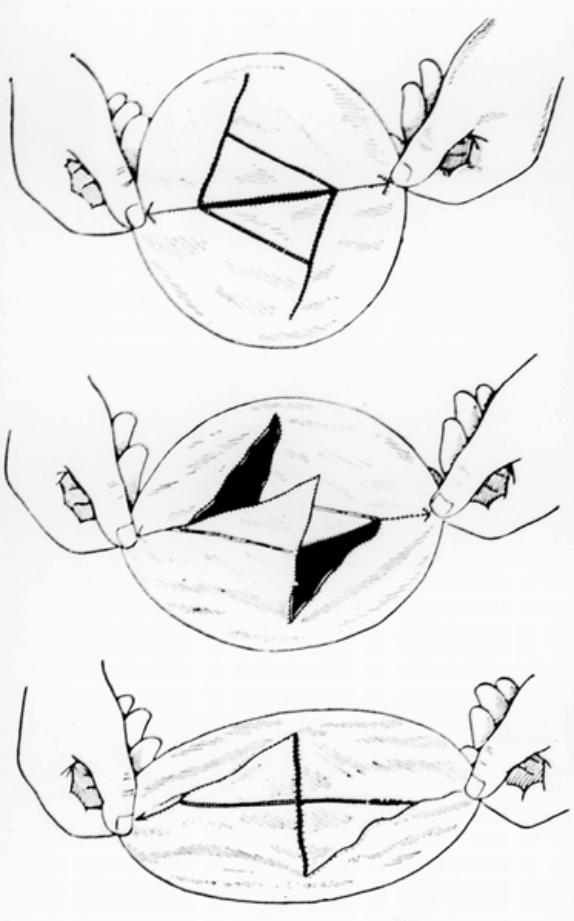

Figure 3–23 Creation of a Z-plasty.

at all sides for tension-free rotation of the interposing flaps. Closure depends on meticulous placement of interrupted subcuticular sutures of synthetic absorbable monofilament. Leveling of the sides of the wound edges is done with fine monofilament or fast-absorbing gut cutaneous sutures. The closure is then reinforced with sterile strips.

W-plasty and the Geometric Broken Line Closure

The running W-plasty and the geometric broken line (GBL) closure of Webster are two techniques that:

1. Camouflage scars in the face that are not parallel to RSTL
2. Are not contracted
3. Do not cross anatomic boundaries
4. Are greater than 2 cm in length[11]

The objective is to excise the scar and close the defect to disguise a straight line, which is easy for the eye to follow into a pattern that is more difficult for the eye to follow. A GBL closure is the more effective of the two because of its random pattern; however, it is more complex in design and more of a challenge to execute properly. The W-plasty scar revision

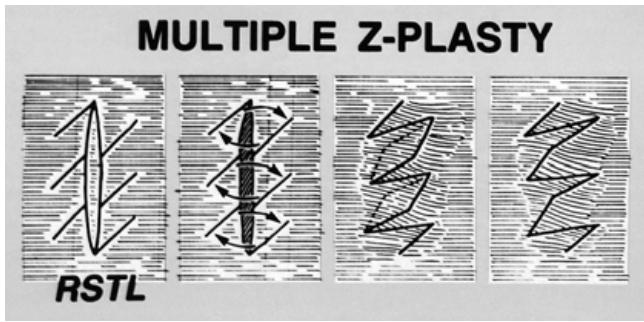

Figure 3–24 Multiple Z-plasties.

procedure was first described by Borges in 1959 (Fig. 3–25). It is important to realize that the running W-plasty is not a multiple Z-plasty and does not cause any increase in scar length. Scar revision of this type should be delayed as long as possible in persons younger than 21 years because delayed scar maturation will exaggerate the resultant defect. There are some general guidelines to aid in designing a W-plasty scar revision. The entire width of the original scar must be excised. No part of the pattern should cross into the scar. No leg of the scar should be greater than 6 mm in length, and the angles of the W's should be about 60 degrees with one set of legs in the direction of the RSTL. Avoid designing any flap that has an angle greater than 90 degrees and avoid designing a repair that disrupts a normal anatomic boundary line, such as the eyebrow or philtrum ridge. A GBL design should be predominantly squares and rectangles for optimal aesthetic appearance of the scar revision. Curved patterns have been found to be both difficult to create and ultimately more obvious to the eye.

After one side is marked out, the mirror image on the other side is drawn. The design should be scratched in with the tip of an 18-gauge needle. Using a no. 11 blade, each cut should be made toward the scar itself. The scar in the W-plasty should be excised as one piece. The techniques of skin-hook stabilization, wound edge handling, and wide, sharp undermining on all sides must be strictly adhered to. The sides are then brought together using interrupted, subcuticular, monofilament or absorbable sutures at the tips of each

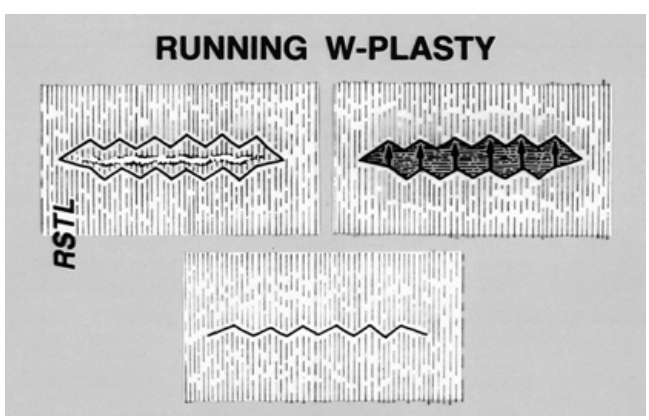

Figure 3–25 W-plasty scar revision.

point along one side only. Skin closure is accomplished with a running locked suture using 6-0 mild chromic catgut at each tip, up one side and then back down the other side. The wound is then reinforced with sterile strips. Although the design of the GBL closure is somewhat more complex, the same principles apply to its excision and closure (Fig. 3–26).

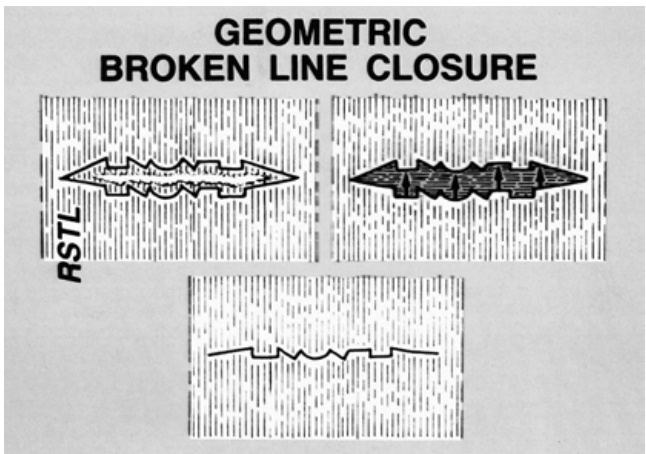

Figure 3–26 Geometric broken line scar revision.

Patients undergoing this type of scar camouflage must be warned that the wound will be somewhat erythematous for several months after surgery before turning pale. They should also plan for dermabrasion of the scar. The best time for this is at 8 to 10 weeks postoperatively, at the approximate end of the proliferative phase of wound healing and prior to complete wound contracture and scar fading. By blending raised edges with the surrounding skin or by lowering healthy skin to a recessed area, dermabrasion aids in resurfacing and blending scars into the surrounding skin. Of note is that dermabrasion is not good for raised, hypertrophic scars; rather, it is best for lowering the height of normal tissue to the level of the scar.

SUMMARY

The basics of soft tissue surgery are not difficult to comprehend, yet their execution and daily practice require patience and discipline. By maintaining a working knowledge of these basic principles, a creative approach to facial soft tissue surgery, and good patient rapport, a surgeon can hope to achieve further improvement in surgical results.

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Chapter 4

Skin Grafts and Local Flaps

Rudy J. Triana Jr., Craig S. Murakami, and Wayne F. Larrabee Jr.

When approaching skin and soft tissue defects, the surgeon must have an in-depth knowledge of the anatomy and physiology of skin grafts and local flaps to ensure the success of the reconstructive effort. This knowledge provides the necessary insight to determine not only the wound requirements, such as skin only, skin and subcutaneous tissue, or a combination involving the underlying cartilage or bone, but also the limitations of the planned reconstructive graft or flap, such as contour, color, degree of vascularity, and presence of pilosebaceous units. With careful use of this information, a well-considered surgical plan can be developed. In many cases the preoperative planning is much more complicated than the procedure. This chapter provides a review of skin graft and local flap anatomy and physiology, with emphasis on the process of evaluation and aesthetic closure of skin and soft-tissue defects of the face.

SKIN GRAFTS

A skin graft is an island of epidermis and dermis that has been surgically removed from a donor site; its blood supply is transferred and is dependent on the recipient site. Skin grafts can be categorized as split-thickness or full-thickness grafts.

Split-Thickness Skin Grafts

Split-thickness skin grafts (STSGs), also known as Thiersch grafts, are usually harvested with a dermatome or razor blade. They consist of epidermis and a superficial segment of dermis (papillary dermis). Thin STSGs may measure 0.008 to 0.010 in. in thickness, whereas a thick (standard) STSG measures between 0.016 and 0.018 in. Epidermal and dermal thickness varies in different parts of the body, in different skin colors, in different age groups, and is generally thicker in males. The skin of an adult is 3.5 times thicker than the skin of a newborn. By age 5 years, the skin thickness approximates that of an adult.[1] Measurements of epidermal and dermal thickness taken from various age groups, sexes, and sites were found to vary from 0.017 to 0.15 in.[2] The skin of the eyelids is the thinnest, and the soles of the feet the thickest.

Though highly reliable, STSGs have limited usefulness in facial reconstruction because of their tendency to contract. The thinner the graft, the greater the degree of contraction, but also the higher the likelihood of graft survival. STSGs typically have a different texture as well as a lighter color and thickness than the neighboring tissue.[3] STSGs may be meshed to increase their surface area, however, this further thins the graft and may compromise the aesthetic result. STSGs in facial reconstruction have been used to repair large defects of the scalp, as well as defects associated with deeply invasive tumors or uncertain margins where close postoperative surveillance of the resection area is especially important (Fig. 4–1).[4]

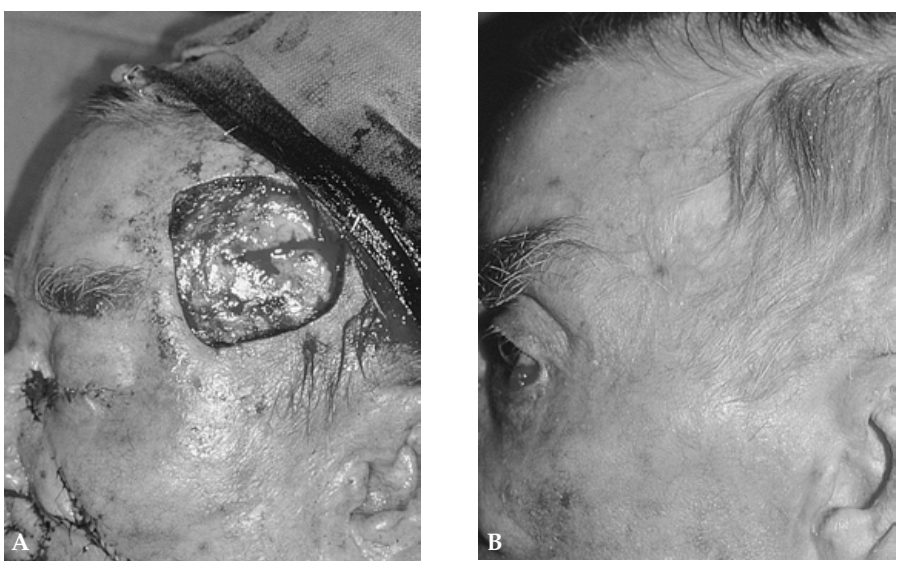

Figure 4–1 Split-thickness skin graft. **(A)** Left temple defect 6 × 8 cm following resection of a deeply infiltrating squamous cell carcinoma of the skin. **(B)** The 4-month postoperative result using a split-thickness skin graft reconstruction.

Full-Thickness Skin Grafts

With full-thickness skin grafts (FTSGs), the entire thickness of the epidermis and dermis is harvested from the donor site and subsequently transplanted. The subcutaneous tissue may be trimmed from the graft to create the appropriate thickness. Hair follicles are preserved so that hair growth may be preserved. FTSGs do not contract and do not change in color or texture. These grafts are thicker than STSGs and are more slowly revascularized, with a higher graft failure rate. An adequate blood supply in the recipient site is required to ensure graft survival. FTSGs are much more resistant to sheering forces than STSGs. The donor sites for FTSG include the pre- or postauricular skin, the supraclavicular skin, and, occasionally, the melolabial fold skin. The FTSG donor site contains no epithelial elements from which reepithelialization can take place; therefore, the donor site must be closed primarily or covered with an STSG. FTSGs are particularly useful for facial defects involving the nasal tip, lateral surface of the auricle, and eyelids (Fig. 4–2).

Dermal Grafts

Dermal grafts are harvested from the dermis after the overlying epidermis has been elevated. These grafts are very reliable, resistant to infection, and can be buried below the skin surface. When buried the epithelial elements atrophy and

Figure 4–2 Full-thickness skin graft. **(A)** Moh's defect, right nasal ala. **(B)** The nasal superficial musculoaponeurotic system elevated into the wound. **(C)** FTSG sutured into position. **(D, E)** The 4-month postoperative result. (From Conner CD, Fosko SW. Anatomy and physiology of local skin flaps. *Fac Plast Clin North Am* 1996;4(4):447–454. With permission.)

become inactive; however, a graft that is exposed or used as a resurfacing graft is capable of reepithelialization.[5] Dermal grafts have been used for intraoral coverage or for subcutaneous implantation to add bulk or contour. Currently, many facial plastic surgeons have replaced the dermal graft with an acellular dermal graft (Alloderm, LifeCell Corp, Houston, TX) for adding bulk and contour to many facial defects.[6–8]

Vascularization of Skin Grafts

Both STSGs and FTSGs are a form of a free tissue transplant from a donor site to a recipient site where a new blood supply is acquired. The revascularization of skin grafts takes place in the following phases: imbibition, revascularization, and organization.

Serum Imbibition Phase

The initial phase of serum imbibition or plasmatic circulation lasts about 48 hours. Graft nutrition is dependent on plasma exudate from dilated capillaries in the host bed. Fibrinogen-free serum, not plasma, enters the graft to nourish it.[9] Erythrocytes penetrate the fibrin clot and are passively trapped. These trapped erythrocytes are suspended in the serum under the graft and are a source for edema of the graft. As revascularization occurs, new blood flow enters the graft and plasmalike fluid is removed from the graft.[10]

Revascularization Phase

Vascular buds begin to grow into the supportive fibrin network during the first 48 hours. Revascularization occurs through both direct ingrowth of host blood vessels in the graft (neovascularization) and the formation of anastomoses between graft and host vessels (inosculation).[11–13] Although inosculation between graft and host vessels occurs, the primary mode of revascularization depends on the ingrowth of host vessels into the graft dermis.[14] Lymphatic circulation between the graft and the host bed is functional by the fourth or fifth postoperative day.

Organization Phase

The organization phase begins within 5 hours of transplantation. A fibrin clot forms an interface between the graft and the host bed. The fibrin clot also acts to adhere the graft to the host bed.[9] Leukocytes begin to infiltrate the deeper layers of the graft, and as revascularization proceeds they are removed and replaced by fibroblasts.[15] By the seventh or eighth postoperative day, fibroblast infiltration of the fibrin clot continues as a collagen matrix is being created. By the ninth day, the graft is firmly anchored by its new blood supply and fibroblast integration. Within 2 months, neural structures begin to regenerate and enter the graft through the base and the sides, following vacated neurilemmal cell sheaths.[16] Skin grafts rarely attain normal sensory innervation after healing is complete.[4]

Donor Sites

The surgeon must consider a variety of factors when choosing a donor site for an STSG. These factors include the characteristics of the donor skin (color, texture, thickness, and vascularity), the amount of skin needed, necessity of hair on the graft, convenience, and potential for deformity. Most donor sites in the head and neck have a great vascular supply; however, a number of different donor sites are used to provide a range of skin color, texture, and thickness.

Good sites for harvesting skin grafts include pre- and postauricular skin, upper eyelid skin, melolabial skin, and skin from the surpraclavicular area and abdomen. The pre- and postauricular skin is thin, hairless, and has a good color and texture match for the face. FTSGs can be harvested from this region and used for defects of the nose and cheek. These donor sites usually allow for primary closure of the defect. FTSG of upper eyelid skin can be obtained from patients with excess upper eyelid skin. This graft is useful for covering defects of the opposite eyelid, concha, nasal vestibule, and external ear canal. Bilateral upper eyelid skin excisions should be performed to ensure symmetry. This donor site provides limited skin and requires primary closure of the donor site defect. Larger amounts of full-thickness skin may be obtained from either the supraclavicular or abdominal skin. Full-thickness skin from the melolabial fold is useful for reconstructing cutaneous defects of the nose. The color, texture, and thickness of this skin make it suitable for restoring defects of the nasal tip. The melolabial donor site can be closed primarily, leaving an inconspicuous scar. Composite (skin and cartilage) grafts can be harvested from segments of the external ear to reconstruct defects of the nasal rim or contralateral ear.[4]

The anterolateral thigh and abdomen provide larger areas for harvesting split-thickness and dermal grafts. Full-thickness grafts from these regions have a poor color and texture match with the face.

Surgical Technique

Instruments commonly used for harvesting skin grafts are a scalpel, or an electric or air-driven dermatome. Both the air-driven Brown or Zimmer dermatome and the Padget electric dermatome are ideal instruments for obtaining a consistently uniform skin graft.

The donor site is prepped with a bactericidal solution and allowed to dry. A thin layer of mineral oil is applied to the donor site skin and to the blade of the dermatome. The Brown or the Padget dermatome should be set between 0.010 and 0.018 inches, depending on the thickness of the graft desired. The dermatome is placed at approximately a 45-degree angle to the donor skin and started prior to contact with the skin. Gentle traction is applied to the donor site skin as the dermatome is smoothly applied with even pressure. This technique ensures the harvest of a good graft. Bleeding from the dermal capillary bed will be noted in the donor site. Telfa soaked in a 1:50,000 solution of epinephrine is applied to the donor site to provide hemostasis until the final dressing is applied. The donor site should be dressed with some type of semiocclusive dressing, such as Opsite or a piece of Xeroform attached to the wound, followed by placement of a slight pressure dressing in the form of a Kerlix or Ace wrap. Reepithelialization of the donor site occurs over the following 2 to 3 weeks.

When obtaining a dermal graft, a strip of split-thickness skin (0.012 to 0.016 in.) is elevated as previously described but is left attached at one end. The dermatome-cutting tract

should be narrowed so that a strip of dermis (0.012 to 0.014 in.) can be harvested and excised. The flap of split-thickness skin is placed over the defect and stapled or sutured into position.

Preparation of the host bed is important in ensuring the survival of the graft. This should include the obtaining of adequate hemostasis, debridement of necrotic tissue, and removal of infected tissue. Bone or cartilage that is not covered by periosteum or perichondrium does not provide a good vascular host bed for the graft and should be avoided.

The STSG can be passed through a graft mesh to provide greater surface area and allow for drainage of serous fluid from the reconstructed site. Unfortunately, meshing grafts creates a thinner graft, which is likely to contract and heal as shiny, thin, atrophic skin. If a graft of adequate size is obtained, a scalpel can be used to cut multiple small slits (5 to 6 mm) in the graft to allow serous fluid to drain from under the graft. The graft can be secured to the recipient site with staples or suture. The most important factor in ensuring the success of the STSG is graft immobilization and pressure over the site. This prevents the graft from migrating and thereby limits the shearing forces applied to the graft that act to disrupt any of the vascular connections that may have formed recently. Fibrin glue may be applied as both a hemostatic agent and an adhesive that helps bind the graft to the host bed.[4] A pressure dressing using cotton, fluffed gauze, or a sponge can be maintained in position using tie-over sutures. Sometimes a stent may be used to provide pressure on a graft, which is placed in the ear or hard palate. These dressings are usually removed within 7 to 10 days.

Skin grafts can be preserved by storage at low temperatures. Grafts can be wrapped in gauze soaked in Ringer's lactate or normal saline and stored in a sterile container at 4°C. The graft should never be totally immersed in saline because it will become macerated.[4] After 14 days of storage at 4°C, the respiratory activity of the skin graft is reduced by 50%.[17]

SKIN FLAPS

A skin flap is composed of skin and subcutaneous tissue that is transferred from one part of the body to another, with a connection to the body or vascular pedicle preserved for its blood supply. The relationship of the vascular pedicle to the flap may vary according to the orientation of the defect to the flap.[18] In some cases, the vascular pedicle can be transected and transferred to a distal site by microvascular anastomosis to another set of recipient (nourishing) vessels (microvascular free flap). Microvascular free tissue transfer may include fascia and skin, or a composite of skin, muscle, and bone.

Wounds or defects can be covered with either a skin graft or a skin flap. Although a skin graft should be considered first, there are many circumstances in which a flap is required. Skin flaps are frequently needed because either the recipient site is poorly vascularized and is unable to nourish a free skin graft or the transfer of a skin flap provides a better match of color and texture. When planning the reconstruction of a facial defect, the surgeon must consider the location of the defect, visibility of the site, and the patient's concern with the final aesthetic appearance. One unique situation involves resection of a tumor with a high chance of recurrence or where the surgical margins were uncertain. In these cases, it is advised to use a temporary STSG to allow close monitoring for tumor recurrence. If after an acceptable observation period there has been no tumor recurrence, reconstruction of the defect with the appropriate flap may be performed.[4]

Vascular Anatomy of the Skin

The anatomic variations in the blood supply of the skin must be understood before one embarks on using various local flaps in reconstruction. The skin is supplied by two principal vascular sources: musculocutaneous vessels and direct cutaneous vessels. Musculocutaneous vessels arise from segmental vessels; their anastomoses with axial vessels course below the muscles. From the muscle vasculature arise perforating musculocutaneous branches that enter the subcutaneous tissue.[19] The musculocutaneous vessels supply the majority of blood flow to the skin, especially in the trunk and extremities. After ascending to the deep reticular dermis, these vessels provide branches to two horizontally arrayed microvascular plexuses in the dermis. The deeper plexus, which is located at the dermal–subcutaneous junction, supplies the adnexal structures, the hair follicles, and the eccrine glands. Projections from this deep plexus anastomose with vessels in the superficial plexus located in the papillary dermis (Fig. 4–3).[20]

Segmental, anastomotic, and axial vessels also give rise to a limited number of direct cutaneous vessels that lie above the muscular fascia and are parallel to the skin. These arteries supplement the musculocutaneous arteries in providing additional nutritive and nonnutritive blood flow to the skin.[18] The direct cutaneous arteries have an associated subdermal vein in addition to paired venae comitantes. The direct cutaneous arteries send branches into the two dermal microcirculatory plexuses and account for the majority of the scalp and facial cutaneous vascular supply.

Flap Design

Random Flaps

Random flaps or random pattern flaps (local cutaneous flaps) are the most common type of flap employed in reconstruction of cutaneous defects of the head and neck. These flaps are created by dissecting the flap at the level of the subcutaneous fat. Their arterial supply comes from perforating musculocutaneous vessels at the flap base arising from segmental vessels that underlie muscle and subcutaneous tissue (Fig. 4–4). The blood flow to the free portion of the flap is supplied by the anastomoses between the deeper dermal–subcutaneous plexus and the more superficial papillary dermal plexus.[21] Random pattern flaps may be divided into two basic types: advancement flaps and rotation flaps (which can include transposition flaps).

The survival of random pattern flaps is unpredictable.[18] Milton[22] disproved the early teaching that a 1:1 length-to-width ratio was required to ensure flap viability. Most flaps can be created with a length-to-width ratio of 3:1 and longer if the facial flap has an axial pattern vascular supply through direct cutaneous vessels (i.e., paramedian forehead flap).[18,23]

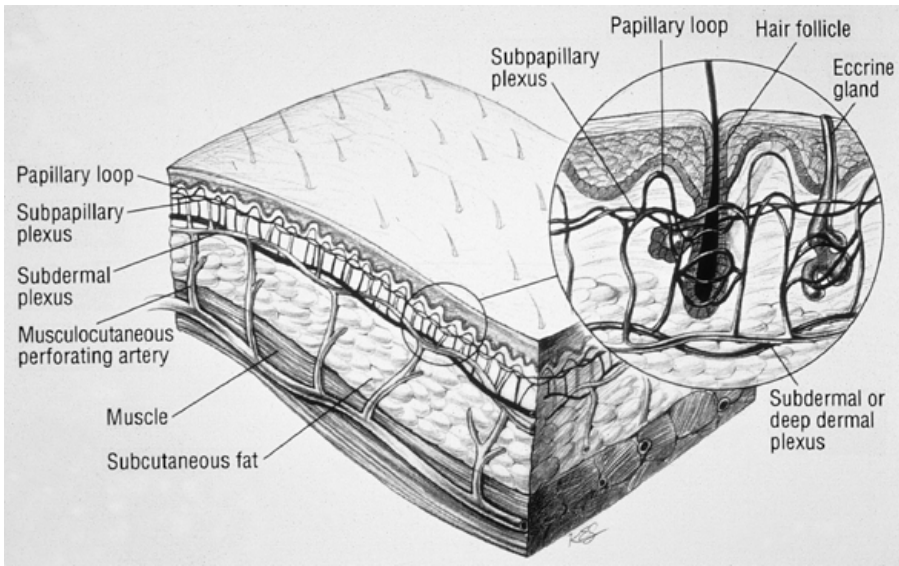

Figure 4–3 Cutaneous vascular anatomy demonstrating the anastomoses between the subdermal and subpapillary plexuses. (From Conner CD, Fosko SW. Anatomy and physiology of local skin flaps. *Fac Plast Clin North Am* 1996;4(4):447–454. With permission.)

Axial Flaps

Axial flaps, or axial pattern flaps (arterial flaps), derive their blood supply from a direct cutaneous artery arising from a segmental, anastomotic, or axial artery.[24] Axial flaps can be of greater length-to-width ratios than random flaps. The distal free portion of the flap is a random flap by nature of its vascular supply. Hence, the dynamic vascular territory is larger than the anatomical territory. This supports the concept of the angiosome, which is the area of skin comprising the flap that is supplied by an axial vessel but may be extended by its communication with branches of an adjacent vessel.[25] Axial pattern flaps are supplied by an identifiable vessel: deltopectoral (internal mammary artery), forehead (supratrochlear artery), or scalp flap (superficial temporal artery). One advantage of the axial pattern flap is that a large area of skin coverage can be provided in a single procedure without the need for inclusion of the bulky underlying muscle. The base of the pedicle need only be as wide to accompany the named vessel supplying the flap.

Free Flaps

Microvascular free tissue transfer or free flaps have evolved over the past decade through the technologic advances in the field of microvascular surgery. These techniques allow the reconstructive surgeon to transfer free axial-pattern skin (fasciocutaneous), skin and muscle (musculocutaneous), or skin, muscle and bone (osteomyocutaneous or osteocutaneous) flaps from a host donor site to a distant recipient site in a single-stage operation. The axial artery and vein that supply the flap are anastomosed under the microscope, with recipient vessels

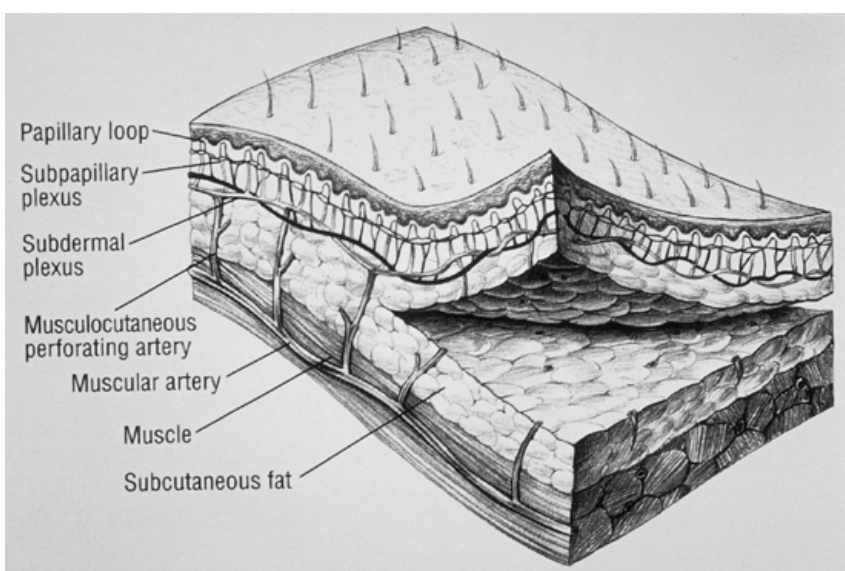

Figure 4–4 Cross-section of a random pattern skin flap. The plane of dissection is in the subcutaneous fat. Musculocutaneous perforating arteries arising from underlying muscular arteries provide the blood supply to these flaps.

near the defect in the head and neck. Donor sites for skin (fasciocutaneous flaps) include the forearm (radial forearm free flap), lateral arm free flap, and the lateral thigh free flap.[26–28] The parascapular, scapular, fibula, and iliac crest tissues are excellent donor sites where the defects include bone and surrounding soft tissue.[29–31] Rectus abdominus and latissimus dorsi are good donor sites where bulk is needed to reconstruct the defect.[32–34] These flaps are usually harvested as muscle with the overlying skin. Although free tissue transfer requires advanced surgical techniques, special equipment, and prolonged operative times, it provides the surgeon with an excellent alternative for reconstruction of complex head and neck defects.

The remaining portion of this chapter focuses on the use of various random pattern skin flaps for the reconstruction of facial defects.

Surgical Planning for Wound Closure

Most of the defects encountered by facial plastic surgeons may be repaired by primary closure or with local skin flaps. Selection of the appropriate method of closure of facial defects requires an understanding of the biomechanics of wound closure.

Biomechanics of Wound Closure

Optimal wound closure requires an understanding of soft tissue mechanics and the principles of wound healing. The mechanical behavior of skin is primarily related to its collagen and elastin content.[35–37] Collagen types I and III provide the principal supporting framework of the extracellular matrix in the dermis. Elastic fibers in combination with collagen provide the elasticity or relative ease of deformation of the skin.[18] As skin is stretched, there is a period of easy deformation (section I) on the stress–strain curve that is controlled primarily by the fine elastin network (Fig. 4–5). In section II of the curve, randomly arranged collagen fibers begin to lengthen in the direction of the force and deformation becomes more difficult. Lastly, in section III, all of the collagen fibers are oriented with the force, and little further deformation is possible. Clinically, when attempts to close a wound result in excessive tensions (section III of the stress–strain curve), little additional tissue can be advanced with more force, and other methods of closure (grafts or flaps) should be considered.[4]

Excessive tension in skin flaps can result in flap necrosis likely caused by reduced blood flow specifically in those flaps with borderline viability.[38] Larrabee et al[38] reported in their animal study using 2-cm-wide random pattern skin flaps that any flap longer than 6 cm (length-to-width ratio being greater than 3:1) underwent necrosis regardless of tension (Fig. 4–6). Any flap less than 2 cm in length (less than 1:1 length-to-width ratio) was viable regardless of tension. Those flaps of intermediate length were most influenced by tension. Flaps closed under 250 g of tension or less tended to survive, whereas those closed under higher tensions underwent necrosis. This study reinforces the clinical impression that tension on flaps of borderline viability increases the incidence of necrosis.[4]

In another study, increasing tension was placed on a random pattern skin flap in piglets and blood flow was measured at four sites along the flap with the Doppler laser. As shown in Figure 4–7, there was decreased blood flow with increased tension, with the blood flow leveling off at about 250 g of tension. To summarize, tension does decrease blood flow in skin flaps; in flaps with excellent blood flow, tension may not be a critical factor, but with borderline viability it increases the incidence of necrosis.[4]

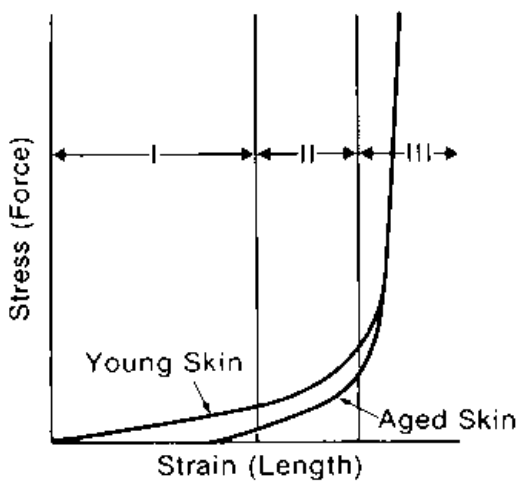

Figure 4–5 Stress–strain curve for young and aged skin. (From Toriumi D, Larrabee WF. Skin grafts and flaps. In: Papel ID, Nachlas N (eds). *Facial Plastic and Reconstructive Surgery*. St. Louis: CV Mosby, 1992. With permission.)

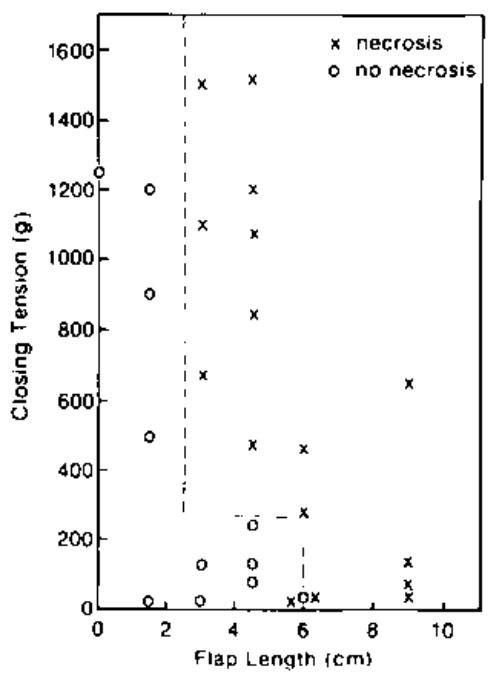

Figure 4–6 Effect of closing tension on skin flap viability. (From Larrabee WF, Holloway GA, Sutton D. Wound tension and blood flow in skin flaps. *Ann Otol Rhinol Laryngol* 1984;93:112. With permission.)

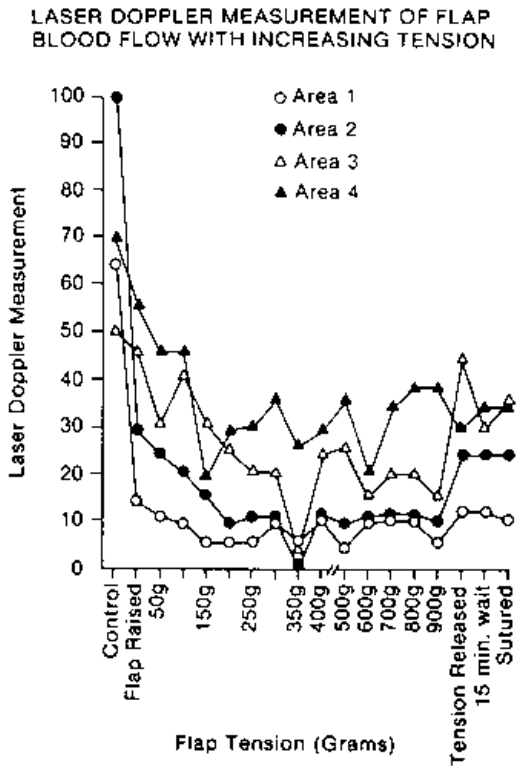

Figure 4–7 Doppler laser measurement of blood flow in 3 × 6 cm skin flaps with increasing tension. Area 1 was at the end of the flap and area 3 at the base. Area 4 was in the region of the pedicle. (From Larrabee WF, Holloway GA, Sutton D. Wound tension and blood flow in skin flaps. *Ann Otol Rhinol Laryngol* 1984;93:112. With permission.)

The forces in skin change over time.[37] Creep is the increase in strain (change in length to original length) seen when skin is placed under a constant stress (force or unit area). Stress relaxation refers to the decrease in stress when skin is held under tension at a constant strain. The surgeon who uses tissue expanders or the technique of serial excision of tissue routinely employs these time-dependent properties of skin.

The attachments of skin to subcutaneous tissue are mechanically critical because undermining the skin a moderate amount decreases wound closing tensions and distributes skin deformation. Larrabee et al[38] studied the mechanical results of skin undermining in an animal model. A series of 2 × 6 cm fusiform defects were created, and undermining from the flap edge was performed in 2-, 4-, and 6-cm increments (Fig. 4–8). The flaps were advanced and a series of curves generated, showing the force required to advance the flap a given distance (Fig. 4–9). In each case, undermining of 2 to 4 cm caused the curve to shift to the right, thus denoting decreased tension on the flap for a given advancement. Undermining more extensively to 6 cm did not result in any significant change in forces and in some cases actually resulted in increased flap tension. In this model, moderate undermining was not helpful in decreasing flap tension but may have helped in tissue redraping.[4] Tissue redistribution can be controlled somewhat by altering the extent of undermining. Sometimes it is necessary to differentially undermine,

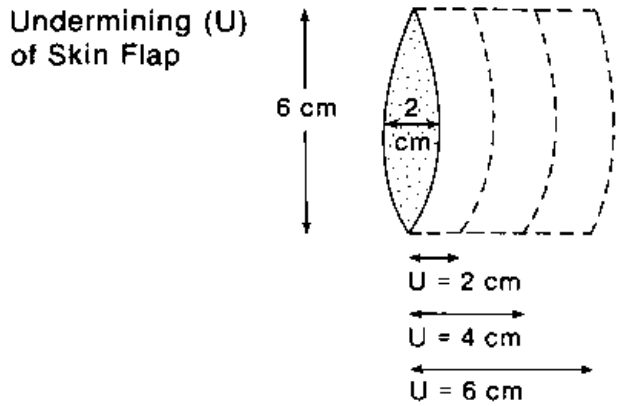

Figure 4–8 Skin flaps undermined to 2, 4, and 6 cm. (From Toriumi D, Larrabee WF. Skin grafts and flaps. In: Papel ID, Nachlas N (eds). *Facial plastic and reconstructive surgery*. St. Louis: CV Mosby, 1992:36. With permission.)

meaning to limit undermining around a specific anatomic structure so as not to distort or deform (e.g., oral commissure, eyelids, brow, and nasal tip).

Fusiform Repair

Most small facial lesions can be excised in a fusiform fashion and a simple closure performed with a good cosmetic result.

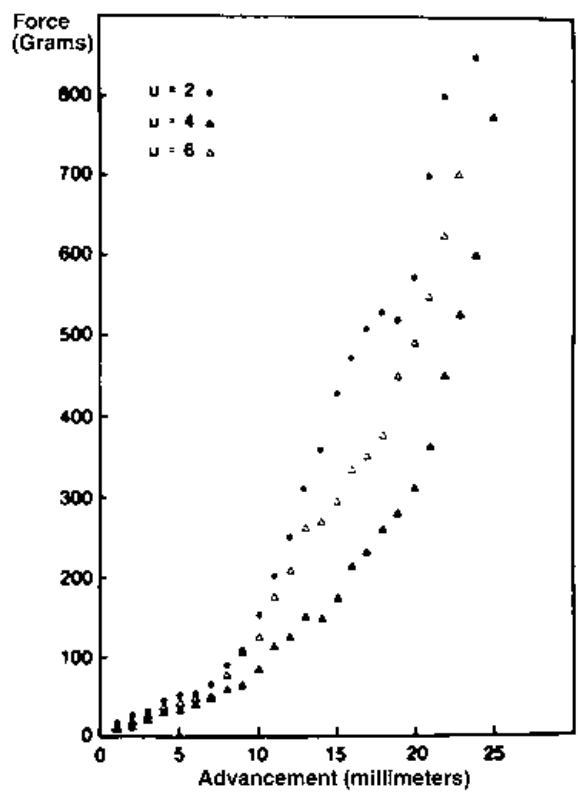

Figure 4–9 Stress–strain curves with 2, 4, and 6 cm of undermining (U). (From Toriumi D, Larrabee WF. Skin grafts and flaps. In: Papel ID, Nachlas N (eds). *Facial plastic and reconstructive surgery*. St. Louis: CV Mosby, 1992:36. With permission.)

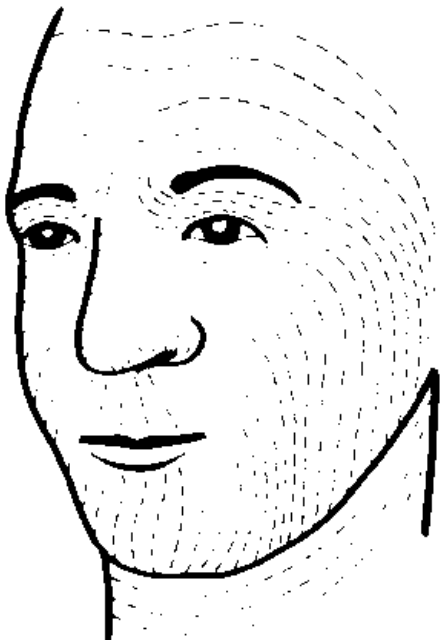

Figure 4–10 Approximation of the relaxed skin tension lines (RSTLs) of the face. When excising a lesion on the face, the lines of excision should parallel the RSTL and parallel the lines of maximal extensibility.

The key to maximizing this technique is to place the lines of excision parallel to the relaxed skin tension lines (RSTLs) whenever possible (Fig. 4–10).[39] As a result, the maximal tension on the wound is parallel to the lines of maximal extensibility (LMEs). LMEs are usually perpendicular to the RSTLs and represent the direction in which closure can be performed with the least tension.[39] If the surgeon wishes to shorten the total length of the fusiform excision, an M-plasty can be used (Fig. 4–11). The M-plasty is especially useful when the standard fusiform excision would cross from one facial subunit to another or cross a normal facial groove (e.g., melolabial fold). A Gillies corner stitch should be used to close the corner of the M-plasty. This pulls the tips of the M-plasty toward the middle of the incision and prevents skin deformation at the end of the incision (i.e., dog-ear deformity).

Skin closure should be performed in multiple layers. An absorbable suture (Vicryl, PDS, Monocryl, or Maxon) is placed in the subcutaneous tissue to evert and approximate the skin edges. Davidson[40] describes placing the subcutaneous sutures farther away from the skin edge to affect extreme wound-edge eversion and minimize tension on the healing incision.

LOCAL SKIN FLAPS

The majority of facial defects that cannot be treated by primary closure can usually be closed with a local skin flap. The blood supply of these random pattern skin flaps is based on the subdermal plexus of vessels. Flaps are usually created with a flap length-to-width ratio of 1:1 to 2:1. Some facial flaps have an axial pattern vascular supply through direct cutaneous vessels (e.g., forehead). These flaps tolerate much higher length-to-width ratios because the vascular supply is generally robust.[23]

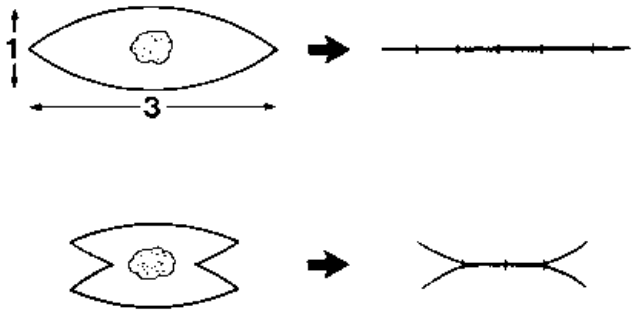

Figure 4–11 M-plasty. A fusiform excision by inverting the end of the incision so that it creates a small M on either end. When these M-plasties are closed it is helpful to use a corner stitch to pull the tips of the M-plasty toward the middle of the incision.

All local facial flaps have rotational or advancement components, or both, in their movement from donor site to defect. Most flaps, including transposition flaps, have a component of both rotation and advancement, and the ratio of rotation to advancement can be tailored by flap design.[23] In the design of local skin flaps, many needs of the defect must be identified and analyzed. The depth and composition of the defect should be analyzed so that the reconstruction restores all layers of the defect. Regional differences in the thickness of the subcutaneous layer of facial skin must be appreciated when choosing the type of flap. For example, a skin-only defect of the eyelid is much thinner than a skin-only defect of the nasal tip.[41]

Advancement Flaps

The classically designed advancement flap has a flap length ratio of 1:1 to 2:1 and advances tissue a distance approximating the width of the flap (Fig. 4–12). These flaps are particularly useful for defects of the forehead. In the forehead,

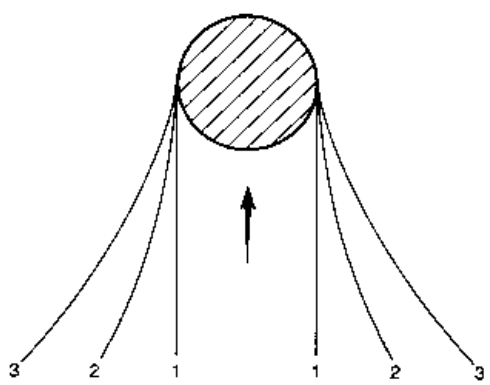

Figure 4–12 Advancement flap design. Classically, these flaps have a length-to-width ratio of 2:1. Modifications can be made to follow the basic aesthetic units or the relaxed skin tension lines. Increasing the width of the flap does not necessarily increase the distal blood flow. (From Murakami CS, Nishioka GJ. Essential concepts in the design of local skin flaps. *Fac Plast Surg Clin North Am* 1996;4(4):455–468. With permission.)

bilateral advancement flaps are designed with the horizontal components placed parallel to the RSTLs and adjacent to normal forehead creases (Figs. 4–13 and 4–14). Occasionally, Burow's triangle excisions are needed but should not be performed until after the flap is advanced.

Rotation Flaps

All rotation flaps also have a component of advancement; therefore, many surgeons prefer the term *rotation–advancement flap*.[42] Lines of rotation tend to follow the natural contours of the face, such as face-lift flap and lower eyelid blepharoplasty flaps. The rotation–advancement flap is usually designed to move along an arc of less than 30 degrees. These flaps are easy to design and generally result in minimal tissue redundancy and wound closing tension. Although tissue redraping may be improved by extending the rotation of the flap beyond 30 degrees, tension in the flap will increase and is found at the donor site, not along the longer length of the flap.[38] The amount of advancement of the rotation–advancement flap can be increased or decreased by alterations in flap design. The classic rotation flap is designed using a radius approximately two to three times the diameter of the defect and extending the length of the flap approximately four to five times the width of the defect, which creates an arc close to 90 degrees. The 90-degree arc flap will rotate 30 degrees to close the defect (Fig. 4–15A). Although usually unnecessary, the arc of the flap may be increased toward the maximum of 180 degrees.

Variations of the classic rotation flap can be created by increasing the radius of rotation (Fig. 4–15B). These changes alter the ratio of advancement and widen the width of the base and distal tip of the flap. The base of the flap is not fixed but advances with movement of the flap into the defect. The amount of advancement can be increased with a backcut. Remember that this will advance the flap and decrease the amount of tension at its distal aspect, but narrows the width of the base of the flap and potentially results in vascular compromise if performed excessively.[23] Rotation–advancement flaps are useful for large cheek defects (Fig. 4–16). Any time

Figure 4–13 Bilateral advancement flaps. **(A)** Proposed 2-cm defect for excision of a basal cell carcinoma (BCCA) of the eyebrow/forehead. **(B)** Bilateral advancement flap closure. **(C)** The 4-month postoperative result.

Figure 4–14 Bilateral advancement flaps. **(A)** Large forehead Moh's defect approximately following excision of a BCCA. **(B)** Bilateral advancement flaps used for partial closure. Central defect left open to heal by secondary intention. **(C)** The 1-month postoperative result, with significant healing noted. **(D)** The 3-month result with forehead completely healed.

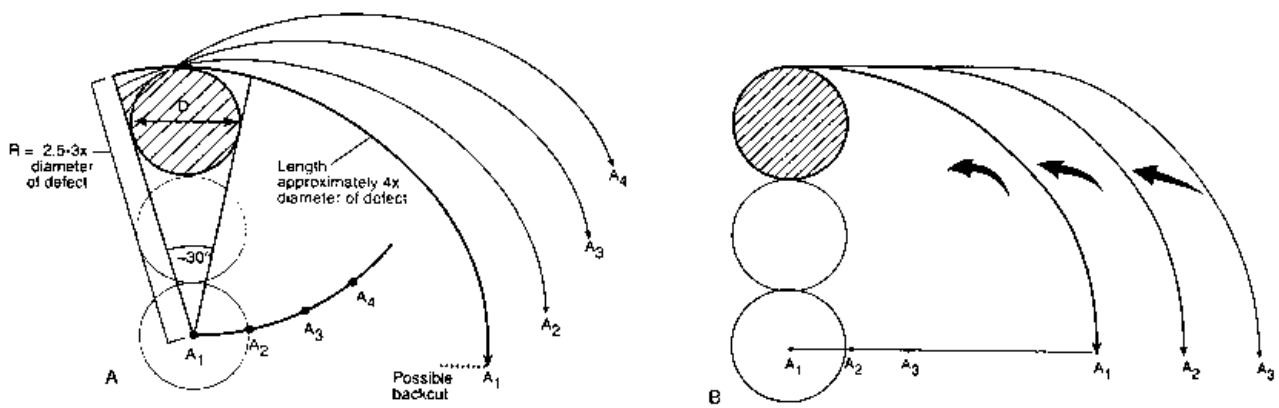

Figure 4–15 Rotation–advancement flaps and modifications. **(A)** The basic rotation flap is drawn using a radius (R) that is 2.5 to 3 times the diameter (D) of the defect. The axis of rotation (A_1–A_4) can be moved along an arc to allow for greater rotation and less advancement. The base and the tip of the modified flaps become wider. **(B)** If the axis of rotation (A_1–A_3) is moved along a perpendicular line, the flap will have a greater advancement component and less rotation. (From Murakami CS, Nishioka GJ. Essential concepts in the design of local skin flaps. *Fac Plast Surg Clin North Am* 1996;4(4):455–468. With permission.)

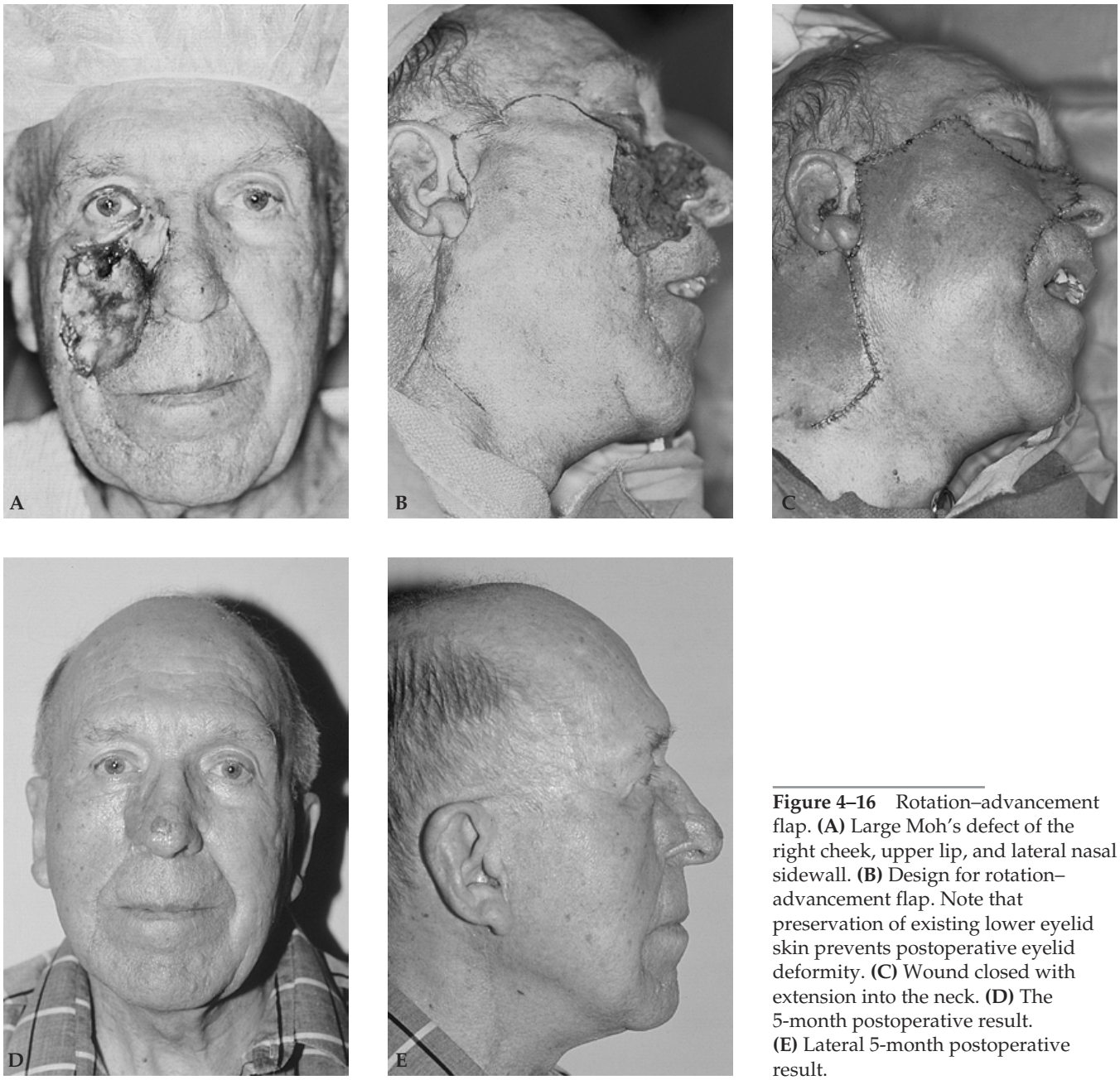

Figure 4–16 Rotation–advancement flap. **(A)** Large Moh's defect of the right cheek, upper lip, and lateral nasal sidewall. **(B)** Design for rotation–advancement flap. Note that preservation of existing lower eyelid skin prevents postoperative eyelid deformity. **(C)** Wound closed with extension into the neck. **(D)** The 5-month postoperative result. **(E)** Lateral 5-month postoperative result.

there is a large triangular defect, such a flap should be considered. Two or three rotation–advancement flaps may be combined to close large circular defects. This is particularly useful for defects of the scalp.[43,44]

Transposition Flaps

Transposition flaps may be created and transposed into a defect with primary closure of the donor site. These flaps may be designed in many different shapes and sizes, making the choice of which flap to use for a given defect somewhat confusing.[23] There are three basic transposition flaps: rhomboid, bilobed, and Z-plasty.

Rhomboid Flap

The 60-degree rhomboid flap is a classic flap described by Limberg,[45] which consists of a rhomboid with two 60-degree angles and two 120-degree angles (Fig. 4–17). The greatest advantage of the rhomboid flap is its simple design, making it easy to position the flap so that maximum tension is positioned along an LME, with the borders of the flap laying in RSTLs.[46] A useful variation of the rhomboid design includes a 30-degree transposition flap that is transposed into a rhomboid defect that has been shortened with an M-plasty (Fig. 4–18).[47] Although somewhat more difficult to design, the 30-degree transposition flap is effective in decreasing the angle of rotation, thereby distributing the tension more evenly along the

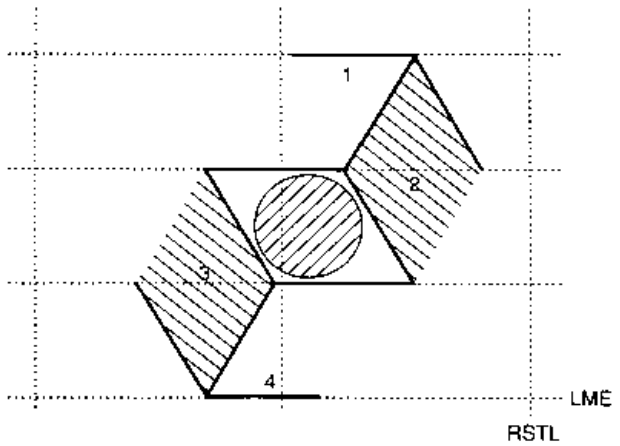

Figure 4–17 Rhomboid flap. The basic 60-degree rhomboid or Limberg flap is designed using the relaxed skin tension lines (RSTLs) and the lines of maximal extensibility (LMEs). Four flaps can be created after the rhombus is placed around the defect. Only flaps 2 and 3 will have maximal wound closure in the LME. This design fails to take into account that defects are usually circular (not rhomboid), and the RSTLs and the LMEs are usually curvilinear. (From Murakami CS, Nishioka GJ. Essential concepts in the design of local skin flaps. *Fac Plast Surg Clin North Am* 1996;4(4):455–468. With permission.)

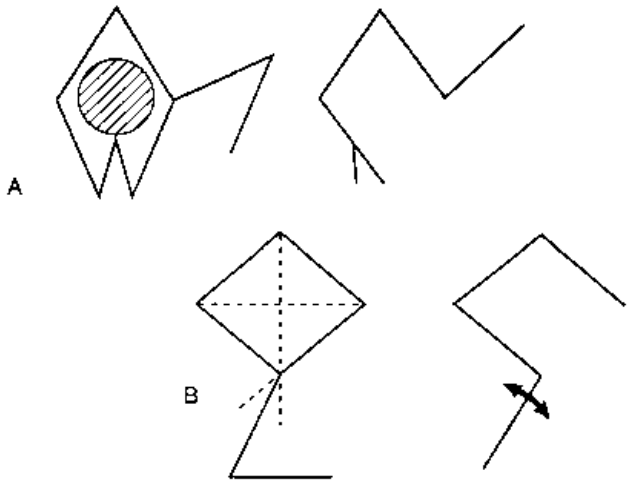

Figure 4–18 Webster and Dufourmental flaps. **(A)** Webster's 30-degree flap. **(B)** Dufourmental flap. These modifications of the basic 60-degree rhomboid flap allow partial closure of the defect using secondary movement of surrounding tissue. The flaps also have smaller angles of rotation that result in smaller standing cones and redundancies. (From Murakami CS, Nishioka GJ. Essential concepts in the design of local skin flaps. *Fac Plast Surg Clin North Am* 1996; 4(4):455–468. With permission.)

surface and minimizing dog-ear deformities. The Dufourmental flap is another modification of the rhomboid flap that may be applied to any rhombic defect, not just 60-degree or 120-degree (Fig. 4–18).[48] It is useful for rhombic defects with an acute angle of 60 to 90 degrees, when the surgeon chooses not to excise additional skin to create a more acute angle.

The majority of the tension of a rhomboid flap is at the closure of the donor site.[46,49] Whenever possible, this line of tension at the donor site closure should be parallel to the LME. Double and triple rhomboids are very useful in the closure of large rectangular and circular defects. A standardized approach to rhomboid flap design allows selection of the optimal flap for a given defect.[39] The surgeon first draws two lines parallel to the LME and creates two rhomboids (Fig. 4–17). The four possible rhombic flaps for each figure are then drawn. Of these four flaps, one of the two flaps with a short diagonal parallel to the LME should be chosen.[49]

The rhomboid flap is particularly useful for defects in the cheek and temple area (Fig. 4–19). Although this flap is reliable, versatile, and easy to design, it does require forcing a facial defect into an arbitrary design. This may result in discarding normal tissue and making final scar placement more visible because of exact geometry.

Bilobed Flaps

The bilobed flap is another common transposition flap that consists of the mobilization of two flaps with a common base to cover the defect. The primary flap is the same size as or slightly smaller than the defect, and the secondary flap is slightly smaller than the primary flap (Fig. 4–20).[50] Early descriptions of the bilobed flap indicated that each flap rotated around an axis of 90 degrees, which often resulted in large redundancies of tissue and excess tension along margins of the flap.[51] Zitelli[52] redesigned the bilobed flap such that each flap rotates approximately 45 degrees. This reduces the amount of redundant tissue and the amount of tension at the flap margins. Sometimes the angles for these flaps are difficult to draw and calculate when the flaps are positioned over a convex or concave surface, such as the nasal dorsum.[23] The circular template technique makes it easy to design bilobed flaps that have primary and secondary flaps with appropriate sizes and angles of rotation.[53] The bilobed flap is commonly used for small defects (1 to 2 cm) of the dorsum and lateral side wall of the nose, or the lateral cheek (Fig. 4–21). The disadvantages of the bilobed flap are the length of the incisions, pin cushioning, and skin deformation.[4]

Z-plasty

A Z-plasty is a double transposition of two flaps of equal size. Z-plasties are frequently used to revise scars by lengthening a contracted scar or change the direction of scar so as to reorient it to favorable RSTLs or the basic aesthetic unit (BAU). The Z-plasty technique may be used to close a defect located on one of its three limbs (Fig. 4–22). Basically, two flaps of unequal size and unequal angles are transferred during closure of the defect. The concept is essentially the same in that there will be

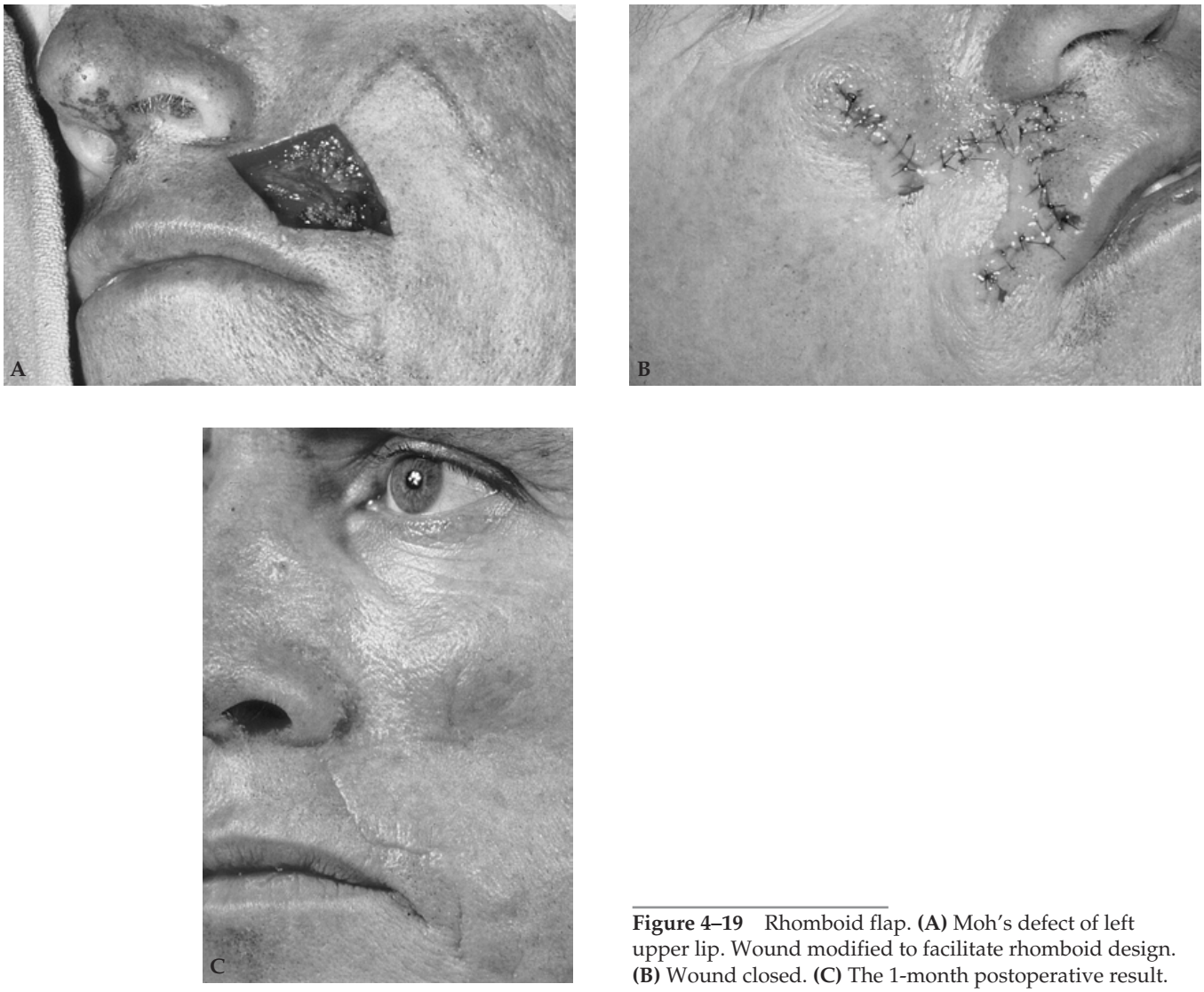

Figure 4–19 Rhomboid flap. **(A)** Moh's defect of left upper lip. Wound modified to facilitate rhomboid design. **(B)** Wound closed. **(C)** The 1-month postoperative result.

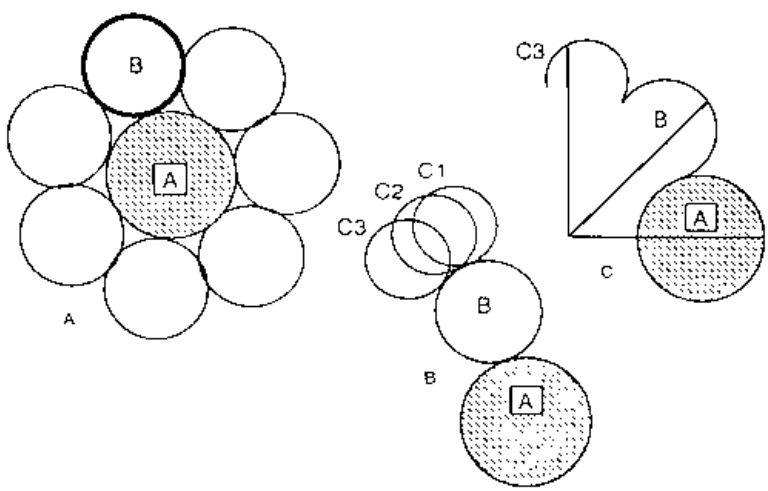

Figure 4–20 Bilobed flap. **(A)** Template B is placed around defect A. **(B)** The C template is then drawn adjacent to circle B. The C position can be modified (C1–3) to control the rotation and advancement components. The C3 flap is at a 45-degree angle to the A–B axis. **(C)** If the C3 template is chosen and the bilobed flap is drawn around the B–C3 template, a bilobed flap similar to the Zitelli bilobed flap is created. (From Murakami CS, Nishioka GJ. Essential concepts in the design of local skin flaps. *Fac Plast Surg Clin North Am* 1996;4(4):455–468. With permission.)

Figure 4–21 Bilobed flap. **(A)** Moh's defect of the nasal tip. Bilobed flap designed. **(B, C)** The 3-month postoperative result.

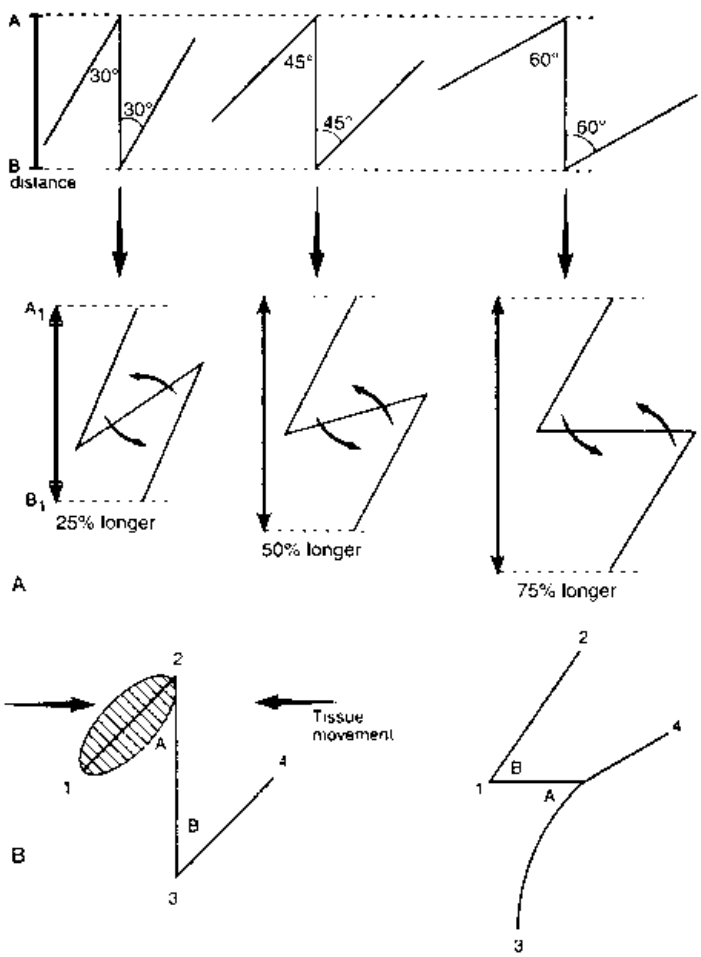

Figure 4–22 Z-plasty flap. **(A)** The standard Z-plasty advances tissue from the lateral margins and expands the tissue along the 2–3 axis. A defect may be placed in any one of the three limbs of the Z-plasty. The A and B flaps must transpose across one another. The transposition of the A and B flaps occurs with all transposition flaps, although it may not be as obvious as in the Z-plasty flap. **(B)** A Z-plasty design used to close a defect placed along one of its three limbs. (From Murakami CS, Nishioka GJ. Essential concepts in the design of local skin flaps. *Fac Plast Surg Clin North Am* 1996;4(4):455–468. With permission.)

elongation in one dimension and contraction in the other with reorientation of the incisions. Lastly, Z-plasty may be helpful when closing wounds that cross the junction between BAUs or to avoid unnecessary traction on important anatomic structures, such as eyelid, nose, and mouth (Fig. 4–23).

Subcutaneous Pedicle Flaps

Subcutaneous pedicle flaps are useful for moving a small amount of tissue a short distance. A triangle or kite-shaped area of skin is incised with its blood supply based on its subcutaneous pedicle.[54,55] It is then mobilized and advanced into the defect. The donor area is closed in a V to Y fashion (Fig. 4–24). The flap can also be designed for rotation or advancement into a nonadjacent defect.[4]

SUMMARY

A comprehensive knowledge of the anatomy, physiology, biomechanics, and design of skin flaps must be achieved before embarking on the reconstruction of a soft-tissue defect of the face. Each defect is unique, and the surgeon often relies on variations of the rotation, advancement, and transposition flaps to close defects based on their specific location, size, and donor tissue.[23] The better one understands these concepts, the better one is able to customize a local flap to suit the specific needs of the defect, avoid complications caused by miscalculations, and attain an aesthetically pleasing closure of the skin and soft tissue defect with minimal associated morbidity.

Figure 4–23 Adjunctive Z-plasty. **(A)** Adjunctive Z-plasty designed to aid in fusiform closure of the large chin defect by borrowing tissue from the submental region. **(B)** Closure of both defects, with the Z-plasty hidden in the submental region. **(C, D)** The 6-month postoperative result. (From Toriumi D, Larrabee WF. Skin grafts and flaps. In: Papel ID, Nachlas N (eds). *Facial Plastic and Reconstructive Surgery*. St. Louis: CV Mosby, 1992:36. With permission.)

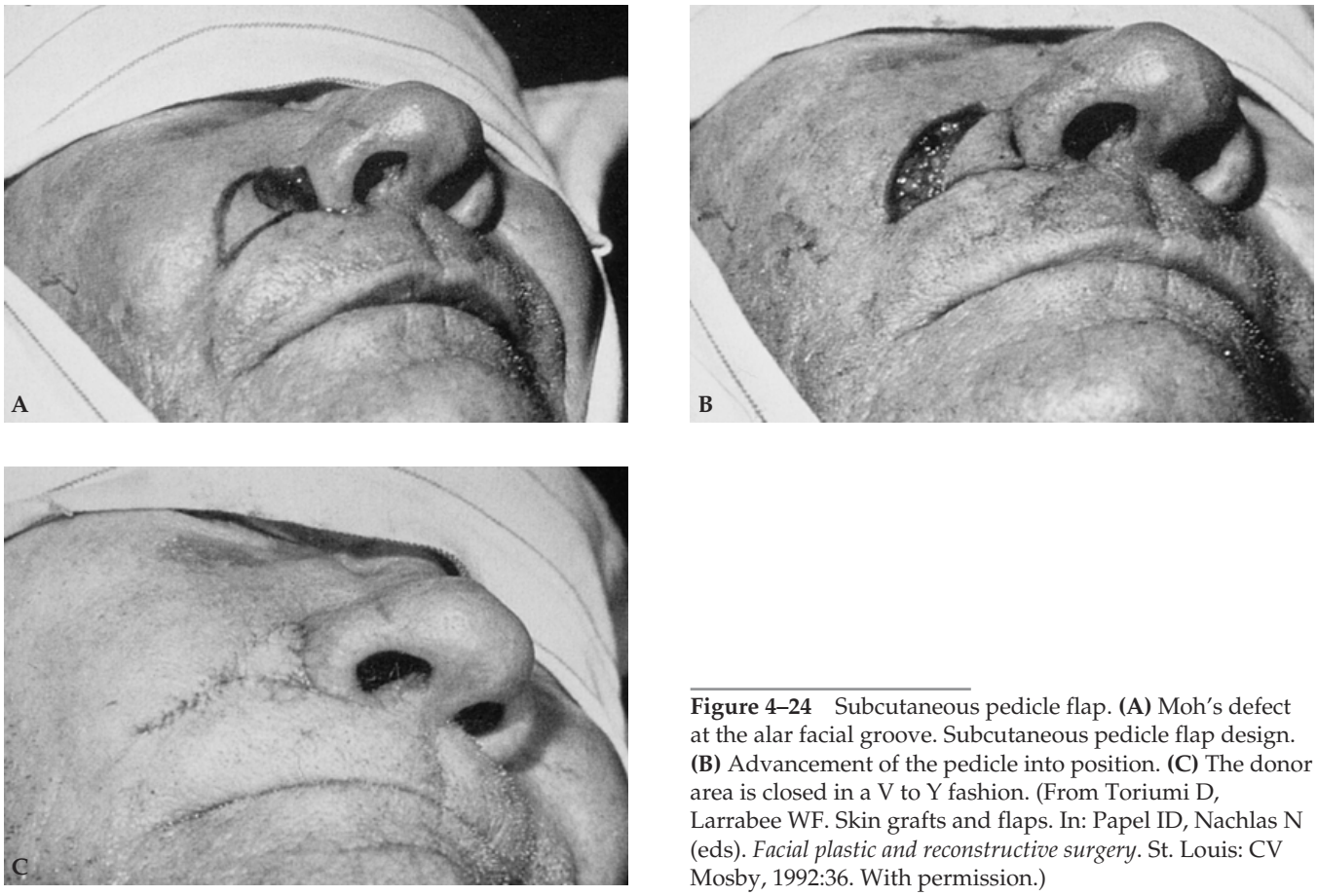

Figure 4–24 Subcutaneous pedicle flap. **(A)** Moh's defect at the alar facial groove. Subcutaneous pedicle flap design. **(B)** Advancement of the pedicle into position. **(C)** The donor area is closed in a V to Y fashion. (From Toriumi D, Larrabee WF. Skin grafts and flaps. In: Papel ID, Nachlas N (eds). *Facial plastic and reconstructive surgery*. St. Louis: CV Mosby, 1992:36. With permission.)

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Chapter 5

Scar Revision

Mimi S. Kokoska and J. Regan Thomas

The purpose of scar revision is to optimize scar camouflage. Although scar appearance can in many circumstances be improved, a scar cannot be completely removed. Patients should be informed as such. The ultimate appearance of a scar is dependent on many factors. The orientation of the scar, amount of tissue loss or injury, scar position on the face, age of the patient, patient's underlying health, genetic predisposition to abnormal scar formation, technique of wound closure, and the presence of wound healing complication all contribute to the final scar result.

Scar position, extent of tissue loss, the patient's age, genetic factors, and underlying health are for the most part beyond a surgeon's control. However, the surgeon can implement specific wound healing and scar formation principles in the surgical planning to effect an optimal outcome for the patient.

Understanding the mechanism of scar formation can be helpful in deciding on the method of scar revision. Blunt trauma, gunshot wounds, and burn scars tend to involve a larger surrounding area of injury than surgical incisional scars. Initially, it may be difficult to determine how much of the adjacent soft tissue is not viable, especially in wounds associated with thermal injury. Debridement during the initial stage of repair should be conservative to preserve as much viable tissue as possible. Scars resulting from these types of injuries may be less amenable to a satisfactory result or require staged revisions.

There are some guidelines for optimizing initial scar formation, which in turn may facilitate later scar revision or even circumvent the need for a secondary procedure. All wounds should be as clean as possible with removal of foreign bodies. Irrigation with sterile saline has been shown to decrease bacterial counts. Clearly devitalized tissue should be debrided with preservation of healthy tissue. The orientation of the scar should not necessarily be altered during the initial injury because scar irregularities may serve to help camouflage the scar and neighboring tissues can be observed for viability and preserved for any required secondary procedures. During initial closure of traumatic injuries, soft tissues should be closed in multiple layers if the injury penetrates the subcutaneous tissues. Conservative undermining may be necessary to approximate wound edges without tension. Tension increases the risk for widened or hypertrophic scars. The wound surface should be kept moist with antibiotic ointment or an occlusive dressing.

SCAR ANALYSIS

The ideal scar is narrow, flat, and level with the surrounding skin. It has similar color match to surrounding skin. The scar should be parallel or within the relaxed skin tension lines (RSTLs) (Fig. 5–1) and possibly in a junction between aesthetic subunits. The scar should not tent or bunch up surrounding skin. Scar revision is indicated for scars that are hypertrophic, widened, depressed, perpendicular to RSTLs, webbed, trapped-door, causing malalignment of a facial landmark (brows, vermilion), or interfering with facial function. Scars that are narrow, within the RSTLs, but hypertrophic may respond to intralesional triamcinolone injection alone (Fig. 5–2).

TIMING OF SCAR REVISION

All scars tend to improve spontaneously after a period of maturation of 1 year. However, the patient frequently wishes for earlier intervention, if warranted. The characteristics of a scar can help guide the timing of the scar revision. If a fresh scar is narrow, flat, situated within the RSTL, but erythematous, it may serve the patient better to reassess the scar after it matures because erythema usually dissipates. However, if the scar has significant unfavorable characteristics, such as malalignment, that will usually not improve with time, then earlier scar revision may be beneficial.

Minor revisions, such as dermabrasion, may be routinely performed approximately 8 weeks after the initial wound repair. Dermabrasion during this early period of wound healing may in theory benefit from the high fibroblast activity. At this time scars are usually still erythematous. Dermabrasion itself causes significant transient erythema. Therefore, early dermabrasion may decrease the total time that a patient has to endure an erythematous scar by overlapping the erythematous periods associated with early scar healing and dermabrasion.

EXCISIONAL TECHNIQUES

Scar Repositioning

Frequently scars can be repositioned to fall within RSTLs, borders between aesthetic units, or hair-bearing scalp. Scar repositioning requires the scar to be in proximity to the more hidden site. This concept can be applied to the facelift

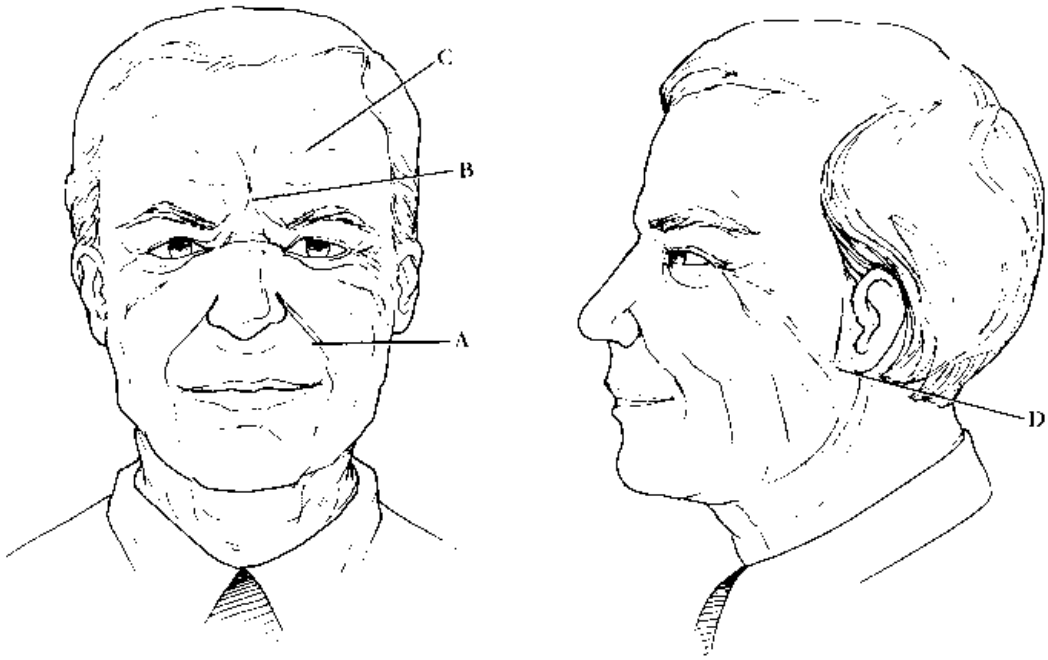

Figure 5–1 Relaxed skin tension lines, which help guide the orientation of scar placement. Examples include the horizontal forehead creases, vertical glabellar furrows, vertical lip creases, and crow's feet. Junctions between aesthetic units can also be used to camouflage scars. For example, the adjacent wounds may be closed with the scar placed in the melolabial fold.

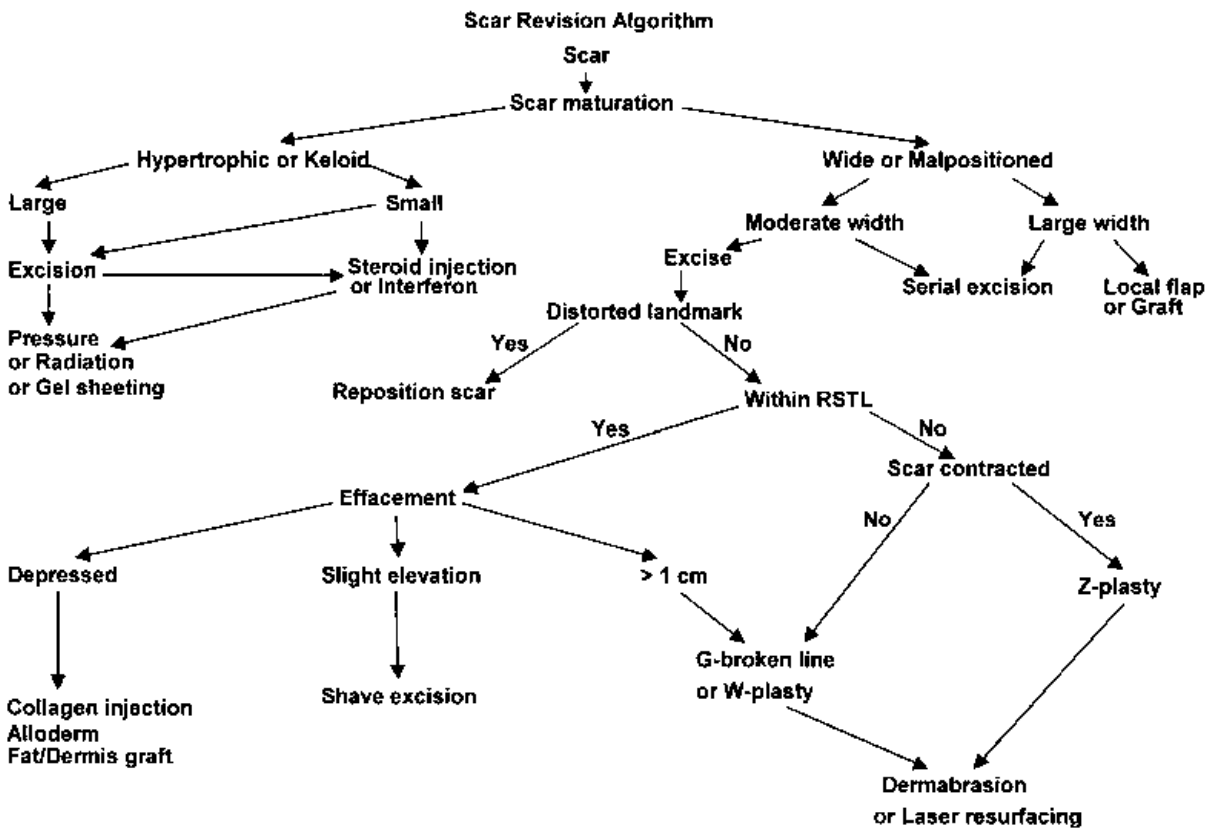

Figure 5–2 This flow diagram demonstrates the preoperative analysis and treatment options for optimal scar revision. (Modified from Thomas JR. Facial scars. In: Thomas JR, Holt GR (eds). *Facial scars: incision, revision, and camouflage*. St. Louis: CV Mosby, 1989. With permission.)

Figure 5–3 **(A)** Patient with wide and malpositioned scar. **(B)** One week after scar repositioning.

or postparotidectomy patient who has a noticeable preauricular scar. Often these scars can be repositioned close to the tragus, resulting in better camouflage (Fig. 5–3). Scars that cause malalignment of an aesthetic landmark can be excised and repositioned.

Simple Excision

Often scars that are malaligned or malpositioned can be improved by simple fusiform excision and redirection of the wound to a favorable position. Simple excisions can provide a finer scar with orientation into an RSTL or a junction of an aesthetic unit for scars that have healed under less than favorable conditions (Fig. 5–4). Fusiform excisions are ideal for small-diameter or short scars. If the ends of the planned fusiform excision approach another aesthetic unit or a facial landmark, an M-plasty can be performed to shorten the end of the elipse.

Fusiform excision angles should be ideally 30 to 60 degrees. Angles greater than 60 degrees result in a standing-cone deformity that requires either M-plasty or further extension of the wound to correct the tissue excess.

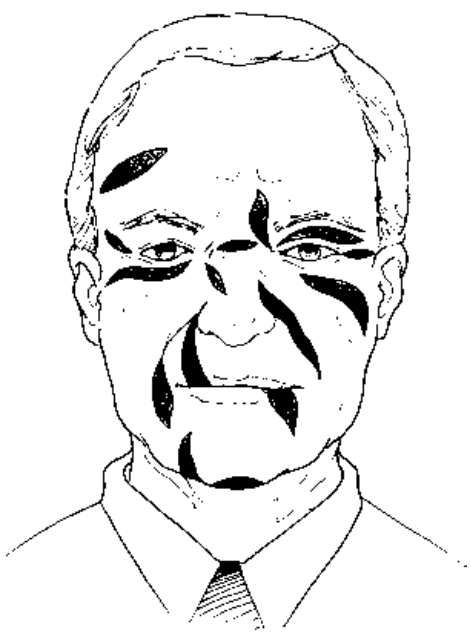

Figure 5–4 Fusiform excisions are ideally situated in relaxed skin tension lines or aesthetic borders.

Serial Excisions

Serial partial excisions are utilized when the scar or skin lesion is too large to allow closure of the surrounding skin in a single stage. Some types of scars that may benefit from serial partial excisions include (1) large scars closed primarily with a skin graft and (2) burn scars. The initial incision is placed within the scar at one margin. The wound edges are undermined, a portion of the scar is excised after advancement, and the wound is closed. After 8 to 12 weeks during which the skin stretches, the procedure is repeated with the incision within the scar border.

In the last excision, the remaining scar is excised and normal skin margins in both sides of the wound are approximated. In this final closure, the skin margins can be approximated in a straight line, W-plasty, or broken-line closure. Skin has a great ability to stretch and accommodate wound closure. Serial excisions utilize the extraordinary ability of the skin to stretch and slowly accommodate over time. Even large wounds that cover up to 50% of the forehead can be serially excised. In addition, serial excisions can be used to move scars to a site that provides better camouflage, such as junctions of aesthetic units, into hairlines and RSTLs.

Z-plasty

Z-plasty is a technique that provides irregularization of the scar while changing scar direction; it lengthens the scar and provides excision. It utilizes the transposition of triangular flaps around the scar that is the central member. The new orientation of the central member is perpendicular to the original scar.

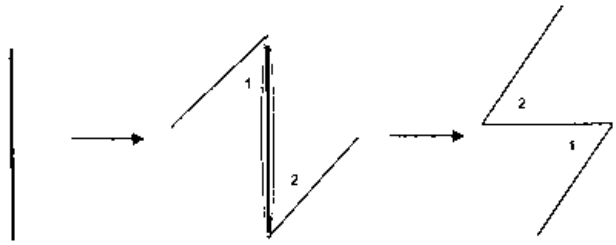

Figure 5–5 Single Z-plasty. Two equal triangular flaps are transposed. Note that the original scar member has been excised and the scar length has increased.

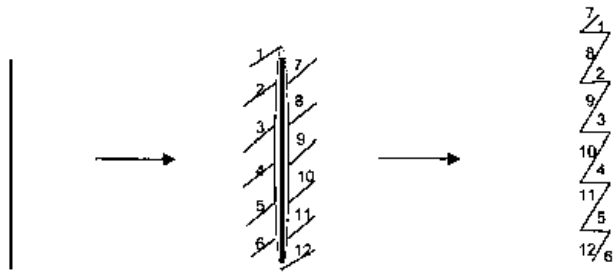

Figure 5–6 Multiple Z-plasty. Placement of several small "Z"s along the wound allowing transposition of several small triangular flaps. Benefits from multiple Z-plasty include scar irregularization and distribution of wound tension into several vectors. Elongation of the wound is inevitable and must be anticipated.

The classic Z-plasty has a central member and two peripheral members, which are equal in length, and two equal triangles (Fig. 5–5). The scar can be excised as the central member or multiple central members, as in multiple Z-plasties. After incision of the members, the triangular flaps are undermined. The triangular flaps are then transposed and sutured in place using multiple layer closures. In theory, angles of 30 degrees will provide lengthening of 25%, whereas 45-degree angles will lengthen a wound by 50% and 60-degree angles will yield a 75% lengthening. Therefore, the lengthening of the scar must be considered, especially when lengthening of the scar encroaches into another aesthetic unit or anatomic structure. For example, Z-plasty on a vertical forehead scar near the brow could cause distortion of the brow position after lengthening. The members should be less than 1 cm to assist in scar camouflage.

Unequal Z-plasty angles can be used to move tissue into an area of tissue deficiency. This is helpful in areas where scar contracture has caused retraction of an adjacent structure. The smaller angle flap has greater rotational potential than the larger angle flap. The smaller angle flap is then used to provide additional tissue to the deficient area. Although it does not provide tissue lengthening in the direction of the original scar, it does provide additional tissue lengthening perpendicular to the original scar.

Multiple Z-plasties

Multiple Z-plasties are used to decrease the scar contracture associated with a wound by redirecting the tension along the entire scar (Fig. 5–6). This is accomplished without excessive member length, which would leave noticeable scars and limit the breakage of the scar line. Pin cushioning or trap-door deformities are associated with circular or semicircular scars. There appears to be edematous tissue "trapped" by a surrounding area of wound contracture. Treatment options include intralesional steroid injections, application of pressure, and scar revision. The thickened flap can be undermined and debulked; then multiple Z-plasties can be used to redirect and lengthen the contracted scar. A web scar, which occurs frequently around the medial canthal region, can also be treated effectively with this technique.

W-plasty

W-plasty is utilized to irregularize and reorient a scar or wound that may lie perpendicular to the RSTL. It is performed by excising successive small triangular skin units from the perimeter of the scar or wound. The triangular flaps are advanced into its opposing triangular defects and the wound is closed (Fig. 5–7). In contrast to Z-plasty, there is no significant wound lengthening. Not only are the limbs of the W-plasty flaps in general shorter than the Z-plasty limbs, but there is no transposition of the W-plasty flaps. For long scars, W-plasty is less ideal than the geometric broken line closure (GBLC) technique. The regular irregular repeating units of the W-plasty wound are more readily identified by the eye than the asymmetric irregular units of the GBLC wound.

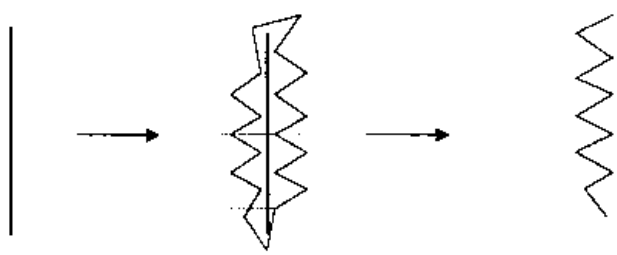

Figure 5–7 W-plasty. Running triangular flaps are interposed resulting in a regular irregular scar. A single long scar can be reoriented into small scars that are situated within the relaxed skin tension lines.

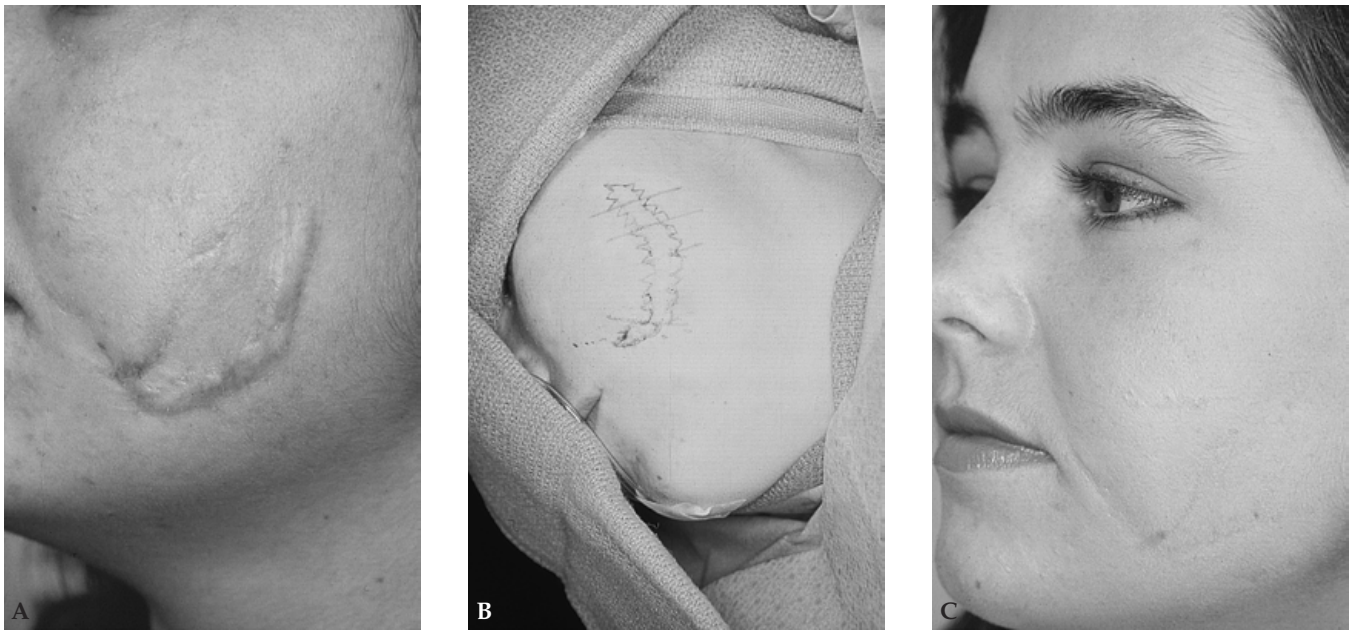

Figure 5–8 **(A)** Preoperative hypertrophic and lengthy cheek scar. **(B)** Intraoperative geometric broken line closure. **(C)** One year after geometric broken line closure followed by secondary dermabrasion.

Geometric Broken Line Closure

The GBLC technique is a more complicated irregularization technique than the Z-plasty or W-plasty. It provides an irregular scar that is less detectable to the eye. It is ideal for lengthy scars that traverse an aesthetic unit, (such as the cheek) (Fig. 5–8).

A series of randomly alternating triangle, rectangle, trapezoid, semicircle, and square patterns are cut on one side of the wound and its mirror image is cut on the other side of the wound (Fig. 5–9). The opposing sides are closed after removal of the cutout and intervening scar segment. The flap limbs should be less than 6 mm to facilitate scar camouflage because longer limbs tend to be followed by the eye.

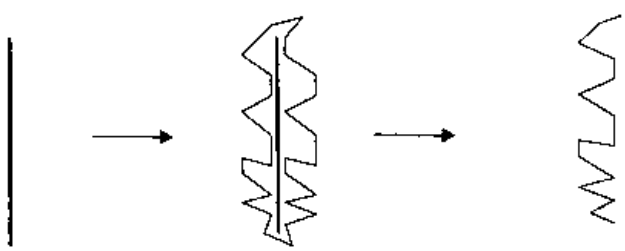

Figure 5–9 Geometric broken line closure. Randomly alternating patterns result in an irregular scar with components oriented in the relaxed skin tension line.

DERMABRASION AND LASER SKIN RESURFACING

Either dermabrasion or laser skin resurfacing can be used to remove the superficial skin layers (epidermis and part of the papillary dermis). The wound is reepithelialized by surrounding epithelium and underlying adnexal structures. These techniques can be used to level a scar, change the texture of a scar, and further blend the scar with the surrounding skin, thus improving the scar camouflage (Fig. 5–10).

Dermabrasion can be performed with a diamond fraise or wire brush attached to a motorized hand piece. A local anesthetic is applied and the skin cleaned prior to dermabrasion. The skin is stretched and the fraise applied to the scar and surrounding skin. The fraise should be rotating in a clockwise fashion and applied perpendicular and oblique to the axis of the scar. Sponges should be kept away from the rotating fraise to avoid accidental snaring of the sponge into the dermabrader. The scar and surrounding skin are stretched taut to provide an even and firm surface for dermabrasion. Skin refrigerants are no longer used in most practices since Freon was outlawed. Deep dermabrasion into the reticular dermis should be avoided to prevent further scarring. Dermabrasion is also valuable as a secondary stage of scar revision after Z-plasty, W-plasty, or GBLC. It can be performed 8 weeks after scar revision to further improve the scar camouflage.

Laser skin resurfacing is usually performed with a carbon dioxide or erbium laser. There may be theoretical advantages

Figure 5–10 **(A)** Pretreatment photograph of forehead scars. **(B)** Two weeks after dermabrasion. **(C)** One year postoperative result from dermabrasion alone.

to laser skin resurfacing over dermabrasion for scar camouflage. It has been suggested that the laser offers increased collagen reorganization and therefore improved scar camouflage. However, the thermal damage associated with laser resurfacing may make the depth of penetration less predictable. Recent advances in laser scanner technology have provided more consistent skin resurfacing results. In addition, certain scanner patterns can selectively ablate the tissue around depressed areas, resulting in a more level plane.

Patient selection is important with either dermabrasion or laser skin resurfacing. Fair-skinned patients are less likely to develop noticeable pigmentary changes and hypertrophic or keloid scarring. Patients who are having perioral resurfacing are prophylaxed with antiviral medication against the herpes simplex virus. All candidates should be counseled on the risk of pigmentary changes, infection, scarring, and the possible need for multiple treatments.

POSTOPERATIVE CARE

After excisional scar revision or dermabrasion, an antibiotic ointment is applied to the suture line or wound for approximately 1 week. A dressing may be applied or the ointment may serve as a semiocclusive dressing. The sutures are usually removed at 1 week unless the patient has compromised wound healing. If any signs of hypertrophic or keloid scarring develop in the following weeks, triamcinolone acetonide (Kenalog) 10 mg/ml is injected into the dermal portion of the scar. In addition to Kenalog, mechanical pressure (digital, earring clips) or silastic gel sheeting may be used to discourage further growth of the scar.

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Chapter 6

Synthetic Implants

Vito C. Quatela and Paul Sabini

Synthetic implants are an invaluable tool for the facial plastic surgeon. Fixation of fractures, soft tissue and bony reconstruction, and cosmetic augmentation may all be addressed with a wide variety of synthetic implants. However, the search for an ideal synthetic implant for facial plastic surgery is an evolving science. The search is fueled by the constant need for adequate tissue substitutes in reconstructive and augmentation procedures of the head and neck. It is fairly indisputable that autogenous grafting is preferred by surgeons when easily available.[1] Harvesting morbidity, graft resorption and distortion, and limited graft availability are deterrents of autogenous grafting. Alternatives to autogenous grafting are synthetic materials and allogeneic tissue. Cadaver specimens provide allogeneic tissue that is available in either lyophilized or irradiated preparation with limited shelf life.[2] The long-term outcome of allogeneic tissues is likewise subject to distortion, absorption, and reaction. Indeed, in certain clinical situations, the outcome of using an implant is more predictable than with autogenous or allogeneic tissues. The lure of not having a secondary surgical site and the limitless abundance of synthetic implants have historically caused an ambivalent relationship with various implants. Technological advances in biomaterials are tempered by the need for long-term clinical trials. Many implants fall into disfavor because they do not survive the 15-year clinical trial.

Gold and silver have had a place in soft tissue augmentation since the sixteenth century. Paraffin and ivory gained popularity in the early 1900s; however, tissue reaction, granulomas, lack of immobilization, and technical difficulties eventually dismissed their use.[3] The turn of the century marked the beginning of the use of synthetic implants, but only in the last 20 years have significant understanding and technological advances been seen. World War II heralded the use of plastic polymers for soft tissue augmentation. Initially, methylmethacrylate, polypropylene, and polyethylene were used extensively, but the lack of malleability and the need for prefabrication led to the development of softer alloplasts. In the 1950s, silicone, Dacron, and nylon gained popularity because of their biocompatibility, ease of fabrication, and properties that make it possible to individualize an implant to the patient's requirements.

Silicone, although easy to sculpt in its vulcanized form of Silastic, did not allow for adequate tissue fixation and was subject to dislocation.[4–6] This led to a great interest in the porous implants, such as polyamide mesh (Supramid), polytetrafluoroethylene carbon (Proplast), and high-density polyethylene (Plasti-Pore, Medpor).

Polyamide mesh has a propensity to resorb over time and has been replaced by polyester fiber (Mersilene).[5,7,8] Silicone has endured the test of time and is presently the most commonly used synthetic implant.[9] Unlike silicone, expanded polytetrafluoroethylene (Gore-Tex), Medpor, and Mersilene display excellent tissue ingrowth and fixation, but this makes removal for any reason more difficult. Injectable synthetic implants for soft tissue contouring are of great interest to cosmetic surgeons. Autologous fat and bovine collagen are more commonly used for soft tissue augmentation; however, both materials are subject to a variable rate of resorption. Liquid silicone, methylmethylpolysiloxane (Bioplastique, Bioplasty Inc., St. Paul, MN), and polymethyl- methacrylate (PMMA) do not suffer this fate. Liquid silicone and Bioplastique have not been approved as injectable fillers by the Food and Drug Administration (FDA), and PMMA has not been subject to a clinical trial.[6]

Certain ceramics, such as hydroxyapatite, and metals, such as titanium, have had appeal in the last decade because of their ability to osseointegrate with bone. Efforts to improve the incorporation of synthetic materials by the host (recipient) through the use of growth factors are under way.[10–12] Ultimately, tissue engineering technology may provide clinicians with a means of inducing the host to regenerate missing tissue guided by resorbable synthetic scaffolding.[11]

THE IDEAL IMPLANT

When designing a new implant material a manufacturer is most concerned with the physical properties of the implant. The ability to withstand different mechanical forces is a measure of strength and hardness. The elasticity of an implant determines its ability to withstand a load over time while maintaining its shape. The surface characteristics of an implant determine its tolerance to degradation.[13] The fewer the surface imperfections, the greater the tolerance to degradation by mechanical forces. The implant must be chemically inert. Implant longevity is also affected by the ability to withstand biochemical interaction and corrosion by the body's fluids. Therefore, as a result of its physical properties, an implant should not be altered by time and should remain essentially maintenance-free for the lifetime of the patient.

The way an implant satisfies these criteria in a clinical setting cannot be determined in vitro. Only through extensive animal studies and long-term clinical trials can clinical efficacy be determined. A primary concern is whether the implant is nontoxic. All implants exhibit a nonspecific inflammatory reaction characterized by acute and chronic phases.[14] The greater the extent and duration of these inflammatory phases, the greater the toxicity. The more toxic an implant is to the tissue, the greater the likelihood that a foreign body reaction will occur. An implant must not react with a patient's immune system; therefore, it must be both nonallergenic and noncarcinogenic. Most polymer implants are macromolecules composed of repeating monomeric units and, because of their molecular weight, are capable of being immunogenic.[8] Immunogenicity of an implant can result in implant rejection and failure or can induce a systemic response in the host.

If a resorbable implant is used or if any component of the implant is degraded, it should not leach chemicals into the organism or release particles that could damage the host. The release of particles smaller than 60 μm has been shown to precipitate a chronic inflammatory response regardless of whether or not the implant is otherwise inert. Particles larger than 60 μm cannot be engulfed by macrophages and will elicit nothing more than a low-grade inflammatory reaction consisting of giant cells and the formation of a fibrous capsule.[15]

Carcinogenesis has been linked to implanted materials in animals. The theory of solid tumor genesis is both a volume- and time-dependent phenomenon and is less related to the actual implant material itself. However, extrapolating to human implantation, no statistically significant causal relationship has been demonstrated between synthetic implantation and tumor induction.[16,17]

The implant's resistance to infection is not clearly related to surface characteristics and geometry. Elek and Conen[18] have shown that different sutures have different capacities to potentiate infection. Exact interactions that occur at the surface of an implant to induce cellular attachments are complex. Karlan et al[19] demonstrated that silicone implants have a greater capacity than bioglass implants to potentiate infection even though surface morphology is similar, illustrating the importance of other variables.

Surface morphology is significant from the standpoint of implant fixation. Porous implants, such as Gore-Tex and Medpor, allow for good tissue ingrowth and implant fixation. The ability of the more porous implants to potentiate infection over nonporous implants has been studied with conflicting results.[20,21] Keichel et al[20] demonstrated that early inoculation of implants produced a greater infection rate in porous implants than in solid implants. In comparing porous materials, Sclafani et al[22] found a difference in implant infection rates based on pore size. A larger pore size allowed for greater fibrovascular ingrowth and resulted in a greater resistance to infection following late inoculation.

Many variables contribute to an implant's ability to potentiate infection. Surgical technique most likely plays a larger role than implant selection. The role of antibiotics in preventing infection of the implant is less clear.

Concerns of the surgeon in selecting an implant are usually more germane than immunogenesis, carcinogenesis, and the physical properties of the implant. Matching of size and consistency merits careful consideration. Ideally, the implant should be fashioned for the individual patient. Therefore, the ease of customizing an implant to suit a specific patient is important. If an implant is not easily carved, it must be prefabricated. Prefabrication is desired by many surgeons because of reduced operating time and handling of the implant. An implant must withstand sterilization by an easy method and without subsequent decomposition. The implant's color must not be offensively visible through the skin and must not discolor. An implant must be easily available and cost-effective.

The surgeon should be concerned that an implant will not dislocate over time. Good immobilization of the implant, with or without trauma, prevents migration. Porous implants, such as Medpor, Mersilene mesh, and Gore-Tex, allow for good tissue ingrowth and thus fixation. However, excessive tissue ingrowth is not desirable when considering the occasional need for removal of an implant. Supramid is virtually impossible to remove in its entirety because tissue ingrowth makes the implant essentially indistinct from surrounding tissue.[23] The attraction of Gore-Tex is that it allows for both maximal tissue ingrowth for fixation and ease of removal.[24,25]

By reviewing all of the properties and qualities of these synthetic implants, the ideal implant can be devised. It would be readily available, sterile, and of the same contour and consistency of the missing tissue to be replaced. It would be nontoxic, nonallergenic, noncarcinogenic, and resistant to infection. It would not be altered by the host or the host's healing process. It would eventually resorb, without degradation products, having induced the ideal replacement for itself that is completely autogenous.

CLINICAL CONSIDERATIONS

Presently, an ideal implant does not exist; the choices are influenced by different clinical settings. The age and health of the patient also influences the decision. Alloplastic implants do not grow with children and, likewise, donor site morbidity may affect growth of the donor area. A healthy, noninfected, nonimmunocompromised recipient is an essential ingredient for implant survival.[26]

The ability to withstand functional stress or trauma is related to the amount of soft tissue coverage and tension of the coverage over the implant. It has been shown that similar implant materials in different anatomic areas have different extrusion rates.[27] In mentoplasty, Silastic implants fare as well as Gore-Tex and Mersilene mesh but, comparatively, their extrusion rate in the dorsum of the nose, because of inadequate soft tissue coverage, is much higher.[4,7,28] Thin avascular skin, irradiated skin, and scars are poor coverage for implants. An increased incidence of alloplastic failure is seen in revision rhinoplasty because of scarring and decreased vascularity of the overlying tissue. The mentum, due to adequate soft tissue coverage, fares equally well with most implants as a recipient site[29,30]; indeed, the most common implant used here is Silastic.[4,7] The nose, because of its skin and structure, remains elusive to an adequate implant and is probably best served with autogenous tissue. Incision is best placed away from the site of implantation. Dissection should be meticulous, and pocket size should be precise. A pocket that is too small causes undue tension; one that is too large

results in migration. Hemostasis is crucial because hematoma potentiates implant infection. An implant may be placed through an intranasal or intraoral incision without any increased infection rate; however, mucosal violation and persistent exposure to these areas will result in implant failure.

Immobilization of the implant may result as a function of a porosity of the implant iteself and subsequent tissue ingrowth. Nonporous implants can be sutured in position or fixed with metallic lag screws or fibrin glues.[31] Subperiosteal placement ensures better fixation. However, subperiosteal placement of solid implants in the mental area can cause bone erosion.[32–34] Johnson and Toriumi[29] combine the benefits of porosity and approach to achieve successful stable implantation. Mersilene mesh is selected on the basis of its porosity and is positioned in the lateral subperiosteal pockets to enhance stabilization. Midline, where tension on the bone is greatest, the implant lies in the supraperiosteal plane (Fig. 6–1). Wang and Cook[35] have reported similar techniques using Proplast.

Bacterial inoculation at the time of surgery is felt to be the most significant threat to early failure of an implant; therefore, many implant manufacturers recommend impregnation of implants with antibiotics.[36] With implants such as Mersilene this is easily achieved by soaking; others, such as Proplast, are impregnated in a vacuum to ensure infiltration of the antibiotics. An aminoglycoside, such as gentamicin or tobramycin, is used to cover the gram-positive and gram-negative organisms that predominate in these infections.[37]

Commercially available implants have met all of the criteria for satisfactory implants. Most often, failure of such an implant can be attributed to faulty judgment in implant selection for a particular site, patient selection, or surgical technique.

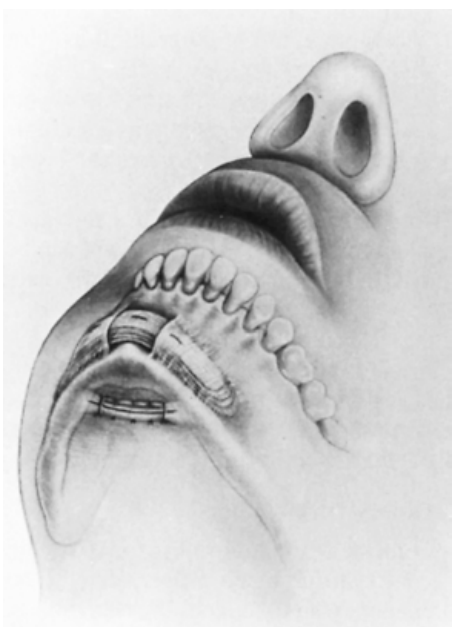


Figure 6–1 Mentoplasty using Mersilene mesh. Lateral aspects of implant are subperiosteal and midline is supraperiosteal. (From Johnson CM, Toriumi DM. *Open structure rhinoplasty*. Philadelphia: WB Saunders, 1990. With permission.)

IMPLANTABLE MATERIALS

Metals

Currently, metals are used in facial reanimation surgery, middle ear surgery, and facial skeletal applications. Lead weights, stapes prostheses, fracture palates, screws, wire, dental implants, and mandible trays are some of the general applications of metals. Corrosive characteristics of metals prevented their widespread use until the 1930s, when cobalt-chromium alloys that were corrosion-resistant, such as vitallium, became popular as dental and orthopedic implants. Gold, cobalt-chromium, stainless steel, and titanium represent the classes of metal alloys used today.[38]

Gold

Gold is chemically inert and evokes minimal tissue reaction. It has poor mechanical properties in its purest form and usually functions best as an alloy when some structural integrity is needed, such as in dental implants. However, when used as a weight in upper eyelid reanimation procedures, the 24-carat, highly polished weight provides less reactivity, greater malleability, and greater success than simple tarsorraphy.[36,39–40]

Cobalt-Chromium Alloys

Historically, the cobalt-chromium alloy was one of the first successful metallic implants to be used for structure. Vitallium was successfully introduced in the 1930s for orthopedic procedures because of its superior corrosion resistance and mechanical properties. The cobalt-chromium alloy is approximately 60% cobalt, 30% chromium, and 10% nickel. It is currently used in orthopedic implants for facial fractures and for trays in cancellous bone in mandibular reconstruction.

Stainless Steel

Stainless steel was patented in 1913 as a steel whose chromium content of 11% to 30% conferred it to anticorrosive properties. Nickel was added to the alloy to harden it. The 316L alloy is used medically and represents the lowest carbon content (to prevent carbide formation), the highest nickel content (for hardening and strength), and adequate chromium (for anticorrosion).[38] It found widespread application in the last decade for plating of skeletal fractures of the face. Recently, however, there has been a shift away from stainless steel to vitallium and titanium in facial plating because of the ease of contouring and certain osseointegrative properties that outweigh the need for the structural strength of stainless steel.

Titanium

Titanium alloy is a product of World War II aerospace technology. Like stainless steel, it is noted for anticorrosiveness and strength but is more lightweight, has the ability to osseointegrate, and is more tolerant to cold. The titanium used for implantation is essentially pure (99.75%). The osseointegration that occurs within the screw flanges and its subsequent immobilization has won favor for this implant over stainless steel. It has been used for dental implants, prosthetic implants, and mandibular and facial skeletal plating

systems.[41–43] These implants tolerate transcutaneous placement and, because of their rigid immobilization and biocompatibility, cause little or no inflammatory changes in the surrounding soft tissues, making them ideal for prosthetics and episthesis attachment even in the irradiated patient. Titanium is neither magnetic nor paramagnetic. Patients with these implants may safely undergo magnetic resonance imaging without concern about dislodgment of the graft or interference with the study.

Plastic Polymers

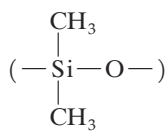
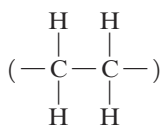
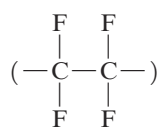
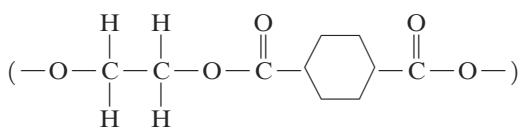
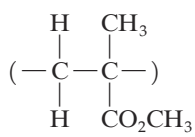
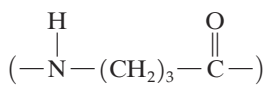
Plastic polymers represent the mainstay for implantable material in the face. Historically, these engineering materials were utilized empirically in surgical applications and through animal clinical trials were categorically eliminated or accepted. Even today, there are few polymers designed specifically for surgical use.

Structurally, polymers are macromolecules composed of long chains of repeating monomeric units (Table 6–1). These chains may vary in length and branching characteristics. The final physical characteristics of a polymer depend not only on the specific repeating units but on the variety of the chain formation, the size of the individual chain, and the position of the chains within the polymer macromolecule. The longer the chain that forms on polymerization, the greater the polymer's molecular weight. In general, lower molecular weight or short-chain polymers exist as liquids: as the length of the chain increases, there is increased viscosity, so that the long-chain polymers exist as plastics. Translinking between polymer chains can increase the tensile strength of a plastic.[44]

Polymethylmethacrylate

Polymethylmethacrylate (PMMA), an acrylic polymer of high molecular weight, was one of the first polymers used as a biomaterial. Polymerization of the methylmethacrylate monomers yields a polymer of high strength and rigidity. Historically, it has found wide-range application as an implant for orbital, malar, and cranial reconstruction.[45–49] Although this implant can be preformed, one distinct advantage is that it can be molded in situ. Cranioplast is supplied as a powdered mixture of polymer and a catalyst for mixing with a liquid monomer. This begins an exothermic reaction of rapid polymerization that cures in 10 to 15 minutes. There have been several complications with its use in orthopedic surgery related to exothermia and to contact of unbound monomer to bone and soft tissues.[50] These untoward effects have not been reported with facial or cranial

TABLE 6–1 Polymeric Composition of Alloplastic Implants

Trade name	Polymer	Monomeric unit
Silastic (Dow Corning)	Polydimethylsiloxane	
Marlex (Phillips)	Polyethylene	
Teflon (du Pont)	Polytetrafluoroethylene	
Dacron (du Pont)	Polyethylene terephthalate	
Cranioplast (Codman)	Polymethylmethacrylate	
Supramid (S. Jackson)	Polyamide	

bone reconstruction. The ability to mold the implant in the tissues and remove it during the exothermic phase of polymerization enables one to obtain an accurate implant in size and shape without causing thermal damage. Perforation of the implant promotes tissue ingrowth, although additional mechanical fixation of the implant is often required. Several surgeons have dealt with this problem by combining PMMA with a titanium mesh for cranioplasty. The mesh, which is held in place by titanium screws, provides a more rigid support and is laid down first. PMMA is then placed over the mesh and can be molded intraoperatively to provide a better cosmetic result. An emerging technology uses computer-assisted manufacturing of implants based on preoperative three-dimensional computed tomography scans. This offers the surgeon a patient-specific implant and saves time in the operating room. This technology is applicable to a wide range of materials used for facial and cranial skeletal defects.[27] PMMA has withstood the test of time and is for some surgeons the implant of choice for cranioplasty and orbital floor reconstruction.

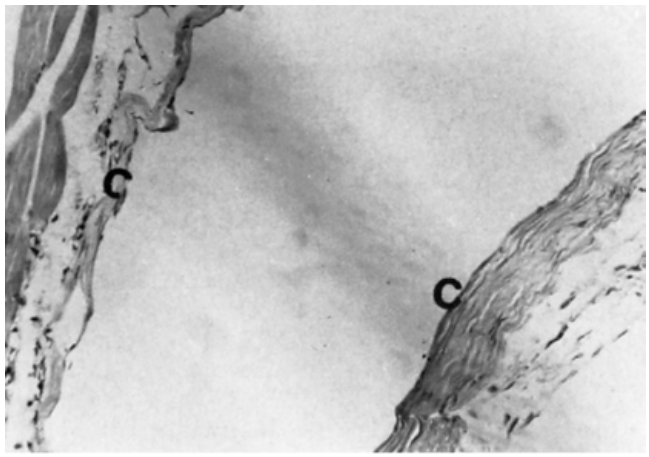


Figure 6–2 Thin fibrous capsule *(C)* showing scant number of mononuclear, chronic inflammatory cells. The cleft was left by the Silastic, which was dislodged during processing. (Courtesy of Jeanne S. Adams, MD.)

Organosilicone Polymers

The term *silicone* describes a larger family of related but differing materials. The material has been used in surgical implants for more than 40 years and has been proven safe. Nevertheless, recent negative press relating to silicone breast implants has created confusion and fear among the lay public with respect to any implant containing silicone. It is hoped that the recently released report from the Institute of Medicine (IOM) will shed some light on this issue. In 1997, following a U.S. congressional directive, the IOM appointed a committee to examine the scientific merits of claims made regarding the safety of silicone breast implants. The IOM committee concluded that there was "no definitive evidence linking (silicone) breast implants to cancer, immunological diseases, neurological problems, or other systemic diseases."[51]

Silicone polymers represent the only noncarbon chain polymers used as implants. The repeating unit is called dimethylsiloxane:

$$\left[\begin{array}{c} CH_3 \\ | \\ (-Si-O-) \\ | \\ CH_3 \end{array}\right]_X$$

The value of *X*, or the length of the chain, determines the viscosity of the silicone. If $X = 130$, the viscosity is 350 centistokes. This is the viscosity of injectable medical grade silicone. When the viscosity is extremely high (centistokes = 10,000) and the substance is vulcanized, the cross-linking of long chains to form the polymethyl silicone known as *Silastic* is produced. Histologic studies of implants by several authors reveal that Silastic becomes enveloped by a thin organized capsule with a mild, chronic inflammatory reaction devoid of histiocytes and giant cells (Fig. 6–2). Because there is no bonding between Silastic and its capsule, it is more prone to being dislodged. Silastic is more apt to be extruded when placed in a pocket with thin overlying coverage, and it gives the most persistent seromas. This is corroborated by the high extrusion rate of Silastic in nasal and auricular applications.[28] Polydimethylsiloxane in its medical grade form is inert, biocompatible, soft, and easily carved into the shape desired; consequently, it has the broadest application of any implant in mentoplasty, malarplasty, and cranioplasty.

Medical grade liquid silicone has been associated with numerous clinical abuses. Most abuses are related to an excessive number of injections and to the use of impure silicone. Complications such as migration of the implant, formation of siliconomas, and intravascular injection have resulted in everything from deformities to death.[52–56] Liquid silicone in small amounts is stable in the tissue. When quantities are limited to 0.1 mL per area and the microdroplet technique using a 30-gauge needle is used, the silicone does not migrate and is stabilized by a fibrous capsule. Interval of injection should not be less than 4 weeks. Excellent results can be achieved with acne scarring, nasal dorsal contouring, and the wrinkles of aging if proper technique is used.[8,30,40,57–59]

Representing a potential advance in injectable silicone, Bioplastique (St. Paul, MN) is currently under investigation. The material consists of solid textured silicone particles ranging in size from 100 to 400 μm, surrounded by a resorbable gel matrix. Both animal and human studies have confirmed the lack of a significant inflammatory response. The gel surrounding the silicone is engulfed within a week and replaced by collagen within six weeks. The silicone particles elicit a low-grade giant cell reaction that does not appear to affect either the implant or the recipient. As with medical grade silicone, successful use of Bioplastique is injection technique–dependent. Placement below the dermis is crucial for obtaining a lasting result. More superficial placement may result in extrusion. Early reports are favorable, and no allergic reactions or serious adverse effects have been noted. Nevertheless, it is premature to advocate widespread use of Bioplastique without further clinical trials.[6]

Polyamide Mesh

Supramid is an organopolymer derivative of nylon. Because of early hydrolytic degradation, nylon is not suitable as a permanent implant. Supramid initially appeared to be stable and indeed had few adverse reactions.[23,60–65] Histologically, Supramid elicits a foreign-body reaction in the tissues. In animal models,[5,66–67] experimental implantation resulted in a moderate number of histiocytes and giant cells, which was lower at 1 year than at 6 weeks (Fig. 6–3). Fibrous tissue ingrowth occurred, but at 1 year there was more fibrosis around the implant than actual tissue ingrowth. Once stabilized, the implant had resistance to infection and a soft consistency.

Microscopically, the experimental Supramid exhibited degradation and resorption in animals. This was later confirmed by clinical observation of resorption of Supramid used for nasal contouring and mentoplasty. Supramid mesh is of historical value now, and most of its proponents have switched to Mersilene mesh, a polyester fiber.

Polyethylene Terephthalate

Polyethylene terephthalate (Dacron) found widespread use in the garment industry. Subsequently, because of its flexibility and low reactivity, it became an implantable patch for vascular surgery. Now it is the implant polymer of choice for certain arterial prostheses. Its use in facial implantation has been limited to the backing of silicone prostheses for mentoplasty and vulcanized Dacron implants for orbital surgery.

Polyester Fiber

Experimental studies on the biologic behavior of polyester fiber (Mersilene mesh) have been few. It is a polyester similar to Dacron that has been researched extensively. In contrast to nylon and nylon derivatives, polyethylene sutures and polyethylene derivatives have little or no degradation in vivo for years. It can be surmised that Mersilene is equally biocompatible, resilient to infection, and flexible. Satisfactory clinical use of Mersilene mesh has been demonstrated by several authors. For example, McCullough[68] reported satisfactory use in chin and malar augmentation with an infection rate of 8%, which he felt was lowered by antibiotic impregnation. Through autoalloplast implantation technique, he also demonstrated excellent tissue ingrowth and biocompatibility. Several authors have used Mersilene successfully in the nasal dorsum, with an infection rate less than 2%. Quatela and Davis reviewed their experience with Mersilene mesh chin implants in 300 consecutive cases and found that only three implants required removal secondary to infection (personal communication, Quatela VC, Davis K, 1999). Johnson and Toriumi[29] prefer Mersilene mesh for chin augmentation because of its consistency, ease of contouring, and low infection rate. Resorption at 5 years has not been appreciated by the authors.

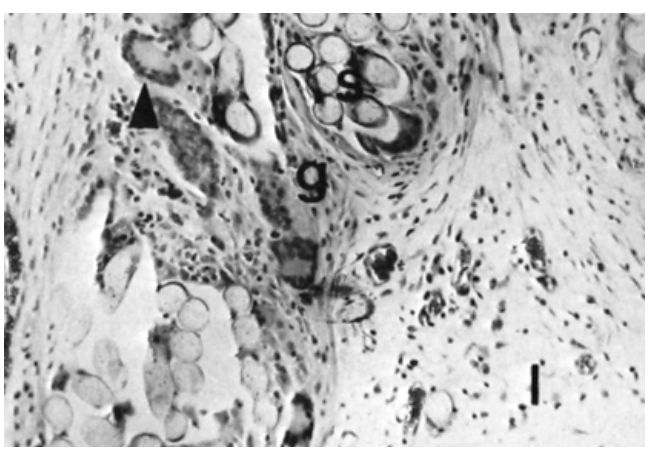


Figure 6–3 Supramid *(S)* surrounded by granulomas *(g)* and foreign body giant cells *(arrow)*. Loose granulation tissue *(l)* is apparent between the strands. (Courtesy of Jeanne S. Adams, MD.)

Polyethylenes

Polyethylenes are polymers consisting of a large number of repeating monomeric units of ehtylenes linked together to form highly branched macromolecules. As a result of the branching, these molecules are loosely oriented and of low density. In the 1940s, Rubin successfully used low-density polyethylenes (molecular weight 20,000) for facial augmentation procedures,[69] finding tolerance in chin and malar areas but a 20% extrusion rate in the nose. He cites a 32-year follow-up on 281 implants with minimal tissue reaction, good implant stability, and lack of carcinogenesis. The major disadvantage of polyethylene was that, as a hard, nonporous implant, it could easily be extruded by trauma or lack of adequate soft tissue coverage.

The need for better fixation and higher tensile strength led to polymerization of high-density polyethylenes (HDPEs). A porous HDPE (Medpor,[70] Porecon,[71]) with pore size 100 to 150 mm, encourages osseous tissue ingrowth with mature bony ingrowth into the surface pores at 1 year (Figs. 6–4 and 6–5).[6,58–59,72–73a] Bikhazi and Antwerp successfully used HDPE subperiosteally in chin and nasal augmentation on a small sample with no extrusion or bony resorption and 100% fixation. Histologic analysis in an HDPE specimen revealed mature fibrous connective tissue ingrowth into pores with minimal foreign-body reaction.[72] Romo et al reported on the use of HDPE in 187 patients undergoing nasal reconstruction. In all patients, implants were placed in the dorsum and columella. In addition, most patients received alar battens. Complications occurred in only 5 of 187 patients. Implant removal was necessary in these cases, although no patient required removal of all implants. Furthermore, no complications occurred with implants placed in the columella where soft tissue coverage is greatest.[73] Kasperbauer et al[24] also demonstrated that porous polyethylene with a pore size greater than 175 mm was invaded by connective tissue and capillaries with minimal cellular infiltration. Porous polyethylene with a 30-mm pore size did not permit tissue ingrowth. The authors' objection was that, when extrusion occurred, it involved extensive skin flap necrosis presumably resulting from the implant's rigidity, stressing the need for adequate soft tissue coverage.

A mesh form of HDPE (Marlex) allows for repair of defects over cavities because fibrous tissue ingrowth extends

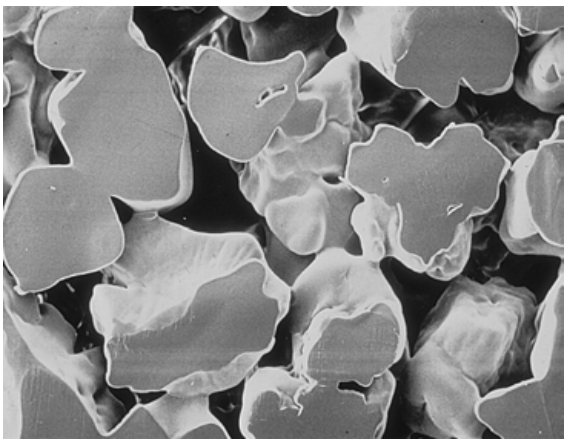


Figure 6–4 Electron microscopic view of porous high-density polyethylene reveals architecture that allows ingrowth of fibrovascular tissue.

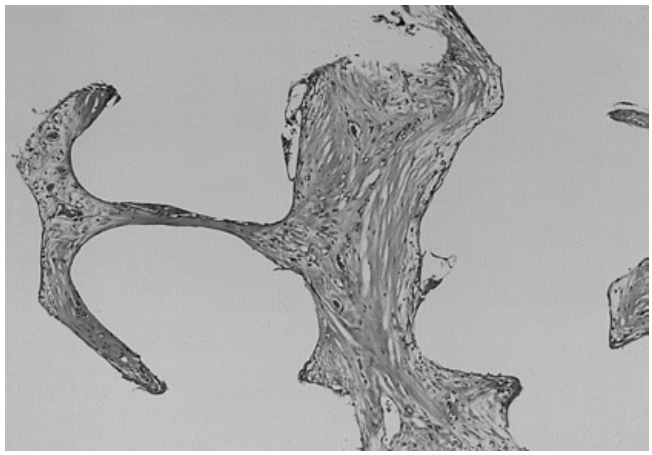


Figure 6–5 Porous high-density polyethylene demonstrating fibrovascular ingrowth (N&E).

throughout mesh. Polypropylene mesh (Prolene) has become popular because it has similar biocompatibility and mechanical properties but can also be autoclaved.

Polytetrafluoroethylenes

As a result of its carbon, fluorine, and oxygen composition, polytetrafluoroethylene's polymers exhibit distinctive chemical and thermal stability. They are generally insoluble and have unique antifrictional properties. In the linear polymer, cross-linking does not occur and, as a result, these have low tensile strength.[11] The stability and extreme inertness of these materials is attributable to the strength of the covalent bonds between the carbon and fluorine elements in the polymer chains. As a linear polymer of lower molecular weight, polytetrafluoroethylene can exist as either a solid (in sheet form) or a paste (Teflon). Clinically, the success of its use as an orbital implant for blowout fractures has been reported by many authors.[74–75] Polytef paste is a suspension of Teflon powder in glycerin. It has some clinical application in treatment of vocal cord paralysis. Its use for soft tissue augmentation has decreased because of foreign-body reactions and technical difficulties associated with injection of the thick paste.

Altering the fluorocarbons so that they are porous and adding short carbon fibers made them more hydrophilic and accepting of tissue ingrowth. The polytetrafluoroethylene-carbon porous implant material Proplast (Porex Surgical Inc. Newman, GA) was one of the first polymers designed for surgical implantation that had undergone rigorous examination for empirical clinical traits. Proplast is a biocompatible implant exhibiting microporosity of 100 to 300 μm and weak mechanical properties. It exhibits a stiff, sponge-like consistency that allows carving at the operating table. Despite initial enthusiasm for the implant, Proplast (specifically Proplast II) has fallen from favor. The history of this material serves as a reminder of the pitfalls inherent in the use of alloplasts.

In 1981, the FDA approval allowed for the alteration of the carbon fibers in Proplast I to aluminum oxide, changing the implant's color to white (Proplast II). This enabled it to be used in more soft tissue applications. Histologically, Proplast initially elicits an intense, giant cell macrophage reaction with stabilization occurring through connective tissue ingrowth, but a characteristic fibrous tissue layer forms at the boundary (Fig. 6–6).[5,11,24,76]

Clinical uses of Proplast confirmed minimal reactivity, thermostability, and adequate tissue fixation. Despite the lack of penetrating tissue ingrowth, overall infection rates were low. Clinical applications included mandibular, nasal, premaxillary, malar, and orbital implants in middle ear ossicular reconstructions and pharyngeal wall implants to correct velopharyngeal insufficiency. By 1985, Proplast II replaced silicone as the implant of choice among oral surgeons who performed temporomandibular joint (TMJ) diskectomy and replacement.[77] By 1987, reports began to appear citing failure rates in the TMJ of up to 50%. Mechanical stress within the TMJ resulted in fragmentation of the implant and persistence of a foreign-body reaction. Failure rates in other anatomic sites were not as common; however, the material was withdrawn from the U.S. market.[78]

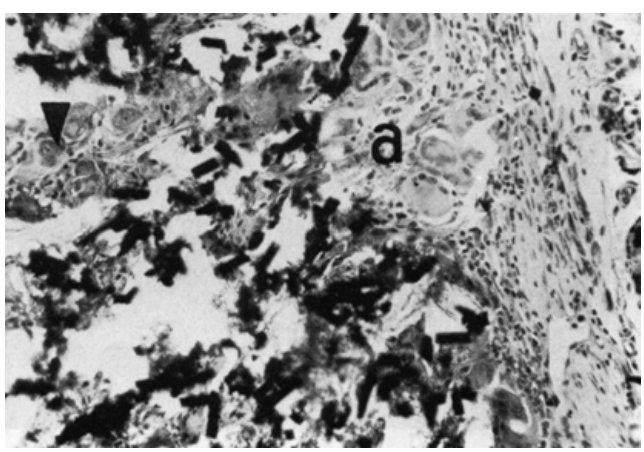


Figure 6–6 Proplast initially elicits an intense, giant-cell macrophage reaction with stabilization occurring through connective tissue ingrowth. However, a fibrous tissue layer forms at the boundary.

Expanded Polytetrafluoroethylene

During the past decade, expanded or fibrillated polytetrafluoroethylene (Gore-Tex) has generated much interest. It is composed of nodules of solid polytetrafluoroethylene interconnected by thin, flexible polytetrafluoroethylene fibrils. Fibrillar length determines the interspacing of the molecules and hence actual pore size and accessibility of tissue regrowth. Gore-Tex has had extensive use in vascular surgery where more than 2 million grafts have been used with excellent biocompatibility. In animal studies, Neel[25,79a] demonstrated that Gore-Tex, with an average internodal space of 30 μm, was anchored by tissue at the surface and penetrated the interstices with minimal cellular reaction (Fig. 6–7). Neel concluded that Gore-Tex with a nominal pore size of 30 μm had better compatibility, consistency, structure, integrity, balance of porosity, and ease of sculpturing and removal than any other implants tested (Silastic, Proplast, Plasti-Pore).[45]

Gore-Tex is now available as a soft tissue patch. It also comes prefabricated for malar and chin augmentation. Schoenrock and Chernoff have placed more than 800 Gore-Tex patches in the face and report a complication rate of less than 1%, with only two implants removed because of infection.[78] Several authors have used the Gore-Tex soft tissue patch for nasal dorsal augmentation with favorable results. [79a] It provides a reasonable alternative to rib cartilage or split calvarial bone. Furthermore, unlike these autogenous grafts, as well as some alloplasts, Gore-Tex does not leave the patient with an unnaturally rigid nose.

Resorbable Polymers

Although not typically considered implants, metal plates and screws are among the most commonly used synthetic materials in the facial skeleton. In most instances, they are well tolerated by the recipient. Nevertheless, theoretic concerns about carcinogenesis and stress shielding, as well as such practical issues as patient dissatisfaction with a palpable mass or interference with magnetic resonance imaging (steel plates) and computed tomography, have prompted clinicians to examine resorbable plates.

In terms of the use of implant materials, permanence is generally a desirable quality. However, when facial fractures are repaired by metal screws and plates, the implants remain in place after the fracture has healed. Gradual dissolution of the material is preferable. Two polymers, poly-L-lactide (PLA) (also known as Dexon) and polyglycolide (PGA), are currently being used in the facial skeleton. Early reports were promising; however, the issue of long-term intermittent swelling has prompted additional work with newer polymers. Polyorthoesters and amino acid polymers, such as polydesaminotyrosyltyrosine hexyl ester (DTH), are two of the more promising materials under investigation.[6]

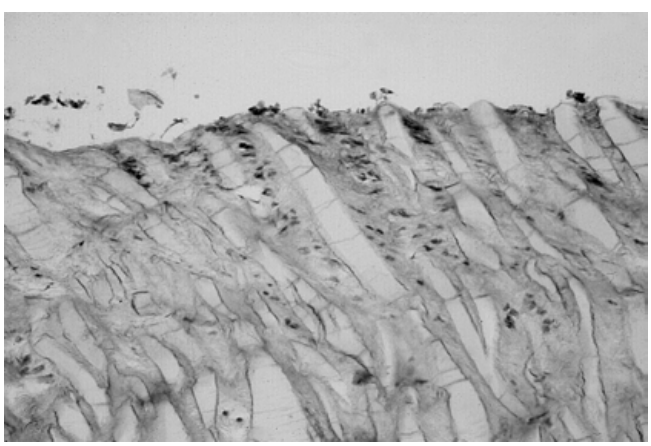


Figure 6–7 Expanded polytetrafluoroethylene shows ingrowth of host tissue and minimal inflammatory response (N&E).

Ceramics

Dentistry popularized ceramics (silicone derivatives) in the early part of this century. In the past 20 years, their value as a surgical implant has been evaluated. Ceramics are characterized by heteropolar bonding of their electrons to other atoms. The fact that more than one type of atom usually exists renders this group ionic in nature, in contrast to metals, which are homopolar and nonionic. Numerous ceramics are available, including aluminum, tricalcium phosphate, carbon fiber (as it is present in Proplast), and hydroxyapatite. Of all of these, hydroxyapatite is of special interest to the head and neck surgeon because of its ability to bond to bone.

Hydroxyapatite

Calcium hydroxyapatite has generated increased interest as an implant because as the synthetic, inorganic constituent of bony tissues it can induce bone growth and bonding. Its uses have included blocks as a bone substitute during genioplasty, alveolar ridge augmentation, and LeFort procedures with stable union and minimal untoward results.[79–81] Although it was initially used in its ceramic form, hydroxyapatite is now available in a nonceramic form. Unlike ceramic hydroxyapatite, which resists absorption, the nonceramic form is capable of undergoing absorption with replacement by bone. Some authors have found that the gradual replacement does not result in a loss of volume or shape. Additionally, mixing of the cement does not produce an exothermic reaction, as is the case with methylmethacrylate.[6]

Tissue Adhesives

The first cyanoacrylate introduced in this country, methyl α-cyanoacrylate (Eastman 910 monome),[82] came from Germany in 1949. The degradation products are formaldehyde and α-cyanoacetate, both of which are extremely toxic.[83] The longer chain derivatives, such as ethyl cyanoacrylate (Crazy Glue) and isobutyl cyanoacrylate (bucrylate), are slightly less toxic[84,85] than Eastman 910. Histoacryl, which is 2-cyanobutylacrylate, has been shown by Toriumi in animal studies to be the least histotoxic and to produce the most enduring bond. Quatela et al (personal communication, 1999) using sulfur-35 autoradiography, have demonstrated that sulfur-35 uptake (a measure of chondroitin sulfate production and viability) was no different in histoacryl cases

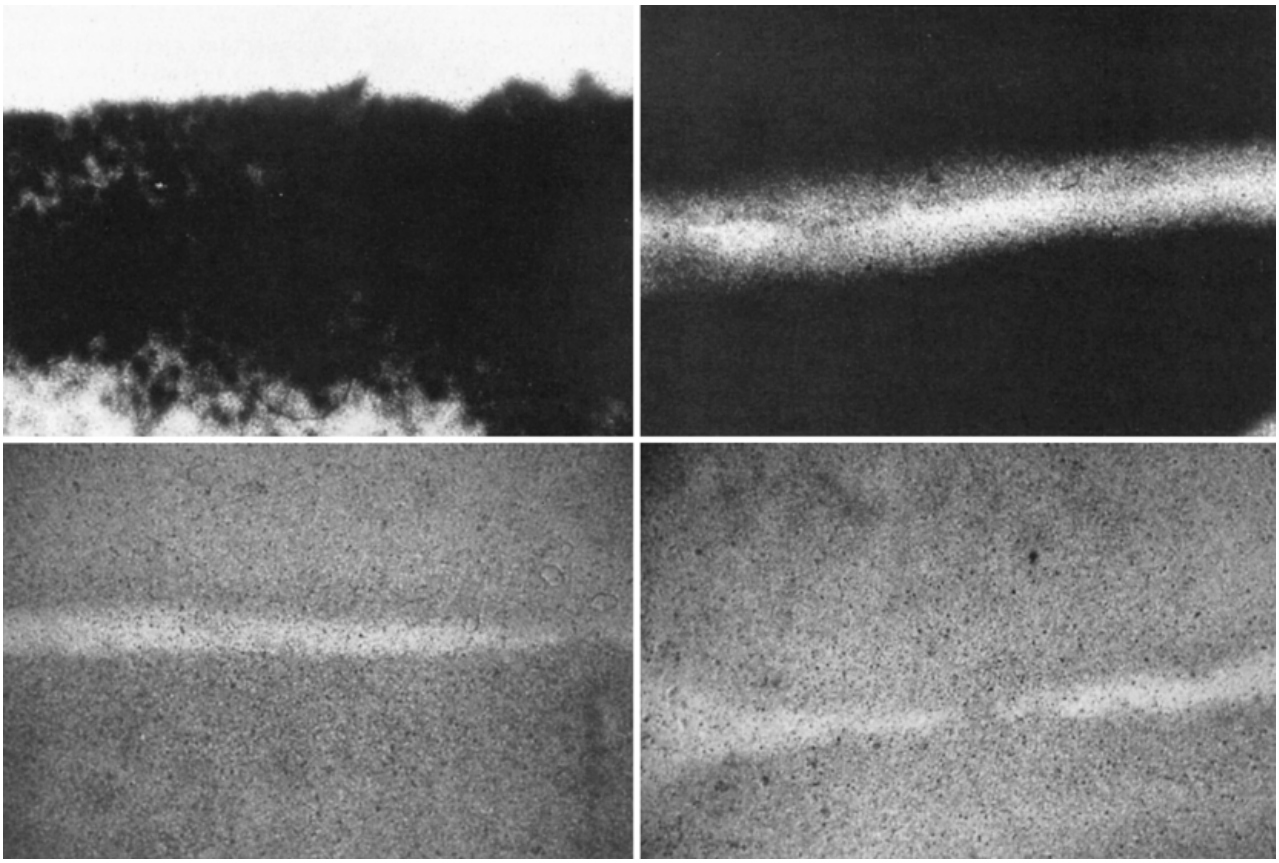


Figure 6–8 **(A)** Sulfur-35 isotope labeling of control cartilage without glue. **(B)** Septal cartilage fragments *(dark areas)*, showing 100% isotope uptake similar to control. Lucent area indicates Histoacryl bond. **(C)** Septal cartilage fragments with bucrylate bond. Uptake of isotope significantly less, indicating more toxicity. **(D)** Septal cartilage fragments with Eastman 910 bond. Uptake of isotope markedly decreased, corresponding to the most toxic cyanoacrylate.

than in control cases, indicating minimal tissue toxicity (Fig. 6–8). Eastman 910, Crazy Glue, and bucrylate all produce a marked decrease in cartilage viability. At this time, histoacryl is the best alternative to suture fixation. It is used safely for middle ear reconstruction, cartilage fixation, and wound closure.[86–87] Fibrin glues are less toxic and can be composed using the patient's own blood, but their ability to form as strong a bond as histoacryl prevents their use in cartilage fixation. Presently, fibrin glues are used for fixation of grafts and flaps. They await further development to enhance their adhesive properties.

SUMMARY

By simply knowing the physical properties of an implant, efficacy cannot be predicted. The global picture, the site of implantation, the long-term clinical trial, the surgical techniques, and the overall biocompatibility of the implant with the tissues must be considered.

Selection of the site of implantation profoundly impacts implant success. Many implants that work successfully in the mental area, such as Silastic and porous polyethylene, have higher extrusion rates in the nose. The long-term clinical trial is vital. As evidenced by historical review, many implants have been retired because they do not endure the test of time; Supramid is an example of this. Meticulous surgical technique is imperative; the correct choice of an implant may still result in failure if strict aseptic techniques are not observed. A determination of biocompatibility is influenced more by overall efficacy than by tissue reaction. Proplast exhibits marked inflammatory reactions histologically, but in clinical trial it is well tolerated and therefore considered biocompatible.

This chapter has discussed qualities of the ideal implant: it should be available, sterile, identical in contour and consistency to the absent tissue, nontoxic, nonallergenic, noncarcinogenic, and resistant to infection. It should be free from alteration by the host or the host's healing properties. It should eventually resorb, without degradation products, having induced the ideal implant for itself that is completely autogenous. At present, however, the ideal implant does not exist. Rather, surgeons are confronted with the challenge of participating in its discovery.

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Chapter 7

Biologic Tissue Implants

Fred J. Stucker, Gary Shaw, and Moshe Ephrat

The adage "everything old is new again" rings particularly true in the use of biologic implants in facial plastic and reconstructive surgery. As early as 1670, Van Meekren employed canine calvarial bone grafts to reconstruct a Russian soldier's skull defect.[1] Since then, an array of biologic materials have been used in reconstructive surgery. Cartilage, dermis, fat, muscle, tendons, fascia, and even sclera have been used for a variety of facial plastic reconstructive purposes. These grafts have been derived from the patient (autologous), cadavers, other humans (homologous), and animals (allograft or xenograft). Surgeons often seek synthetic materials that are accepted by the host in lieu of biologic implants. Although varying degrees of success have been achieved, many suffer from extrusion or other untoward reactions. These experiences prompt a bias toward autologous tissue and, to a lesser degree, homologous materials. This chapter outlines the advantages and disadvantages of a variety of biologic materials, commonly used both as implants (nonbiologic) and grafts (viable). These materials include cartilage, bone, dermis, dermal fat, and free fat.

CARTILAGE

Cartilage possesses a number of characteristics that satisfy the criteria for an ideal graft. It is readily carved but maintains its structural integrity. It is easily harvested from the patient or procured from donor banks and is easily preserved. Surprisingly, although autologous cartilage grafts were first used experimentally by Bert in the 1860s, they were not applied to humans until Koenig used them in 1896 by fashioning a rib for soft tissue augmentation.[2,3]

Classification and Early Controversy

Traditionally, cartilage is characterized according to its location, its function, and the type of fiber present. Thus the terms used in classification are *fibrous*, *articular*, and *elastic hyaline*.[4] However, Gibson points out that, for practical purposes, these categories are of little value because all cartilage contains the precursors to all of the other types, and when transplanted, metaplasia does not occur.[5] Therefore, transplanted cartilage from rib, septum, larynx, and all other sites maintains its respective structure, and each type should be considered individually.

The following three components are present in all cartilage: the chondrocyte, the matrix, and water. The matrix is secreted by the chondrocyte; it is composed of a collagen unique to cartilage and a proteoglycan matrix whose molecular structure permits large amounts of water to be covalently bonded. It is this water layer that allows nutrients to diffuse to the metabolically active chondrocytes. This is critical because cartilage is completely avascular. The matrix also serves to immunologically protect the chondrocyte, which is the more antigenic component of cartilage. Elves has conclusively shown a major histocompatibility group of antigens on this cell.[6] This explains the different findings among investigators. Those who use diced or carved cartilage implants exposed the chondrocytes, thus initiating an immunologic response. Clinically, this would also explain why a number of surgeons found a variable amount of absorption in homologous cartilage grafts.

There are a variety of methods used to preserve nonviable cartilage, including storage in thimerosal, boiling, freezing, formalin fixation, and megavolt radiation. Cartilage for implantation has been harvested from humans, cattle, pigs, and other animals. The main advantages of the nonautologous cartilage are the unlimited supply and the fact that nonviable cartilage does not warp and is supposedly easier to carve than viable cartilage. Most report significant long-term absorption when using preserved cartilage.[7] Notably, the Soviet surgeon, Mikhelson, reported only three cases of absorption in more than 1800 cases using preserved cartilage.[8] His method of preservation consisted of maintaining the harvested human cartilage at a temperature below 6°C and implanting it within 3 months. Subsequent studies have noted that these cooled grafts are most likely still viable at the time of transplant.[9] A report by Schuller et al showed a mere 1.4% absorption rate in irradiated cartilage.[10]

In 1993, Kridel and Konior reported a low level of graft warping with irradiated homograft costal cartilage, which is consistent with other reports.[11] In 1998, Adams et al performed a controlled study that compared the in vitro warping characteristics of irradiated and nonirradiated homograft costal cartilage.[12] Their results demonstrated no significant difference. They also found that the warping continued over time for at least 4 weeks.

Donald and Cole in a 1981 survey of facial plastic surgeons indicated that most surgeons preferred autologous cartilage because of significantly less long-term absorption compared to all types of preserved cartilage except irradiated

cartilage.[13] A subsequent animal study by Donald appears to contradict the claim of irradiated cartilage's longevity.[14] His 3-year follow-ups indicate that none of the implanted irradiated cartilages survived. In addition to the questionable absorption of homologous cartilage, many physicians and patients are concerned with the potential for transmission of pathogenic viruses. Although no case has been reported of a viral disease stemming from transplanted preserved cartilage and it is extremely unlikely that these viruses could survive the various devitalizing techniques, this concern of an anxious public is not likely to diminish. With these considerations, autologous fresh cartilage harvested from the nasal septum, auricular concha, or rib is used by most surgeons for a variety of procedures.

Common Uses of Cartilage Grafts

The most ubiquitous uses of cartilage grafts have been in cosmetic and reconstructive nasal surgery and ear reconstruction. Since rhinoplasty is the most commonly performed aesthetic operation, it is not surprising that it is also the most common application of cartilage grafts. The following specific problems that can be addressed by a cartilage graft were summarized by Ortiz-Monasterio et al: (1) retracted columella and nasal spine, (2) acute nasolabial angle, (3) vertically long upper lip, (4) insufficient anterior projection of nose, (5) bulbous fatty nasal tip, (6) low bridge of dorsal defect, and (7) depressed piriform area.[15] Other nasal uses include effacing or deepening the nasofrontal angle, closing septal perforations, and correcting the nasal valve. There are also numerous uses in African Americans and Asians, as well as in patients with congenitally deformed noses, especially those with cleft lip and palate. The majority of grafts used in rhinoplasty are used for either columellar support or tip augmentation. Dorsal augmentation is also a common use, but we prefer to restrict its application to replacement of structural support or to augmentation of no more than 3 to 4 mm. There are numerous techniques for harvesting and placement of such grafts. The rhinoplastic surgeon routinely harvests the autologous cartilage grafts from the septum. Less commonly, they are obtained from the concha and infrequently from the rib. Principles of utilization include care when handling and carving these grafts and insertion into an adequate but snug pocket. Absolute hemostasis is mandatory. Fixation is usually not necessary unless there is motion or if migration is possible. Migration results when the undermined area is larger than the graft. In these cases, fixation by suture is advocated. Conchal cartilage has been successfully employed in the nasal valve area to provide structural support for collapse of the cartilaginous vault (Fig. 7–1). Rib cartilage is used in auricular reconstruction for microtia and anotia. Use of the seventh and eighth rib, popularized by Tanzer and modified by Brent, is currently considered the gold standard in reconstruction of the auricle.[16,17] Orbital reconstruction and tarsal plate defects are also areas where cartilage grafts are used in facial plastic surgery.

In conclusion, because of its ubiquity of donor sites, high degree of malleability, long-term viability, and resistance to resorption, autologous cartilage is a favored method used by many reconstructive facial plastic surgeons.

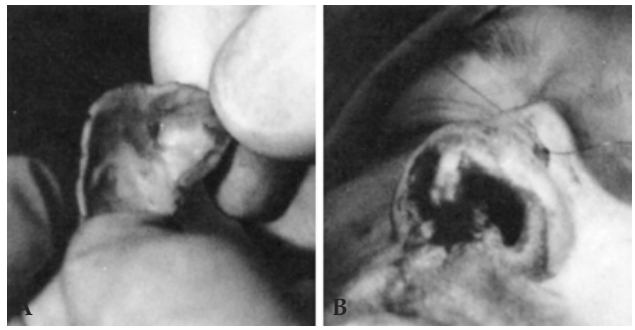

Figure 7–1 **(A)** Conchal cartilage graft fashioned for placement. **(B)** Percutaneous placement of mattress suture for fixation of cartilage graft and obliteration of dead space.

BONE

Classification, Type, and Structure

Bone, like cartilage, should be considered as a viable dynamic tissue. It is composed of cells (osteocytes) that occupy cavities (lacuna) in a dense matrix of condensed collagen and amorphous ground substance (calcium hydroxyapatite). Bone tissue is classified by its origin. Chondral bone is formed by epiphyseal cartilage slowly transforming into bone, and mesenchymal bone (membranous) is formed by the replacement of a preexisting membrane of mesenchyme.

All bone contains two types of tissue. Cortical tissue is the outer-component layer that is penetrated by small vascular canals (Volkmann's canals). It is covered by a two-layer periosteum, an external layer of fibrocytes, and an internal layer of endothelial-like cells. Cancellous tissue is the other type of bone tissue. It forms a trabeculated framework, surrounding the marrow, traversed by haversian canals, and populated by osteoblasts.

The type and structure of bone is important when this tissue is used as a graft. Until recently, bone grafts were handled cavalierly, the same way a cabinet maker would handle wood. Historically, Ollier, a contemporary of Claude Bernard, was the first to demonstrate the importance of periosteum in new bone growth.[18] In 1914, Phemister was the first to note that split-graft survival rates were better than intact-bone survival rates when autotransplanted.[19] Robertson and Baron confirmed the superior osteogenic potential of cancellous bone and introduced the custom of drilling holes into grafts to expose cancellous bone and packing cancellous chips around the transplanted grafts.[20]

The steps involved in the assimilation of transplanted bone grafts were delineated in 1960. The first step is vascularization of the graft from the host vessels along the graft's haversian system. Demineralization of the graft takes approximately 6 months, followed by a healing period of approximately 16 months. The bone graft is slowly recalcified and resumes the original donor osteon structure during the healing period. In addition, it had been found that membranous bone (i.e., calvarial) is revascularized twice as fast as endochondral bone. Experimental studies confirmed 90% mainte-

nance of membranous bone compared with approximately 50% of endochondral bone.[21] Like cartilage, bone was once thought to be immunologically protected. In fact, this is not so, but the majority of antigenic sites are in the marrow and attached to soluble proteins. These can be reduced by a number of preservation techniques, thus allowing the use of homografts and xenografts. These preserved grafts should really be called implants because their nature requires nonviability, and they function as a scaffold. Even with good autolysis, osteogenesis will not occur in cancellous bone unless the host bed is well vascularized, adequately immobilized, and in apposition to viable host bone.

Primary Uses of Bone Grafts

The primary uses of bone grafts by the facial plastic and reconstructive surgeon have been for mandibular reconstruction, repair of traumatic midfacial defects, orthognathic surgery, and craniofacial surgery. More recently, particularly in terms of calvarial grafts, cosmetic and rhinoplastic applications have increased. Historically, the inner table iliac crest, the tibia, and rib grafts are common donor sites. More recently, calvarial bone grafts have been used because of harvesting ease and significantly less donor morbidity when compared with more traditional sources.

Grafts can be both free and vascularized. Vascularized bone grafts may be pedicled (e.g., pectoralis major with rib, temporalis with outer table calvarium, or trapezius with scapular spine) or be a free microvascularized graft (e.g., iliac crest osteomyocutaneous graft).

In addition to mandibular reconstruction, we regularly use bone grafts in areas of posttraumatic deficits where soft tissue grafts are not appropriate. This includes the orbit, forehead, zygoma, and total and partial nasal reconstruction where all or significant bony support is lost (Fig. 7–2). Craniofacial surgeons regularly use bone grafts to correct cranial and orbital synostoses, as in Treacher–Collins syndrome. We frequently fix grafts to neighboring solid bones using mini-compression plates or lag screws (Fig. 7–3). External appliances or intermaxillary fixation are not necessary when plating is used. In total nasal reconstruction the bone graft can be doweled into the frontal bone and sinus and the flap draped over the newly constructed periosteal covered bony framework (Fig. 7–4).

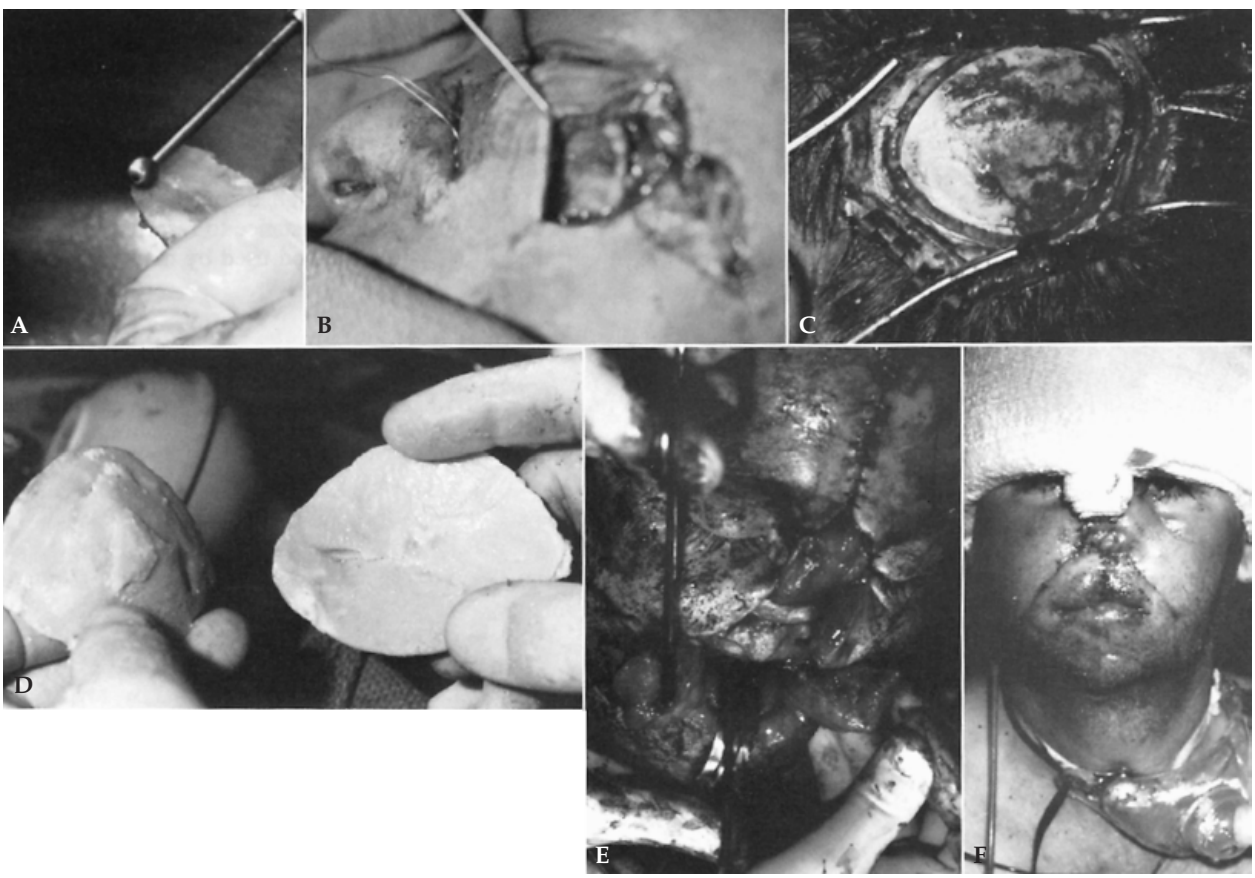

Figure 7–2 **(A)** Shaping iliac bone graft with a drill. **(B)** Iliac bone graft to augment infraorbital deficit. **(C)** Periphery of calvarial bone graft drilled. **(D)** Inner and outer tables separated. One closes the skull defect, and the other serves as the graft. **(E)** Calvarial bone graft used for premaxillary replacement. **(F)** Calvarium replacing and stabilizing loss of entire midline bony structures.

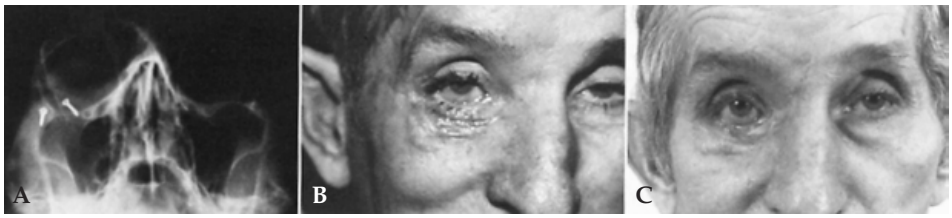

Figure 7–3 **(A)** One-year postoperative x-ray demonstrating fixation of infraorbital bone graft with lag screws. **(B)** Postoperative view of infraorbital rim reconstructed with bone graft and covered with perichondrial cutaneous graft. **(C)** Six months after graft has been placed.

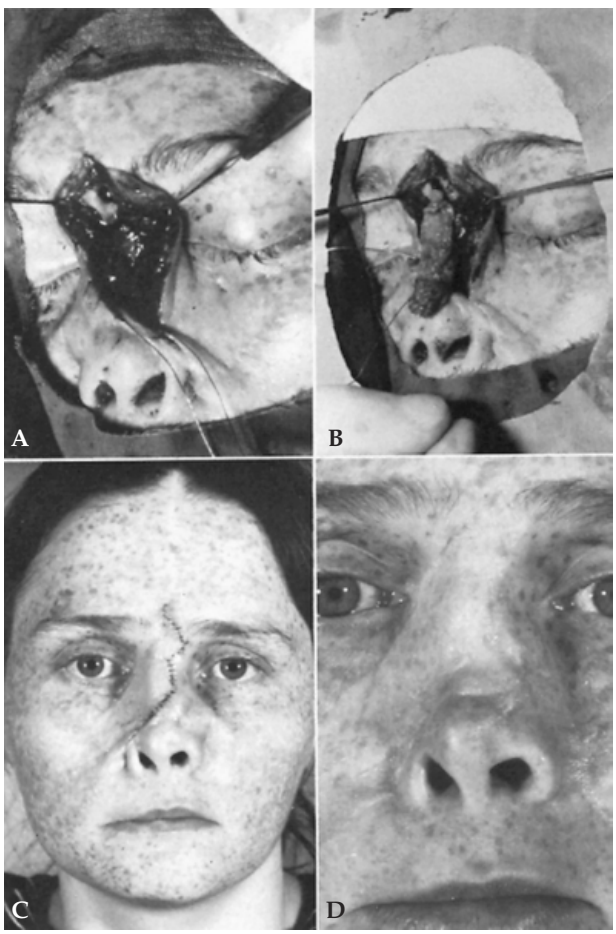

Figure 7–4 **(A)** Hole drilled in frontal sinus as recipient for dowel end of bone graft. **(B)** Periosteal covered iliac bone graft with dowel fitted into hole. **(C)** Five days after surgery. **(D)** Two years after surgery.

Dermis and Dermal Fat

Soft tissue deficits and asymmetry are reconstructive deformities often seen by the facial plastic surgeon. When these defects are subcutaneous in nature, pliable autologous soft tissue is desirable for augmentation. Before 1914, surgeons utilized buried skin grafts for augmentation. These were complicated by the presence of epithelial cyst formation and chronic inflammation and infection. In 1914, Lexer was the first to use dermis to augment facial contours.[22] In addition, dermal fat grafts have been used in a variety of procedures, including tendon repair, hernia repair, mandibular ankylosis, closure of dural defects, great-vessel protection, and intraoral and oral pharyngeal cavity reconstruction. Dermal fat grafts were originally used in breast reconstruction and have since been applied to a variety of soft tissue deficit repairs, including hemifacial atrophy, gun-shot trauma, and radical parotidectomy.

In 1950, Peer demonstrated that dermal fat grafts had significantly less resorption than free-fat grafts.[23] In spite of this, up to 80% were resorbed. Longacre used dermal fat flaps pedicled with a local blood supply for breast reconstruction, and Neumann used them for hemifacial atrophy reconstruction.[24,25] They postulated that the pedicled blood supply would allow for even less resorption. More recently, transfer of dermal fat flaps with microvascular reanastomosis has been performed.[26] We have also described the use of island pedicled flaps, particularly in relatively small areas of deficiency such as the inferior orbital sulcus.[27] The early concerns of many surgeons centered on epidermoid cyst formation.

The classic technique of obtaining free dermal and dermal fat grafts has been well described. Essentially, a split-thickness skin graft (0.14 to 0.16 in.) is lifted with a dermatome. The graft should be harvested in an area of relatively thick but hairless skin (i.e., buttock or thigh). If a dermal graft is also desired, a second pass is performed with the dermatome at approximately the same thickness. A dermal fat graft is harvested using the knife, taking care to keep the fat attached to the dermis. It is important not to traumatize this tissue. Deepithelialization of skin may also be performed using the CO_2 laser. This technique is especially helpful when island or pedicled flaps are used. The hand-held CO_2 laser is set at 10 W power using the 1-mm spot size. The area to be deepithelialized is systematically lasered by using the hand piece held far enough away to slightly defocus the beam. When the circumscribed area has been covered with the laser, it is wiped or debrided of the vaporized epidermal cell layers with a wet sponge. Often two or three passes with the laser are necessary to adequately deepithelialize the tissue. This is detected by a notable white color and tissue contracture (Fig. 7–5). Care must be taken not to go deeper with the laser as this could potentially lead to permanent scarring. We have laser-deepithelialized many grafts and flaps, including pedicled fat grafts, and have found this technique to be reliable and expeditious, with limited long-term resorption.

FREE AUTOLOGOUS FAT

Autologous fat transplantation has been performed for more than a century in the correction of facial defects. It was popularized in Europe by Czerny and Lexer in the 1890s.[28,29]

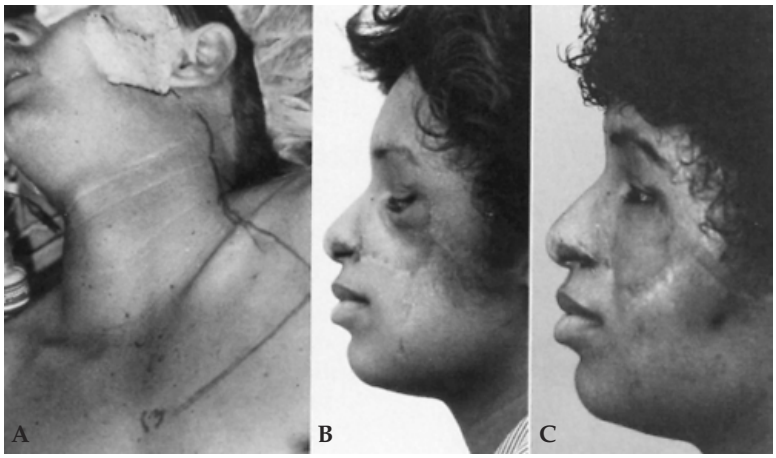

Figure 7–5 **(A)** Laser deepithelialized split-thickness skin graft, allowing its burial beneath a rotating flap. **(B)** Preoperative photograph. **(C)** Postoperative placement of dermal graft from back to malar region.

It gained early and widespread acceptance in the early twentieth century. However, many surgeons are disappointed by the inordinate and relentless rate of resorption, reported to be from 30 to 100%.[30] Because of the increased reliability of dermal fat and the advent of collagen and synthetic silicone, free-fat augmentation was a neglected technique until recently. Despite Peer's elegant study in the 1930s, this demonstrated that transplanted fat does indeed survive indigenously and with its own blood supply. The popularity and interest in free-fat grafts has resurfaced recently. In 1984, Illouz described the use of fat extracted from liposuction surgery and transplanted via injection to correct skin defects.[31] This provided the surgeon with an abundant supply of viable adipose tissue that could be used to augment soft-tissue deformities. Many others have since used this technique with success, incorporating several refinements. One refinement involves centrifuging to separate fat from serum and blood, thus reducing the inflammation and hopefully decreasing the amount of resorption.[32] Exposing the fat cells to an insulin-rich solution also reduces resorption because insulin is an antilipolytic agent.[33,34] This works in vitro but has not proved successful clinically. Another approach used only type I (i.e., genetic fat) cells. These cells have a high concentration of antilipolytic receptors (αI) and are therefore less likely to be resorbed. Anatomically, they are found in the abdominal and trochanteric regions. Conversely, adipose tissue in the face, arms, and upper torso has a high concentration of lipolytic (βII) receptors and is therefore a poor harvest site for fat transplantation.[35]

ACELLULAR DERMAL GRAFTS

Alloderm (Lifecell Corporation, Woodlands, TX) was designed as a dermal replacement. A process that entails removal of the entire epidermis and all of the dermal cells is used on cadaveric human skin. The acellular dermis is then freeze-dried without damaging the extracellular matrix proteins. Immunohistochemical staining confirms the absence of antigens that induce rejection. This graft has been shown to integrate with the surrounding tissue both histologically and immunologically.[36]

The advantage of this material is that because the body recognizes it as an "autograft," it becomes remodeled in the body and avoids donor site morbidity associated with harvest of autogenous tissue. As the use of these types of grafts has become more popular, the concern over transmission of viral diseases has been raised. The cadaveric skin used in these grafts has been screened in accordance with the U.S. Food and Drug Administration's protocol on human tissue. The tissue banks used follow the appropriate protocol for donor blood testing and social screening. In addition, the process removes all cellular components, and the graft is treated with an antiviral agent that has been proved to inactivate concentrated human immunodeficiency virus. There have been no reported cases of viral transmission in any patient thus far.[37]

This material has been used in the treatment of cutaneous burns. Cosmetic and reconstructive applications include nasal dorsal augmentation, lip augmentation, facial soft tissue filling, scar revision, and nasal septal perforation repair.[37,38]

A LOOK AHEAD

New cell culture techniques have made possible the in vitro creation of cartilage. The methodology involves the use of single cells rather than whole tissue for transplantation. In the liver, hepatocytes are used to support liver function. The possibility of cartilage transplantation in a similar manner may develop with increasing knowledge of chondrocyte differentiation.

Chondrocytes have been isolated from human tissue (i.e., septum) and have been transferred to a biodegradable scaffold (i.e., polyglycolic acid) in vitro. After one week, these were transferred to subcutaneous tissue of nude mice. Histologic analyses after up to 24 weeks revealed growth of both type I and II collagen as well as vascular ingrowth. This method may become ideal for cartilage replacement in large defects.[39]

Autologous dermis and collagen implants may also be used in injectable form. Patients undergoing cosmetic surgery may now have their excised skin sent to a tissue bank for future use. When the need arises this tissue may be used in the form of injectable autologous collagen implant material (Dermalogen, Collagenesis Inc., Beverly, MA). This may be used for soft tissue augmentation in the nasolabial fold, perioral rhytids, and vermilion augmentation. Future clinical studies will determine if the use of human autologous collagen injection results in a sustained clinical improvement due to decreased collagen degradation when compared with bovine collagen.

SUMMARY

Repair of facial defects has long been a goal of the facial plastic surgeon. Many biologic and synthetic materials have been used. No perfect material has been found for all types of defects. Because of this, it behooves the surgeon to be familiar with a number of reconstructive methods and techniques. We regularly use a variety of biologic and synthetic materials successfully. Nevertheless, we and many others continue to search for more suitable materials.

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Chapter 8

Lasers in Facial Plastic Surgery

William Russell Ries and Eric S. Powitzky

Around the turn of the century, Einstein theorized the processes that must take place for a laser to radiate energy in a publication titled "The quantum theory of radiation."[1] The first laser was built in 1960 by Maiman.[2] Since then, there has been an explosion of laser technology development leading to a great diversity of lasers that encompasses the entire electromagnetic spectrum. Increasingly, lasers are being coupled to other technologies, including imaging systems, robotics, and computers, to improve delivery of the laser to its target. Through the marriage of the fields of physics and bioengineering, medical lasers have become an important part of the armamentarium of surgeons for the treatment of disease. Initially, these lasers were cumbersome to use and were utilized by surgeons who had been specially trained in the physics of lasers. In the past 15 years, medical laser design has evolved toward ease of use, and many surgeons are taught the fundamentals of laser physics during residency or through continuing medical education programs.

In this chapter, laser biophysics, laser–tissue interactions, lasers currently used in facial plastic and reconstructive surgery, general laser safety precautions, and future considerations in the field of cutaneous laser surgery are discussed.

LASER BIOPHYSICS

Lasers emit light energy that travels in a wave form, which is true of any ordinary light (Fig. 8–1). The wavelength is the distance between two successive peaks of a wave. The amplitude is the height of the peak and is related to the intensity of the light. Frequency, or the period of the light wave, is the time required for one full wave cycle. To understand how a laser functions, it is important to review quantum mechanics. The term *laser* is an acronym that stands for *l*ight *a*mplification by *s*timulated *e*mission of *r*adiation. If a photon, a unit of light energy, strikes an atom, it will raise one of its electrons to a higher energy level. The atom in this excited state is unstable and will re-emit a photon as the electron drops to its original lower energy level. This is a process known as *spontaneous emission* (Fig. 8–2A). If an atom is in a high-energy state and is struck by another photon, it will emit two photons that have the same wavelength, direction, and phase when the electrons revert to lower energy levels. This process is known as *stimulated emission* of radiation and is the underlying principle of laser physics (Fig. 8–2B).

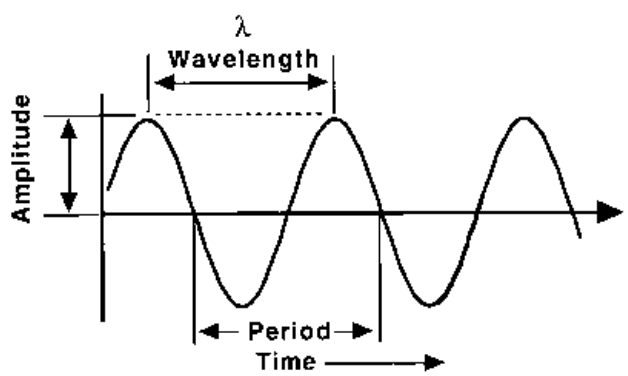

Figure 8–1 Wave properties of light.

Regardless of type, all lasers contain four main components: an excitation mechanism or power source, a laser medium, an optical cavity or resonator, and a delivery system (Fig. 8–3). Most clinical lasers used in facial plastic surgery use an electrical excitation mechanism. Some lasers (e.g., flashlamp-excited dye laser) use light as an excitation mechanism. Others may use high-energy radio frequency waves, and still others may use chemical reactions to provide the energy for excitation. The excitation mechanism pumps energy into the resonating chamber that contains a laser medium, which may be a solid, liquid, gas, or semiconductive material. The energy dumped into the resonating chamber elevates electrons of the laser medium atoms to a higher energy state. When half of the atoms in the resonating chamber have reached this highly excited state, a population inversion has occurred. Spontaneous emission occurs, with photons radiating in all directions and some striking atoms in an already excited state, leading to stimulated emission of paired photons. Amplification of stimulated emission takes place as the photons that travel along the axis between the mirrors are preferentially reflected back and forth between the mirrors. This leads to further stimulation as these photons strike other excited atoms. One mirror is 100% reflective and the other is partially transmissive, allowing radiant energy to escape from the resonating chamber. This energy is transmitted to the intended tissues by a delivery system. Most lasers have a fiberoptic delivery system. A notable exception is the carbon dioxide (CO_2) laser, which has mirrors in an articulated arm system. Waveguides for use with the CO_2 laser are available, but they limit the spot size and power output.

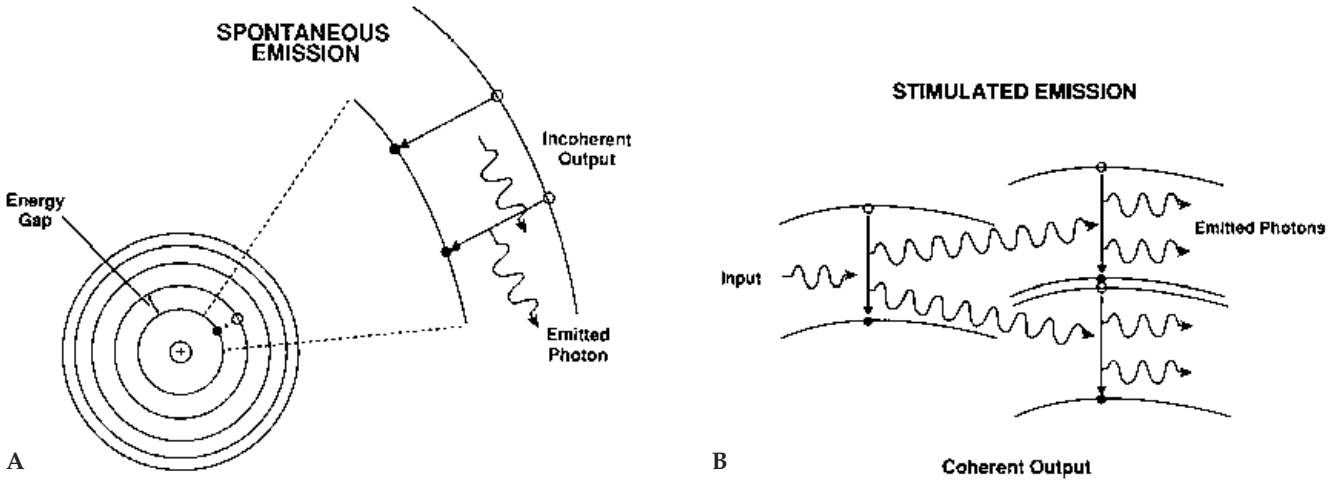

Figure 8–2 **(A)** Spontaneous emission. **(B)** Stimulated emission.

Laser light, when compared with ordinary light, is more organized and intense in its qualities. Because the lasing medium is one kind of molecule or atom, the photons emitted by the stimulated emission are of one wavelength, thus creating the quality of monochromaticity. Ordinary light diverges widely when emitted from a source. Laser light is collimated; thus it diverges little as it travels, giving laser energy its persistent intensity over long distances. Not only do photons of laser light move in the same direction, but they are also in the same temporal and spatial phase. This is called *coherence*. These properties of monochromaticity, collimation, and coherence differentiate laser light from the disorganized energy of ordinary light (Fig. 8–4).

LASER–TISSUE INTERACTION

There is a spectrum of effects that a laser can have on biologic tissue, from modulation of biologic function to vaporization (Fig. 8–5). Most of the laser–tissue interactions currently clinically available use the thermal effects of lasers to coagulate or vaporize. In the future, lasers may be used in a nonthermal capacity as probes to control cellular function without cytotoxic side effects.

The effect that a particular laser has on a specific tissue depends on the following three factors: tissue absorption, laser wavelength, and laser energy density. As a laser beam impacts tissue, its energy may be absorbed, reflected, transmitted, or scattered (Fig. 8–6). In any laser–tissue interaction, all four processes occur in varying degrees, with absorption being the most important. The extent of absorption depends on the chromophore content of a tissue. Chromophores are substances that absorb a particular wavelength efficiently. For example, CO_2, laser energy is absorbed by soft tissues of

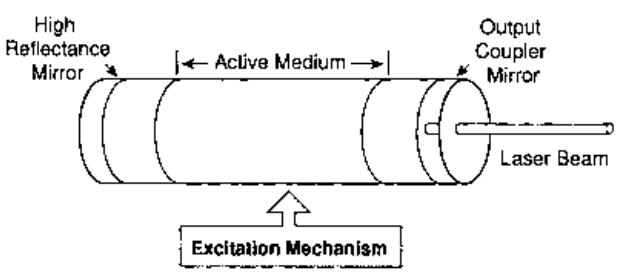

Figure 8–3 Laser components.

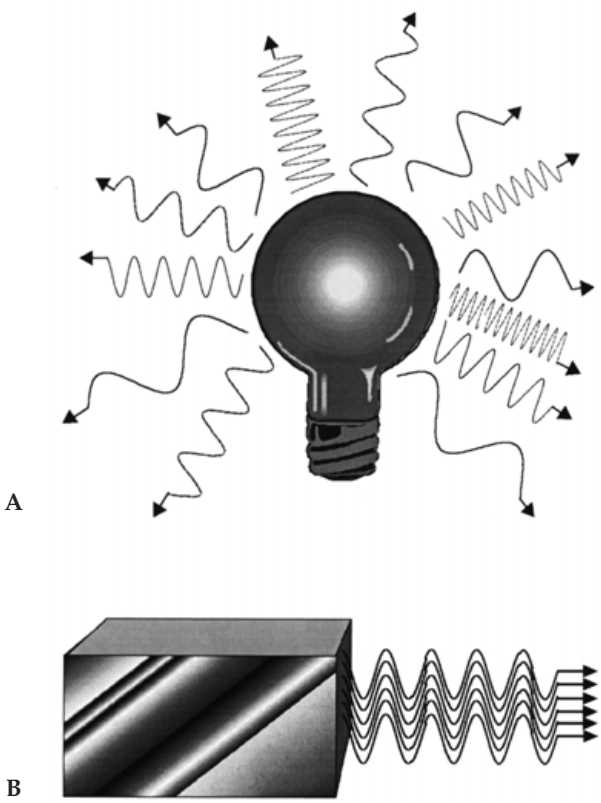

Figure 8–4 **(A)** Ordinary light. **(B)** Characteristics of laser light: collimated, monochromatic, coherent.

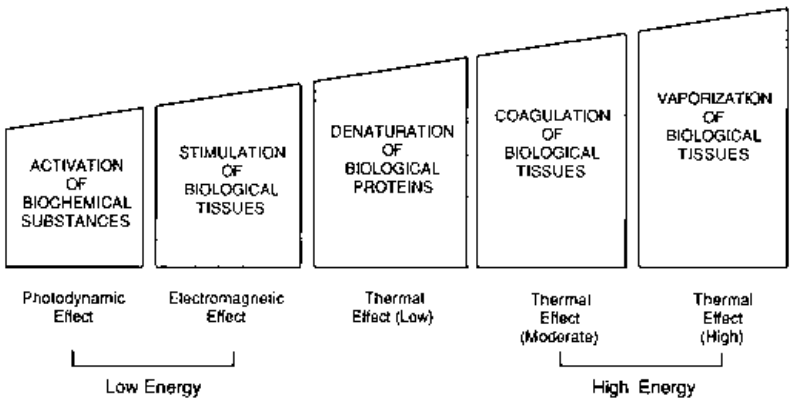

Figure 8–5 Spectrum of biologic laser effects.

the body. This is due to the CO_2 wavelength being well absorbed by water molecules that make up 80% of soft tissues. In contrast, the CO_2 laser is minimally absorbed by bone. This is due to the low water content of osseous tissue. Initially, as a tissue absorbs laser energy, its molecules begin to vibrate. Absorption of additional energy causes protein denaturation, coagulation, and, finally, vaporization.

When tissue reflects laser energy, the tissue is unaffected because energy is deflected at the surface. Similarly, if laser energy is transmitted through overlying tissues to a deeper layer, the intervening tissue is unaffected. If a laser beam is scattered within tissue, the energy is not absorbed at the surface but is dispersed in deeper layers in a random fashion.

The third factor affecting laser–tissue interaction is energy density. Energy density is equal to the power density of the incident beam multiplied by the time for which the tissue is exposed. Power density is the power expressed in watts divided by the cross-sectional area of the laser beam (spot size).

$$\text{Energy density} = \text{power density} \times \text{time}$$

$$\text{Power Density} = \frac{\text{power (W)}}{\text{Cross-sectional area of laser beam (spot size)}}$$

In a laser–tissue interaction, with all other factors held constant, varying the spot size or the time of exposure can alter the tissue effects. As the spot size of a laser beam decreases, the amount of power reaching a particular volume of tissue increases. Conversely, as the spot size increases, the energy density of a laser beam decreases. To change the spot size, the delivery system can be focused, prefocused, or defocused on the tissue. With both the prefocused and defocused beams the spot size is larger than the focused beam, leading to less power density.

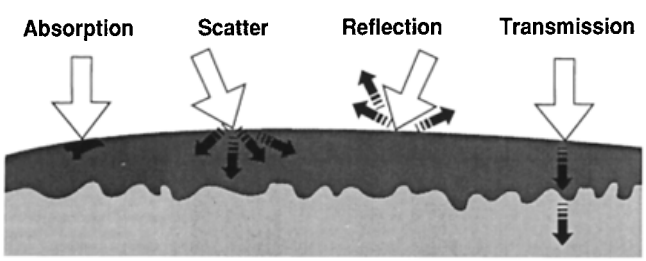

Figure 8–6 Possible interactions of laser at tissue surface.

Another method of varying tissue effects is pulsing of laser energy. All pulsed modes of irradiation alternate periods of power on with periods of power off (Fig. 8–7). Because energy is not reaching tissue during the off periods, heat is allowed to dissipate during those intervals. If the off periods are longer than the thermal relaxation time of the targeted tissue, there is less chance of damaging the surrounding tissue by heat conduction. The thermal relaxation time is the amount of time required for an object to dissipate one-half of its heat. The ratio of the on interval to the on-plus-off intervals is termed *duty cycle.*

$$\text{Duty cycle} = \frac{\text{on}}{\text{on} + \text{off}}$$

There are a variety of pulsed modes available. Energy can be pulsed by setting the time that the laser is on (i.e., 0.1 second). The energy can be shuttered, in which case the continuous wave is blocked for specified intervals by a mechanical shutter.[3] In a superpulse mode the energy is not simply blocked but is stored within the power supply of the laser during the off interval and then released during the on interval. Thus, the peak energy of the superpulse mode greatly exceeds that of the continuous or shuttered modes.

In a Q-switched laser the energy is also stored during the off time, but it is stored in the laser medium. This is accomplished by a shutter mechanism in the resonating chamber between the two mirrors. The shutter in the closed position prevents lasing but allows energy to be stored on either side of the shutter. When the shutter is in the open position the mirrors interact, causing the emission of a highly energized laser beam. The peak energy of a Q-switched laser is extremely high with a short duty cycle. A mode-locked laser is similar to a Q-switched laser in that a shutter exists between the two mirrors of the resonating chamber. The mode-locked laser opens and closes its shutter, synchronized with the time required for light to reflect between the two mirrors.

LASER CHARACTERISTICS

CO_2 Laser

The CO_2 laser is the most commonly used laser in otolaryngology/head and neck surgery. Its wavelength is 10,600 nm, an invisible wavelength that is in the far-infrared (far-IR)

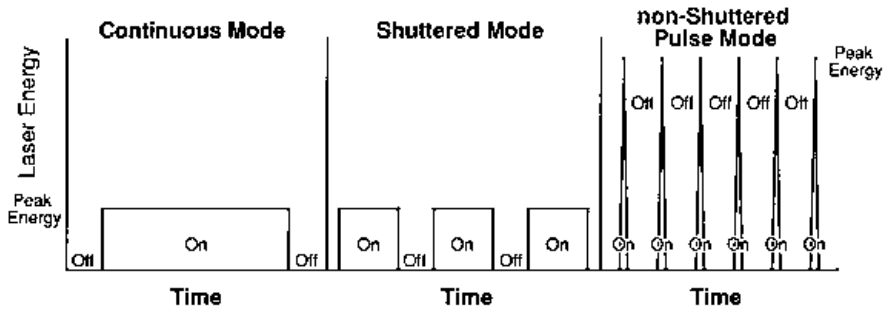

Figure 8–7 Continuous versus pulsed modes.

range of electromagnetic radiation (Fig. 8–8). A helium–neon laser aiming beam is necessary to allow the surgeon to visualize the intended area of impact. The laser medium is CO_2 gas. This wavelength is well absorbed by water molecules in tissue. Its effects are superficial because of high absorption and minimal scatter. Currently, it can be delivered only through mirrors and specialized lenses placed in an articulated arm. The articulated arm may be attached to a microscope to allow for microscopic vision and precision. The energy may also be delivered through a focusing handpiece attached to the articulated arm.

Nd:YAG Laser

The Nd:YAG laser's wavelength is 1064 nm, in the near-IR spectral region. This is not visible to the human eye and requires a helium–neon aiming beam. The laser medium is neodymium:yttrium aluminum garnet. Most tissues in the body do not absorb this wavelength well. However, pigmented tissue absorbs it better than nonpigmented tissue. It is transmitted through the superficial layers of most tissues and is scattered into the deeper layers.

Compared with the CO_2 laser, the scatter of the Nd:YAG is considerably greater. Therefore, the depth of penetration is greater and the Nd:YAG is well suited for coagulating deeper vessels. Experimentally, the depth of maximum coagulation is about 3 mm (coagulation temperature 60°C).[4,5] Apfelberg et al[6] report good results in treatment of perioral deep capillary and cavernous lesions with the Nd:YAG laser. Others report successful laser photocoagulation of hemangiomas, lymphangiomas, and arteriovenous malformations.[7–9] The increased depth of penetration and nonselective destruction, however, also predispose a patient to increased postoperative scarring. Clinically, this is minimized by conservative power settings, a pointillistic approach to the lesion, and avoidance of treatment in areas of thin skin. The use of the Nd:YAG in port-wine stains has been virtually replaced by the yellow-wavelength lasers. However, it is useful as an adjuvant laser in cases of nodular port-wine stains.[10]

In both fibroblast cultures and in normal skin in vivo, the Nd:YAG laser has been shown to suppress collagen production.[4] This suggests an advantage of this laser in the treatment of hypertrophic scars and keloids.[4] Clinically, however, the recurrence rate in keloid excision is high unless vigorous local steroid treatment is used adjunctively.[5]

Contact-Tip Nd:YAG Laser

The use of the Nd:YAG laser in the contact mode drastically alters the physics and absorption properties of the laser. The contact tip consists of a sapphire or quartz tip that attaches to the end of the laser fiber. The contact tip is directly applied to tissue and functions as a thermal scalpel to cut and coagulate simultaneously. A wide range of soft tissue surgery using the contact-tip laser has been reported. Its applications are closer to that of an electrocautery unit than to the noncontact mode of the Nd:YAG. In essence, the surgeon is no longer using the original laser wavelength to cut tissue but rather to heat the tip.

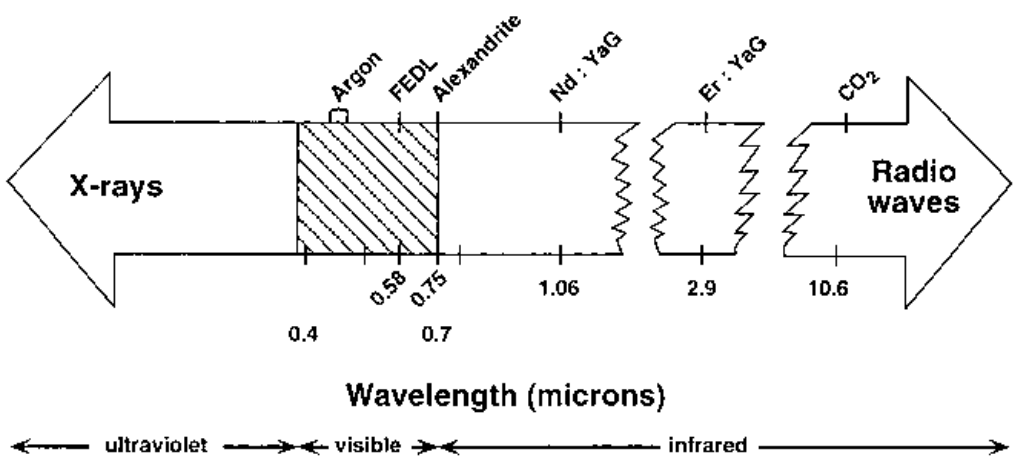

Figure 8–8 Electromagnetic spectrum.

Therefore, the principles of laser–tissue interaction do not apply. The response time of the contact-tip laser is not immediate like the free fiber, and therefore there is a lag time for heating up and cooling down. With experience, however, this laser is useful for raising cutaneous and muscular flaps.

Argon Laser

The argon laser is a visible-wavelength laser that has a range from 488 to 514 nm. Because of the makeup of the resonating chamber and the molecular structure of the lasing medium, a band of wavelengths is produced by this type of laser. A particular model may contain a filter that limits the output to a single wavelength. Argon laser energy is well absorbed by hemoglobin, and its scattering effect is intermediate between the CO_2 and the Nd:YAG lasers. The delivery system for the argon laser is a fiberoptic carrier. Because of the high absorption in hemoglobin, vascular lesions of the skin absorb argon laser energy.

KTP Laser

The KTP (potassium titanyl phosphate) laser is an Nd:YAG laser whose frequency is doubled (wavelength halved) by passing the laser energy through the KTP crystal. This results in a green light (wavelength 532 nm) that corresponds to an absorption peak of hemoglobin. Its tissue penetration and scatter is similar to that of the argon laser. The laser energy is delivered by a fiber. In the noncontact mode the laser vaporizes and coagulates. In the semicontact mode the tip of the fiber barely touches the tissue as it becomes a cutting instrument. The higher the energy setting used, the more the laser behaves like a hot knife, analogous to the CO_2 laser. Lower energy settings are used primarily to coagulate.

Flashlamp-Excited Dye Laser

The flashlamp-excited dye laser (FEDL) was the first medical laser designed specifically to treat benign vascular cutaneous lesions. It is a visible-light laser with a wavelength of 585 nm. This wavelength closely coincides with the third absorption peak of oxyhemoglobin, and therefore the laser energy from the FEDL is preferentially absorbed by hemoglobin. In the 577- to 585-nm range there is also less absorption by competing chromophores, such as melanin, and less scatter of the laser energy in the dermis and epidermis.

The laser medium is a rhodamine dye that is excited optically by a flashlamp, and the delivery system is a fiberoptic carrier. The handpiece of the FEDL has an interchangeable lens system that allows the use of 3-, 5-, 7-, or 10-mm spot size. The laser is pulsed at 450 milliseconds. This pulse width was chosen based on the thermal relaxation time of ectatic vessels found within benign vascular cutaneous lesions.

Copper Vapor Laser

The copper vapor laser is a visible-wavelength laser that produces two separate wavelengths: a pulsed green wavelength at 511 nm and a pulsed yellow light at 578 nm. The laser medium is copper that is excited (vaporized) electrically. A fiberoptic system delivers the energy to a handpiece that has variable spot sizes ranging from 150 to 1000 μm. The exposure time is variable from 0.075 second to continuous operation. The time between pulses is also variable from 0.1 to 0.8 second. The yellow light of the copper vapor laser is used in treating benign vascular lesions of the face. The green wavelength may be used to treat pigmented lesions, such as freckles, nevi, and keratoses.

Continuous Yellow Dye Laser

The continuous-wave yellow dye laser is a visible-wavelength laser that produces yellow light at 577 nm. Like the flashlamp-excited dye laser, it is tunable by changing the dye within the activation chamber of the laser. An argon laser excites the dye. The delivery system for this laser is also a fiberoptic cable that may be focused to various spot sizes. The laser light may be pulsed by mechanical shutters or a Hexascanner handpiece can be used at the end of the fiberoptic system. The Hexascanner places the pulses of laser energy in a random pattern within a hexagonal outline. Like the FEDL and the copper vapor laser, the continuous-wave yellow dye laser is ideally suited for treating benign vascular lesions of the face.

Erbium Laser

The erbium:YAG laser takes advantage of the 3000-nm band of the water absorption spectrum. Its wavelength, 2940 nm, corresponds to this peak and results in strong tissue water absorption (about 12 times that of the CO_2 laser). This laser, in the near-IR spectrum, is invisible and must be used with a visible aiming beam. The laser is a flashlamp-pumped laser macropulsed with pulse width ranges from 200 to 300 microseconds, which themselves are composed of trains of micropulses. These lasers are used with a handpiece attached to an articulated arm. Scanners can also be incorporated into the system, allowing for more rapid and even removal of tissue.

Ruby Laser

The ruby laser is a flashlamp-pumped laser emitting light at 694 nm. This laser, located in the red region of the spectrum, is visible. It can be Q-switched to achieve short pulse widths and deep tissue penetration (greater than 1 mm). The long pulse ruby laser is used to deliver preferential heating to hair follicles for hair removal. This laser is transmitted using mirrors and an articulated arm system. It is not well absorbed by water but is strongly absorbed by melanin. Various pigments used in tattoos also absorb the 694-nm beam.

Alexandrite Laser

The alexandrite laser, a solid-state laser that can be flashlamp-pumped, has a wavelength of 755 nm. This wavelength, in the red region of the spectrum, is not visible and thus requires an aiming beam. It is absorbed by blue and black tattoo pigments and melanin but not hemoglobin. It is a relatively compact laser that can be delivered with a flexible-light guide. This laser achieves relatively deep penetration, making it a useful tool in hair and tattoo removal. Seven and 12-mm spot sizes are available.

Diode Laser

Recently, diodes using superconducting materials have been directly coupled to fiberoptic delivery devices, resulting in laser light emission of varying wavelengths (depending on the characteristics of the materials used). The characteristic of diode lasers is their efficiency. Diode lasers can convert incoming electrical power to light at efficiencies of 50%. This efficiency, resulting in less heat production and power input, allows compact diode lasers to be constructed without large cooling systems. The emitted light is delivered fiberoptically.

Filtered Flashlamp

The filtered flashlamp, used in hair removal, is not a laser. Instead, it is an intense, noncoherent, pulsed spectrum. The system utilizes crystal filters to emit light with wavelengths of 590 to 1200 nm. The pulse widths and fluences, also adjustable, do satisfy the criteria for selective photothermolysis, so are often mentioned with the lasers available for hair removal.

LASER APPLICATIONS

Vascular Lesions

The vascular lesions of the face and neck differ in their cause and natural history. They do, however, share important characteristics that allow them to be selectively treated by lasers. The lasers useful in this area can inflict damage on the abnormal vessels while sparing surrounding tissue. The specific lesions discussed here include port-wine stains, telangiectasias, and hemangiomas.

Port-Wine Stains

Port-wine stains, which are more correctly termed congenital capillary vascular malformations, are benign vascular lesions that commonly involve the face and neck. Approximately 5% of port-wine stains are associated with Sturge–Weber syndrome and Klippel–Trénaunay syndrome.[11] Unlike hemangiomas, port-wine stains are usually apparent at birth. They usually appear as flat, pink-to-red lesions. As the patient ages, they often become darker in color and develop a thickness and nodularity of their surface. Hemangiomas, on the other hand, often undergo spontaneous involution. Histologically, port-wine stains are composed of large ectatic vessels located in the reticular dermis. Hemangiomas have endothelial hyperplasia in the ectatic vessels. This distinguishes them histologically from port-wine stains.[12]

Laser Selection

Some surgeons have used the CO_2 laser to treat port-wine stains.[13–15] However, to eradicate the vessels within the dermis, the overlying epidermis and a portion of the dermis must be vaporized with the CO_2 laser, which can lead to scarring and hypopigmentation.[16] The argon laser has been used extensively for the treatment of port-wine stains because its blue–green light in the 488- to 514-nm range is absorbed by oxyhemoglobin.[17,18] A variety of treatment techniques using the argon laser have been described, but regardless of technique, hypertrophic scarring has been a complication.[19–21] Differing degrees of success in treating port-wine stains with the KTP[22] and the Nd:YAG laser[8] have been reported.

The yellow-wavelength lasers (FEDL, copper vapor laser, continuous-dye laser) have provided a breakthrough in the treatment of port-wine stains. These lasers function based on the principle of selective photothermolysis that was described by Anderson and Parrish.[23,24] This process is the selective heating of the ectatic vessel within a cutaneous lesion by preferential light absorption and heat production. To achieve ablation of a port-wine stain, the ectatic vessel must be heated to a temperature high enough to damage the endothelial lining. The yellow-wavelength lasers accomplish this by heating the blood within the vessel and the heat is conducted to the vessel wall. Simply coagulating the blood within the vessel without damaging the vessel wall allows recannulation to occur. Localization of heat to the target vessel and sparing of surrounding tissue are achieved by using the proper wavelength and taking into account the thermal relaxation time of the tissues being treated. The wavelength of the yellow lasers is in the 577- to 585-nm range. The 577-nm wavelength precisely matches the third absorption peak of oxyhemoglobin. In comparison with other laser wavelengths, such as the KTP or argon, there is a decrease in absorption by the competing chromophore melanin and less scatter in the dermis and epidermis[25] (Fig. 8–9). Tan et al[26] showed that the FEDL at 585 nm causes deeper penetration of laser energy, with no loss of vascular selectivity. With deeper penetration, there is faster clearing of the lesion.

The yellow-wavelength lasers use different mechanisms to obtain adequate thermal relaxation times for the ectatic vessels within port-wine stains. The FEDL has a set pulse width of 450 milliseconds; this was calculated on the average diameter of vessels within port-wine stains. The copper vapor laser allows for variability in setting the pulse width and the time between pulses. The continuous-wave yellow dye laser may be used with a Hexascanner, a device that mechanically varies the position of laser pulses placed within a hexagonal

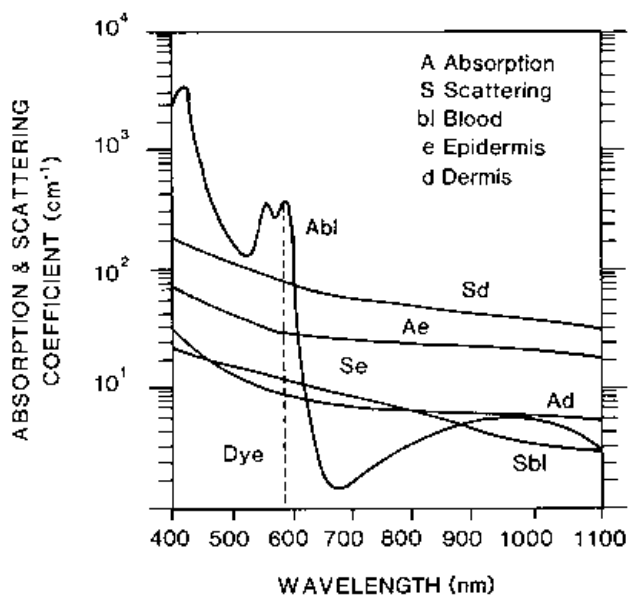

Figure 8–9 Hemoglobin absorption curve.

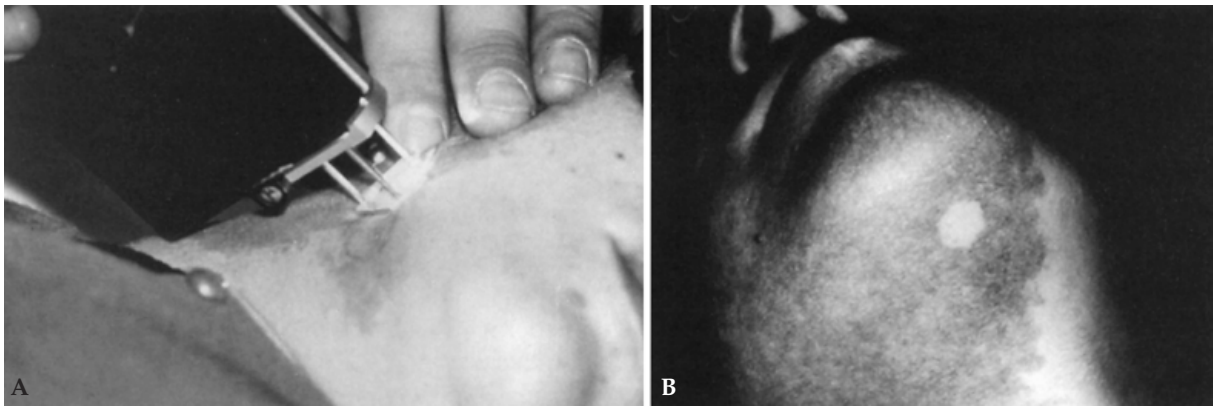

Figure 8–10 **(A)** Application of yellow dye laser energy using Hexascanner. **(B)** Hexagonal pattern of clearing after using the Hexascanner.

pattern. By placing pulses in nonadjacent areas, the previously treated tissue has time to cool[27] (Fig. 8–10).

Treatment

When the FEDL is used to treat facial port-wine stains, the first step is to determine the correct laser energy to be used for that patient. This is done by performing a purpuric threshold determination on normal skin of the volar aspect of the patient's forearm. Beginning at 2.0 J/cm^2 and increasing by 0.5 J/cm^2, successive pulses of laser energy are applied until the entire area of the spot is purple. The energy level at which this purpuric lesion appears is the patient's threshold level. This value is then multiplied by 1.5 or 2 to obtain the energy density to be used for a test area. The test is then performed by placing 10 to 20 slightly overlapping spots in a representative area of the patient's lesion. The test area is assessed 6 weeks after treatment at which time adjustments in the energy density are made, depending on the patient's response. Any crusting or blistering is an indication that the energy density should be decreased. An irregular pattern of clearance is an indication that the energy density should be increased. After the correct energy density is determined, the lesion is treated in aesthetic units. Patients with darker skin may require an increase in energy density. Lesions involving the eyelids, upper lip, mucosa, and neck often require less energy. An area may be re-treated every 6 weeks. The number of treatments necessary to clear a facial port-wine stain varies according to the size, color, and location of the lesion (Fig. 8–11). An average of 6.5 laser treatments per lesional area was reported by Tan in a series of 35 children with port-wine stains.[28]

When using the copper vapor laser to treat port-wine stains, a test area is also performed. The 100-μm spot size is used, and the power setting varies depending on the age of the patient and type of port-wine stain being treated. Application of the laser energy is done with the surgeon using 6× magnifying loupes. For lesions in which individual vessels are clearly identified under magnification, the clinical end point is where the vessel disappears. The handpiece must be moved at the correct speed, which depends on the power setting. For lesions in which no distinct vessels are identified,

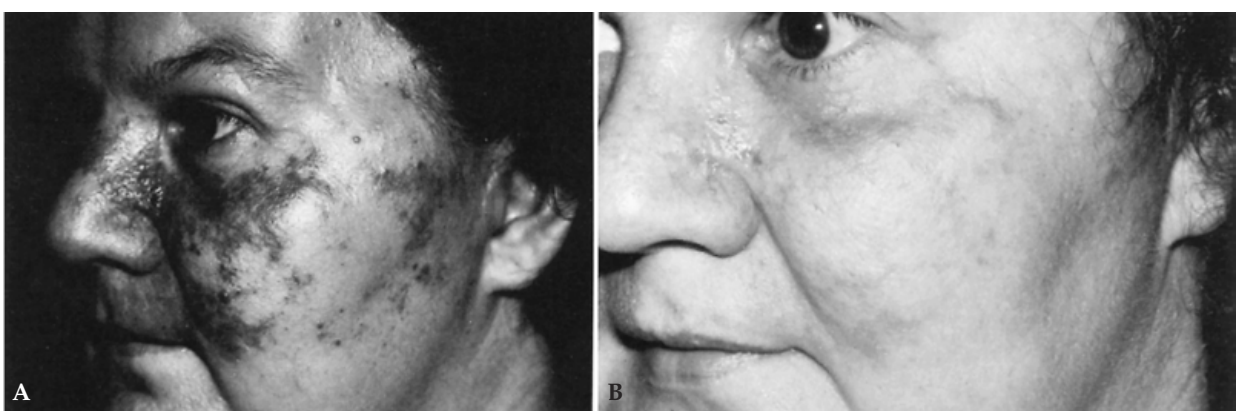

Figure 8–11 **(A)** Pretreatment view of left facial port-wine stain. **(B)** Appearance after treatment using the flashlamp-excited dye laser (eight treatments).

the area to be treated is painted by moving the laser rapidly from one area to another. The power setting determines the speed at which the laser must be moved.

The test spot is evaluated at 6 weeks and modifications in the power setting are made, depending on the clearing of the test area. Using the correct power setting, treatment is begun. Areas of 2 cm^2 are outlined and the lesion within the defined area is treated.

The technique using the continuous-wave dye laser is similar to that used with the copper vapor laser. If a Hexascanner is used, then nonadjacent areas of the lesion are treated with the hexagonal pattern and the intervening areas are treated on return visits. If the Hexascanner is not available, then the lesion may be treated with a beading technique, vessel blanching with magnification, or laser painting. The beading technique is performed by placing successive pulses of laser energy in a pattern of non-overlapping circles to cover the desired treatment area.[12,15]

The vessel blanching technique is often termed the Australian method[29] and is similar to that described for the copper vapor laser. The individual vessels are treated under 6× magnification.

With the paintbrush technique, laser energy is applied to the lesion until blanching is noted. This technique is often useful with thick nodular port-wine stains or for touch-ups of intervening areas where no individual vessels are readily identified. The laser must be moved rapidly over the lesion to avoid damage to the dermis and epidermis that may result in scarring or pigmentation changes.

Telangiectasias

Telangiectasias of the face are small ectatic vessels within the dermis. They occur in a variety of types, including linear, arborizing, reticular, punctate, and spider. Spider telangiectasias are often called spider nevi or spider angioma. These are acquired vascular marks that commonly appear on the face of young children. A study by Anderson[30] found spider telangiectasias in 47.5% of 1380 healthy school children. Lesions of similar appearance have been noted during pregnancy. They usually appear in the second trimester and enlarge until delivery. The spider telangiectasias of pregnancy are similar to the lesions found in patients with liver disease. Estrogen is thought to play a role in their formation.[31]

Telangiectatic lesions have also been noted after nasal surgery (e.g., the red nose of rhinoplasty). Other patients seem to have a hereditary predisposition to developing facial telangiectasias, and these lesions are classified as essential hereditary facial telangiectasias.

Laser Selection and Treatment

The copper vapor laser and continuous-wave yellow dye laser may be used to treat facial telangiectasias, and the treatment techniques are similar. With a spot size that is adequate to obliterate the dilated vessel (0.1 to 0.2 mm), the vessels are traced until the dilated vessel disappears. The smallest spot size and lowest power should be used to minimize damage to the surrounding normal tissue and reduce the incidence of posttreatment scarring (Fig. 8–12). Spider telangiectasias require a slightly different technique; the radial vessels are first obliterated from the periphery toward the center and then the larger central vessel is treated.

When using the FEDL to treat facial telangiectasias, the 3-mm spot size is used to treat individual vessels and the 5-mm spot is used for treating vessels that have associated erythema. The laser spots are placed in a contiguous or slightly overlapping pattern over the vessel. As with the other yellow lasers, when treating the spider lesions, the radial vessels are treated first from the periphery toward the center; then the central vessel is treated. The energy densities used for treating telangiectasias are usually lower than those for treating port-wine stains and are often in the range of 5.5 to 6.0 J/cm^2. Re-treatment with yellow dye lasers can usually be performed safely 6 to 8 weeks after the previous treatment.

Hereditary Hemorrhagic Telangiectasia

Hereditary hemorrhagic telangiectasia (HHT), or Rendu–Osler–Weber syndrome, is an inherited autosomal dominant disease manifested by multiple telangiectatic lesions that appear on the skin and mucosal membranes.[32] Epistaxis,

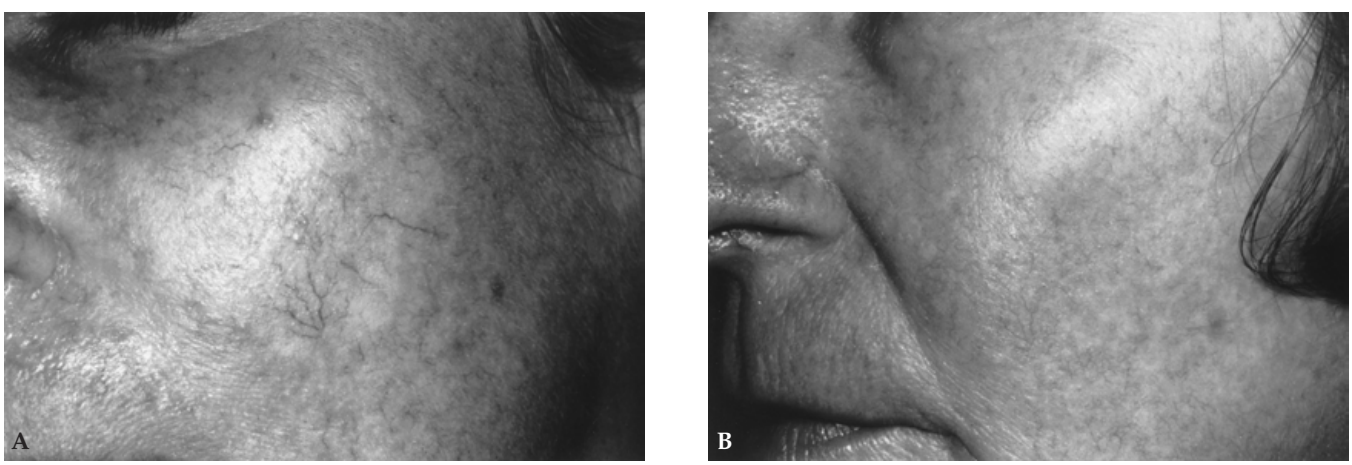

Figure 8–12 **(A)** Telangiectasias of the face, pretreatment. **(B)** Appearance after single treatment with the KTP laser.

caused by bleeding from the nasal lesions, is the most common presenting symptom. Bleeding from lesions of the lips, gingiva, tongue, buccal mucosa, or hard palate may also occur. Histologically, ectatic vessels with incomplete surrounding muscular layers are observed.[33]

Patients with severe epistaxis have been treated successfully using septal dermatoplasty.[34] However, recurrent telangiectasias may appear at the edges of the graft or in some cases in the graft itself. Estrogen therapy has been advocated for the treatment of HHT. It is thought to be effective by reducing squamous metaplasia of the nasal mucosa and thereby reducing the incidence of bleeding.[35]

Laser Selection

The CO_2 laser,[36] argon laser,[37] Nd:YAG laser,[38] and KTP laser[39] have been used to photocoagulate the nasal and oral telangiectasias found in HHT. The CO_2 laser is not ideal for the treatment of telangiectasias because its effects are superficial and vaporization of the overlying mucous membrane covering the lesion may cause bleeding. In addition, fiber-directed lasers (Nd:YAG, KTP, and argon) have the advantage of accessibility to posterior sites and lateral nasal wall sites. The argon and KTP lasers with preferential oxyhemoglobin absorption offer the theoretic advantage of vascular selectivity. In addition, dedicated nasal instruments available with the KTP laser facilitate its use in the constricted nasal cavity. Although the Nd:YAG laser is not preferentially absorbed by oxyhemoglobin, its deeper penetration makes it extremely effective in coagulating these lesions (Fig. 8–13A, B).

Treatment

Whichever fiber laser is chosen, the free fiber is held above the mucosal surface and the individual vessels are treated in a rosette fashion by first encircling the central portion of the lesion with pulses of laser energy and then coagulating the central lesion (Fig. 8–14). For the Nd:YAG laser, power settings usually range from 10 to 25 W and the exposure time used is 0.5 second. With the KTP laser, the power is set to 6 W, exposure time is 0.5 second, and the beam is used in a slightly defocused mode. The laser energy should be applied perpendicular to the mucosal surface. This obviously becomes more difficult as lesions located deeper in the nasal cavity are treated.

Hemangiomas

The treatment of capillary or cavernous hemangiomas has been reported with CO_2, Nd:YAG, argon, and KTP lasers.[6,9,22,40] The vascular specificity of the KTP and argon lasers enhances the selectivity of the photocoagulation.[13] Nevertheless, the Nd:YAG laser is useful in nodular or mucosal lesions when a greater depth of coagulation is desired (Fig. 8–14).[9] The maximum tissue penetration is about 1 cm and thus limits external treatment of large lesions. In these cases, even large hemangiomas can be treated with intralesional application of the Nd:YAG laser utilizing the bare fiber inserted through a puncture site (Fig. 8–15).[68] Rosenfeld et al[8] reported on Nd:YAG laser treatment of 37 capillary and cavernous hemangiomas, with improvement in 29 cases. Only 2 cases of scarring were reported. Similar success rates were reported by Apfelberg et al.[6]

KTP and argon lasers offer the advantage of selectivity and decreased depth of penetration compared with the Nd:YAG laser. The potential to minimize risks of scarring exists with either laser. Excision of large hemangiomas of the nasal cavity and paranasal sinuses is facilitated by the KTP or contact-tip Nd:YAG lasers that complement traditional surgical approaches.

Pigmented Lesions

Cutaneous pigmented lesions include benign pigmented lesions and exogenous pigment (tattoos). Benign pigmented lesions include lentigines, freckles, café au lait spots, congenital nevi, and melasma. Exogenous tattoos can occur as a result of professional tattooing or accidental tattooing as in an explosion or puncture injury. Both selective and nonselective lasers have been used to remove pigmented lesions. For example, nonselective vaporization of the lentigines and freckles has been accomplished with the CO_2 and erbium lasers. The principle of selective photothermolysis has guided the development of several lasers that reliably remove pigment without damaging surrounding tissue. The mechanism of pigment destruction is not completely understood, but it is probably a combination of photoacoustic damage to the cell by rapid heating and expansion of melanosomes, break-up of pigment, and systemic rephagocytosis and clearing.

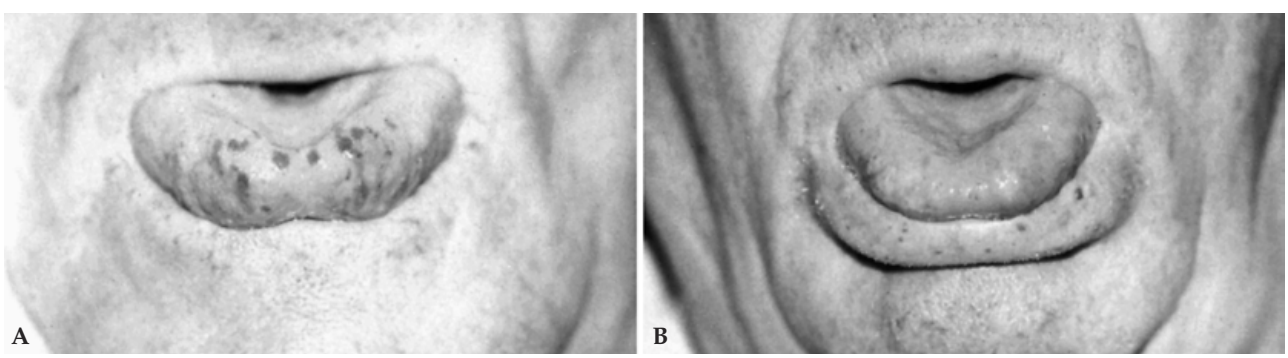

Figure 8–13 **(A)** Lingual telangiectasia, pretreatment. **(B)** Appearance 2 weeks after treatment using the Nd:YAG laser.

Figure 8–14 **(A)** Pretreatment view of right buccal hemangioma. **(B)** Posttreatment appearance after use of the noncontact Nd:YAG laser.

Figure 8–15 **(A)** Right periorbital hemangioma in a 2-month-old. **(B)** Clinical response to intralesional Nd:YAG. This lesion was also treated with intralesional corticosteroids and the flashlamp-excited dye laser (three treatments). (Courtesy Archives of Otolaryngology, Head and Neck Surgery.)

Laser Selection

Lasers that target pigment include the pulsed dye laser (510 nm), copper vapor (511 nm), frequency-doubled Q-switched Nd:YAG (532 nm), KTP (532 nm), Q-switched and long-pulsed ruby laser (694 nm), Q-switched and long-pulsed alexandrite (755 nm), and the Q-switched Nd:YAG (1064 nm).

The pulsed dye laser, with characteristic short wavelength and shallow tissue penetration, is excellent in clearing epidermal pigmented lesions, such as lentigines, freckles, and café au lait spots, but less ideal for removal of dermal pigment, such as tattoos. However, it can effectively remove brightly colored pigments, such as red, purple, and orange.[41] The shallow depth also leads to treatment of melanosomes but not melanocytes, which may partially explain recurrence rates in café au lait spots, Becker's nevi, and melasma.[42]

The ruby laser (694 nm) is minimally absorbed by hemoglobin, preferentially absorbed by melanin, and has deeper

tissue penetration, making it more effective in the dermis than the pulsed dye laser. The Q-switched ruby laser is highly effective for the removal of amateur tattoos, moderately effective for the removal of black professional tattoos, and less effective for the removal of brightly colored professional tattoos. Amateur tattoos respond more favorably in fewer treatments than professional tattoos do.[43] Green tattoos respond variably,[44] and red tattoos are most problematical.[45] One study, which compared the three lasers, found the Q-switched ruby laser to be most efficacious in removing blue–black tattoos, the Q-switched alexandrite laser best for blue and green tattoos, and the frequency-doubled Q-switched Nd:YAG useful for red tattoos.[46]

The Q-switched alexandrite laser is also useful in treating pigmented lesions. As with the ruby laser, a longer wavelength (755 nm) allows for deeper penetration. Lentigines, freckles, and café au lait spots can be removed with the alexandrite laser. It is best at removing green tattoos but less effective at removing blue–black or brightly colored tattoos. Long-pulsed ruby and alexandrite lasers have also been shown effective in treating laser-resistant congenital nevi.[47] The Q-switched Nd:YAG's usefulness can be expanded by placing a doubling crystal in the laser beam's path, resulting in a laser that can be operated at 532 nm or 1064 nm, giving the clinician greater flexibility. The 532-nm wavelength is well absorbed by melanin and hemoglobin, making it useful in the treatment of both vascular and pigmented lesions. Epidermal lesions can be lightened considerably. Pigment in the deep dermis can be removed using the 1064-nm Q-switched Nd:YAG laser. The Q-switched Nd:YAG laser clears most amateur blue–black tattoos.[48]

Treatment

In general, superficial lentigines and freckles can often be managed in one treatment. Congenital nevi, dermal tattoos, melasma, and café au lait spots generally require multiple treatments and still may recur in some cases. Q-switched lasers are often used without a local anesthetic or with a topical application such as EMLA cream. In the case of tattoos with multiple pigments, more than one laser treatment may be needed. Higher fluences may be required to affect some congenital nevi and tattoo pigments. Treatments with the pulsed dye laser are initiated at 2 to 3.0 J/cm^2 using a 5-mm spot. The frequency doubled Q-switched Nd:YAG should be initiated using fluences of 2 to 2.5 J/cm^2 in 2-mm spots at 5 to 10 Hz. Higher fluences are needed for the red lasers, including ruby and alexandrite. The ruby laser uses fluences 5 to 6.0 J/cm^2 through an articulated arm to a 6.5 mm spot. Five to 10 J/cm^2 can be used for tattoos. Tattoo removal usually requires 5 to 10 treatments. The alexandrite laser should begin with fluences of 6 to 8.0 J/cm^2. Finally, the Q-switched Nd:YAG is operated at fluences of 3 to 12 J/cm^2.

Hair Removal

More than $500 million is spent annually by consumers purchasing products to remove unwanted body hair. Laser-assisted hair removal is a new and effective means for removing unwanted body hair. Although none of the currently approved lasers can boast permanent hair removal, laser-assisted hair removal is less painful than electrosurgical hair removal and provides longer lasting results than the more traditional means of hair removal, including shaving, waxing, plucking, electrolysis, and use of depilatories. Removing hair from any body area, including the face, groin, extremities, and axilla, is now safely done with appropriate laser systems and settings. The principle underlying hair removal is selective photothermolysis. As previously mentioned, this involves the selective absorption of light energy by the hair follicles with suitable pulse energies and pulse durations that are equal to or less than the thermal relaxation time of targeted follicles in the skin. In laser-assisted hair removal, the target chromophore is the pigment melanin. Lasers with wavelengths between 690 and 1100 nm are in the approximate range. This includes red-light lasers (694 nm ruby), infrared (755 nm alexandrite, 800 nm diode, 1064 nm Nd:YAG), and the filtered flashlamp producing a spectrum of intense 590 to 1200 nm light. Pulse duration is also an important parameter in laser-assisted hair removal in that the pulse width must approximate the thermal relaxation time to provide sufficient heating to the target follicles. Ideally, this is done without causing damage to the surrounding epidermis (which also contains melanin). Cooling systems are utilized in hair removal laser systems to decrease collateral thermal damage.

Laser Selection

The long-pulsed ruby and alexandrite, the diode, and the Nd:YAG (used in conjunction with a carbon suspension) are the primary lasers used for hair removal today. The long-pulsed ruby laser emits light at 694 nm, is strongly absorbed by melanin, and has sufficient tissue penetration to reach the depth of the hair follicles. Several studies have confirmed the efficacy and safety of using long-pulsed ruby-based systems for the temporary removal of hair and long-term hair reduction.[49,50] The long-pulsed alexandrite laser (755 nm) is also strongly absorbed by melanin. It also achieves selective heating of the hair follicles and adequate tissue penetration, resulting in effective hair reduction.[51] The diode lasers, emitting light in the 800 nm range, are also available. In addition, the filtered flashlamp, using a noncoherent spectrum of light, is also useful for hair removal and has somewhat adjustable features for treating different skin types and tones. The soft-light system, utilizing an exogenous chromophore (a topical carbon suspension) and the Nd:YAG laser, has also been shown to effectively provide temporary and long-term hair reduction.

Treatment

In general, the previously mentioned lasers all produce light in the visible and near-IR spectrum utilizing the selective absorption of melanin for the destruction of hair follicles. As was also mentioned, the pulse duration should be less than or equal to the thermal relaxation time, which has been calculated to be approximately 10 to 100 milliseconds. For hair removal, treating at the maximum tolerated fluences results in better long-term results. However, as with any treatment utilizing the laser, initial parameters should be conservative and increased once it is demonstrated that they will be well tolerated by the patient. Dark-haired, light-skinned people have the best results with laser-assisted hair removal. Darker skin tones are at higher risk for hypopigmentation at fluences required to remove hair.

The biggest hurdle to long term results, however, has to do with the biology of hair growth itself. Hairs in the growth or anagen phase are sensitive to laser irradiation because they are associated with melanocytes during this active phase (Fig. 8–16). Hairs in the catagen and telogen phases are much less affected. Hairs in these latter stages of the hair growth cycle lose much of their melanin, which is the target of the currently used laser systems. In addition, portions of the hair follicle are resorbed

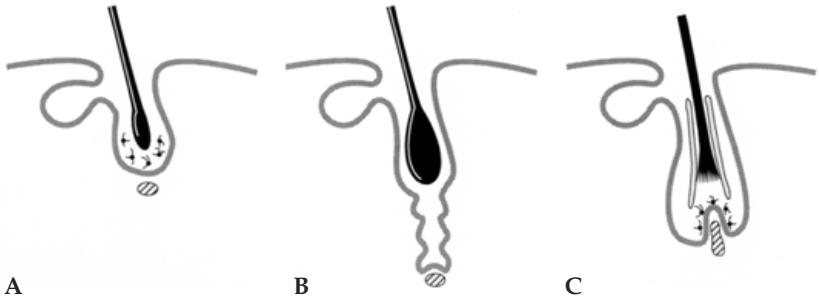

Figure 8–16 **(A)** Phases of hair growth: the growth phase or anagen, **(B)** the transitional phase (catagen), and **(C)** a resting stage (telogen).

altogether.[52] The amount of hair in any given phase varies among patients and anatomical sites. Multiple sessions are therefore required to treat all of the hairs in any given region.

The long-pulsed ruby lasers are generally started at fluences of 10 to 20 J/cm^2 or lower if the laser system does not have an incorporated cooling mechanism in the handpiece or cooling gel. The alexandrite lasers are similar in setting. The filtered flashlamp uses a software system to determine initial settings based on the patient's skin type and produces fluences of 30 to 65 J/cm^2. The soft-light system uses the Nd:YAG laser at lower fluences to propel the carbon into the hair follicles followed by another pass at higher fluences (2 to 3 J/cm^2) for hair removal. The diode laser produces fluences of 5 to 40 J/cm^2 over a 9 × 9 mm area. A cooled sapphire lens is incorporated into the handpiece to provide for additional epidermal protection. Most patients require more than one treatment for permanent hair reduction, although temporary hair removal can easily be accomplished in one treatment. Typically, two to five treatments are necessary for permanent hair reduction depending on the laser selected.

Rhinophyma

Rhinophyma is a disease of the nose and skin of the midface that occurs almost exclusively in men.[53] It usually begins in midlife or later and is characterized by hyperplasia of the sebaceous glands and connective tissue.[54]

Henning and von Gemert[55] reported the use of the argon laser for the treatment of rhinophyma; however, most laser surgeons use the CO_2 laser[56,57] because it offers distinct advantages. The ability to precisely excise and ablate the rhinophymatous tissue allows the surgeon to sculpt the nose. Intraoperative bleeding is kept to a minimum because of the hemostatic properties of the CO_2 laser. Postoperative pain is minimal, and wound care usually requires only antibiotic ointment. Most laser surgeons use the CO_2 laser in a range of 5 to 10 W and in the continuous mode. Large nodules of rhinophymatous tissues are excised; then the laser is defocused to ablate the remaining portion of the lesion in the paintbrush fashion. This may require several applications of energy to reach the appropriate depth of tissue ablation. The carbonaceous debris and char are removed between each application of laser energy (Fig. 8–17).

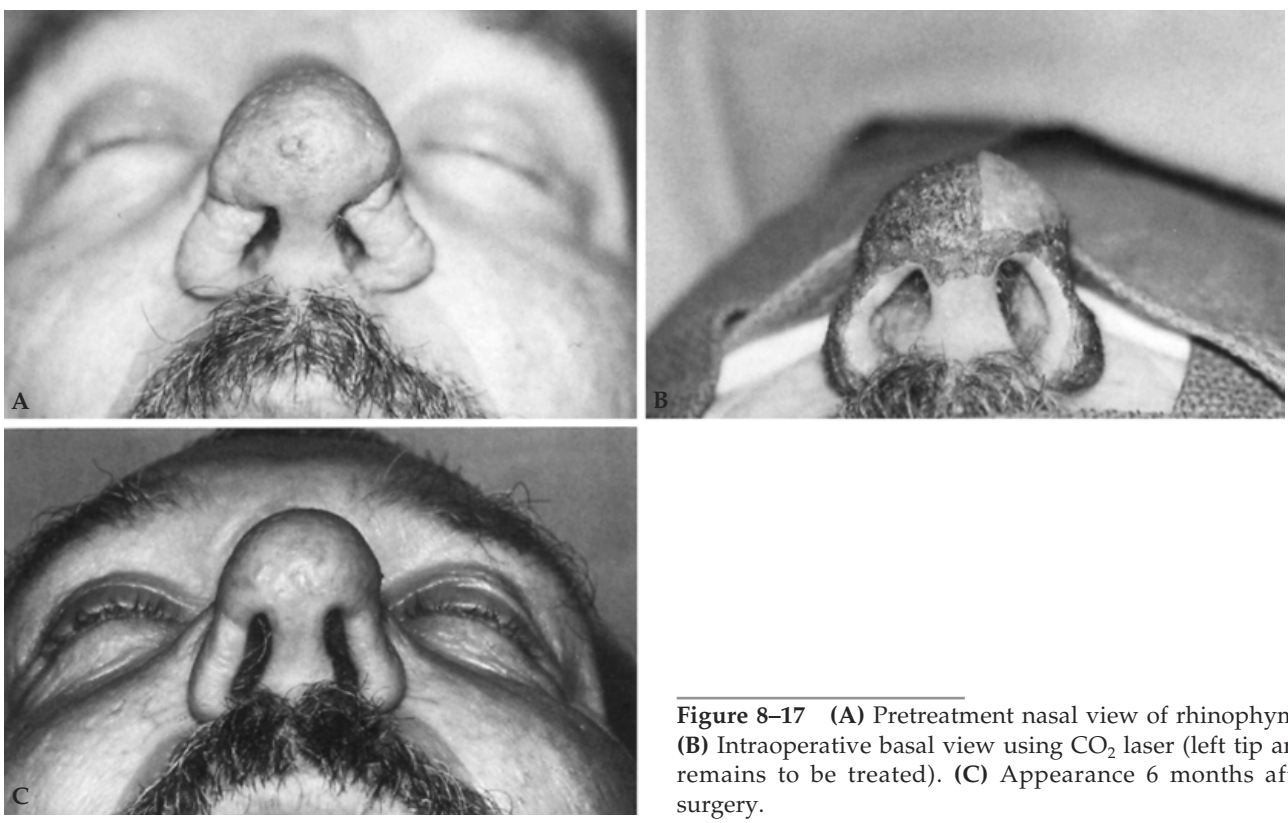

Figure 8–17 **(A)** Pretreatment nasal view of rhinophyma. **(B)** Intraoperative basal view using CO_2 laser (left tip area remains to be treated). **(C)** Appearance 6 months after surgery.

Skin Resurfacing

Laser resurfacing offers potential advantages of improved control and reproducibility in comparison with traditional methods of chemical peeling and dermabrasion. The principle involved, selective photothermolysis, utilizes the chromophore water as a target to vaporize thin layers of tissue with minimal heat diffusion. As described previously, the target must be exposed to the laser light for a period less than or equal to its thermal relaxation time. Thus, resurfacing lasers must be capable of delivering sufficient fluence during this brief time to achieve vaporization during a single laser pulse. For skin, this is approximately 5 J/cm^2 delivered in less than 1 millisecond.

Patients who may benefit from laser resurfacing include those with rhytids (Fig. 8–18), photoaging (including actinic keratosis, actinic chelitis, and dyschromias), and scarring resulting from trauma, iatrogenic causes, or acne. Small areas or the entire face can be treated in one setting. The laser is also useful in procedures that require deepithelialization of a flap or a portion of a flap. A few of the specific clinical entities are mentioned in the following sections.

Laser Selection

CO_2 and erbium lasers are the primary ones used in resurfacing. Both lasers utilize tissue water as the ablative target and have been engineered to achieve fluences for tissue vaporization. Although laser–tissue interaction is similar, two types of technologies have been developed for resurfacing. The first are high-energy, short-pulsed systems capable of producing single pulses of 600 milliseconds duration with fluences of 5 to 7 J/cm^2 for the CO_2 laser. Thermal damage, which occurs when heat is conducted to surrounding tissue, is directly proportional to the length of time for which energy is applied to the tissue. High-energy, short-pulsed systems allow ablation of thin layers while minimizing thermal damage. A computer pattern generator, used in conjunction, produces patterns up to 19 mm in diameter. The individual patterns comprise a series of collimated beams that are overlapping by varying degrees to maximize uniformity. The second type of technology that has proved useful in resurfacing is scanning. Scanning technology utilizes a continuous laser beam with a microprocessor-controlled scanner that rapidly moves the focused beam across the tissue. The pattern of movement is designed to ensure that dwell time on any point is less than thermal relaxation time (simulating a pulse). Fluences of 5 to 15 J/cm^2 for the CO_2 laser are delivered with this system. Scanning diameters may vary from 3 to 16 mm. Both the CO_2 laser and the erbium laser are useful in resurfacing. The differences between the two lie primarily in the biophysics of each. The CO_2 laser, in contrast to the erbium laser, has an additional thermal effect in the base of the treated wound. This thermal effect gives the CO_2 laser its characteristic ability to coagulate and to induce collagen remodeling in the dermis.[58] The erbium laser, with its much higher absorption coefficient, rapidly ablates tissue with very little thermal effect (a rim of 20 to 50 μm). Histologically, this translates to less tissue shrinkage[59] and more rapid reepithelialization.[60] Wound healing after erbium laser resurfacing is similar to that after such cold techniques as dermabrasion. The depth of tissue injury corresponds closely to the depth of ablation because thermal damage is extremely limited. This allows for quicker healing and less postoperative erythema.

Treatment

Preoperative planning is critical to the appropriate treatment of resurfacing patients. Skin tones and textures, thickness of the areas to be resurfaced, areas previously resurfaced with the laser or skin treatments, and a history of sun exposure, isotretinoin (e.g., Accutane) usage, and exposure to radiation are all important. Peri-operative care, including skin preparation, herpes prophylaxis, and the appropriate use of local anesthesia, is also important to the achievement of optimal cosmetic results. Local anesthesia then is used with a weak epinephrine solution (1 : 200,000) so that severe vasoconstriction will not obliterate the color indicators of depth. The surgeon should be familiar with the ablation characteristics of the laser system used. A pink color indicates removal of the

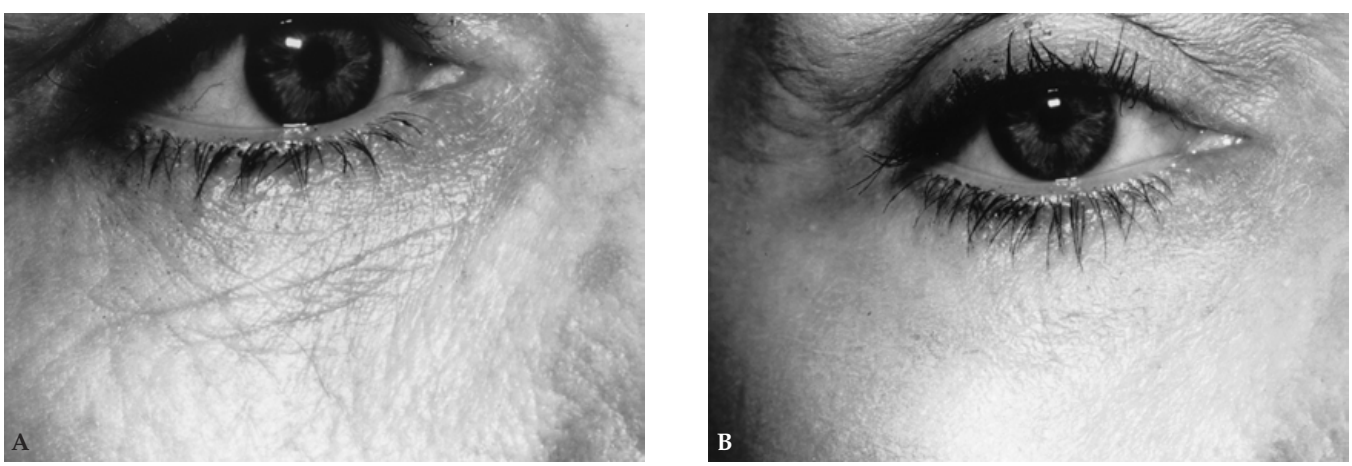

Figure 8–18 **(A)** Pretreatment view of periorbital rhytids. **(B)** Posttreatment after resurfacing with the CO_2 laser.

epidermis, a uniform gray appearance signals the papillary dermis, and a chamois yellow heralds the reticular dermis. These important end points may be altered in patients who were previously treated, in patients taking isotretinoin, or in those with a history of radiation exposure.

Complete superficial laser ablation of anatomical units is performed. Several passes are usually needed, depending on the degree of photodamage and the laser used. In general, the erbium laser requires more passes than the CO_2 laser because its tissue effect depends almost completely on the depth of ablation and not the thermal effect. Residual tissue is then removed completely with a very moist saline sponge between passes. Fluences typically range from 5 to 10 J/cm^2. The erbium and carbon dioxide lasers can be used in a complementary fashion as well. For example, the epidermis can be removed with the carbon dioxide laser and the erbium laser used to sculpt scars in finer detail. This technique combines the heating properties of the carbon dioxide laser with the ablation characteristics of the erbium laser.[61]

These same principles of tissue ablation can also be applied to the removal of specific photodamage lesions that have the potential for malignant transformation. Actinic cheilitis and keratoses are examples of precancerous dermatosis that occurs in patients with a history of chronic sun exposure.[62,63] Actinic cheilitis, appearing as superficial milky or silver–gray lesions of the lower lip, is often atrophic, and focal areas of scaling or crusting can be found. Because of the superficial nature of this lesion and its high water content, vaporization of the lesion using the CO_2, laser is an excellent treatment option. Continuous lasers that have been used to ablate and excise these lesions include that used in laser vermilionectomy.[64] Newer technologies, such as the high-energy, short-pulsed CO_2 laser coupled with the computer pattern generator, and the scanning continuous laser, have led to better results and improved healing rates.[61] Complete reepithelialization of the lip should occur in less than 4 weeks.

Cutaneous Malignancies

Basal and squamous cell carcinomas may be excised using the CO_2 laser as a light scalpel. The CO_2 laser offers some distinct advantages in performing excision surgery of facial cutaneous lesions.[57] One advantage is hemostasis. The CO_2 laser can seal blood vessels up to 0.5 mm in diameter when used in the focused mode. In the defocused mode, it can seal even larger vessels. Another advantage of the CO_2 laser is in flap elevation or undermining. Since the instrument does not contact the skin, there is theoretically less tissue trauma and edema. By using the CO_2 laser for excisional surgery, nerve endings are sealed; this reduces postoperative pain. A frozen section evaluation of the margins of resection has not been difficult when the CO_2 laser is used[65] (Fig. 8–19).

Photodynamic Therapy

Photodynamic therapy (PDT) is currently an experimental treatment modality that combines the use of light-sensitive drugs and lasers to destroy nonmelanoma skin malignancies. Photosensitizing drugs are administered intravenously and taken up by all cells of the body but are preferentially concentrated in tissues of the endothelial system and in tissues with rapid turnover, such as skin and neoplasms. Approximately 48 to 72 hours after administration of the drugs, they are activated by a laser light. The laser energy then drives an oxidative phototoxic reaction that results in cell death. Several photosensitizing drugs are being investigated for their potential in treating cutaneous and noncutaneous malignancies of the head and neck. Most of the work done in PDT so

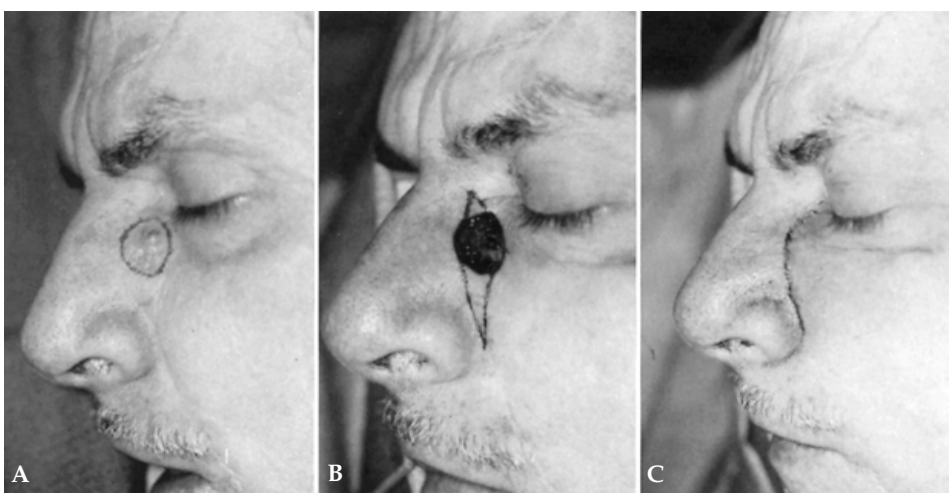

Figure 8–19 **(A)** Left nasal basal cell carcinoma outlined for CO_2 laser excision. **(B)** Completion of laser excision and outline of areas to be excised with laser before closure. **(C)** Immediate postoperative appearance after closure of defect.

far has involved the use of hematoporphyrin derivative (HPD) and its commercially available preparation, Photofrin. More than 20 compounds are currently under evaluation.

Many studies have been published to date establishing the efficacy of PDT in the treatment of patients with cutaneous malignancies of the head and neck. The most dramatic effects have been on localized basal and squamous cell tumors without extensive invasion. Many new drug delivery models and drug–laser combinations hold promise for treatment of many malignancies in a targeted way.

SAFETY CONSIDERATIONS

Any chapter on laser surgery would be incomplete if it did not address the issue of safety. Lasers are potentially hazardous instruments. Eye damage, skin damage, and endotracheal tube ignition are some of the problems that may occur during laser surgery. An understanding of how they occur and how to avoid them is essential. Ocular damage can result from corneal or retinal burns. Wavelengths ranging from 400 to 1400 nm that are in the visible and near-IR range of electromagnetic radiation cause retinal damage. This occurs because laser energy is focused on the retina to a small spot size by the cornea and lens of the eye. Laser wavelengths of less than 400 nm (ultraviolet) or greater than 1400 nm (far-IR) produce corneal injury. If the injury is of a recurrent or chronic nature, cataracts may develop.[66]

The eyes of the patient, surgeon, and operating room personnel must all be protected during surgery. If operating near a patient's eyes, corneal protectors should be used. If the surgery proposed is not in close proximity to the eyes, then eye pads with overlying reflective material, such as aluminum foil, can be applied to the eyes. With the CO_2, laser, wet eye pads are applied to the closed eyelids and taped in place. For the surgeon and operating room personnel, eyeglass protection of an appropriate tint, recommended by the laser manufacturer, should be worn. When laser surgery is being performed in the operating room, signs should be posted on all entrances to prevent personnel from entering without eye protection.

Inadvertent laser irradiation of unintended skin areas, due to either direct or reflected beams, is a problem that is particularly important to the facial plastic surgeon. It can be prevented by placing the laser on stand-by or turning it off when not in use. It is also important to cover as much of the patient's skin as possible with wet towels, with the obvious exception of the area to be treated. In many instances during facial plastic procedures, the patient's skin is marked with a pen to delineate areas of intended surgery. It is important to realize that these marks may change the absorption of a particular wavelength and alter the intended tissue effect.

Laser irradiation may be used close to an endotracheal tube, particularly when treating perioral or intraoral lesions. If a laser beam strikes an unprotected, non–laser-resistant endotracheal tube, a fire can easily occur. The surgeon is responsible for ensuring that a laser-resistant tube is used. The ventilating gas mixture should contain the least amount of oxygen possible combined with helium. Helium decreases the combustibility of the upper airway gas mixture during anesthesia.[67]

It is imperative that every hospital performing laser surgery have a laser safety committee. This committee is responsible for establishing guidelines and protocols for performing laser surgery and setting the basic minimum requirements for a surgeon to acquire laser surgery privileges. The committee is also responsible for ensuring that the surgeon, anesthesiologist, and operating room personnel are all up to date on the latest safety precautions as they relate to the different-wavelength lasers. Hands-on laser surgery courses attended by otolaryngologist/head and neck surgeons have decreased the incidence of laser complications. Similar courses should be required for all surgeons who plan to use lasers in their practice.

FUTURE CONSIDERATIONS

The use of lasers in facial plastic surgery is well established and even the treatment of choice for certain lesions and applications. Laser technology, utilizing the principle of selective photothermolysis, allows the surgeon to choose a tool for a very specific purpose. Further improvements in laser–tissue interaction by optimizing laser wavelength, pulse parameters, and energy delivery will certainly lead to new lasers with unique applications. Improvements in these parameters will also lessen the deleterious effects of lasers, including hypopigmentation and scarring.

Existing laser systems are getting smaller and less expensive, increasing their use and usefulness. Further developments in materials manipulation will lead to more versatile lasers that can be carried by the surgeon from one location to another. Hopefully, making the technology more widely available will lead to further innovations by physicians who previously did not have access to certain types of lasers.

The coupling of laser technology with computers, robotics, and imaging systems will probably be the area of greatest progress in the near future. The precise and efficient control of the laser utilizing these technologies not only will maximize results but will reduce morbidity. Delivery systems that increase the speed, uniformity, and versatility of laser application not only support the development of new uses but make the current applications more tolerable. Either way, many patients who previously had few options for treatment will have laser therapies available to them.

Finally, new drugs useful in photodynamic therapy will be developed. Targeting tumors with agents that interact with laser light in a lethal way has revolutionary potential. Molecular markers unique to certain tumor cells could be targeted with antibody-delivered chemicals with specific absorption characteristics. When exposed to a particular wavelength of laser light, a lethal blow could be delivered to tumor cells with minimal damage to surrounding normal tissue. With proper delivery, the same technologies could be extended to benign lesions as well. Many exciting improvements in clinical practice are to be expected for the facial plastic surgeon who stays abreast of the advances in this field.

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Chapter 9

Aesthetic Facial Proportions

Marion B. Ridley and Steven M. VanHook

During every recorded age of history, and undoubtedly even earlier, humankind has sought to define and measure beauty and thereby be enabled to create it. Indeed, it has been stated that the prime requisites of a civilization are intellectual energy, freedom of the mind, and a sense of beauty.[1] *Aesthetic* is derived from the Greek word *aisthesis*, which means having a sense or love of that which is beautiful. Individuals have unique perspectives on aesthetics that are related to their personalities and environmental milieux.[2] Thus no two people would likely describe their concept of beauty in exactly the same way. Although a universal canon of beauty cannot be established because of differences in time, culture, ethnicity, and age, there are found proportion and harmony among the parts of certain faces, which confer on the whole a timeless beauty.[3]

Defining an ideal beauty has been an elusive, unattainable goal of every civilization. In interpreting the definition of ideal beauty from civilizations past, we are limited in the resources available. Often we are left to interpret the most popular artistic creations of the time and assume that this is how society felt beauty should be portrayed. At other times, we are able to read the historical record and writings about the subject from the people of those eras. The people of Ancient Greece attempted to describe beauty through the perfection of the mind and body in an ordered universe. Their civilization focused on art, literature, and politics while also prizing the value of beauty in society. There were rewards for those of society with beauty, and often people were referred to with names that described specific aspects of their beauty.[4] Attempts were made to define beauty through mathematical equations and geometric formulas (i.e., laws by which much of nature seemed to abide).[5] The Athenian philosopher Plato stated that "the qualities of measure and proportion invariably constitute beauty and excellence." He wrote that there are three wishes of every man: to be healthy, to be rich by honest means, and to be beautiful. Although Plato started defining beauty in terms of mathematics, he also realized that beyond physical proportions, beauty was also the result of good taste and balance.

HISTORY OF BEAUTY IN ART

Several other Greek figures played important roles in helping to define ideal beauty. Polyclitus developed a canon of proportions in the fifth century BC that he felt produced a figure with a flawless body. He experimented with proportions taken from nature and from those proportions created figures appearing more aesthetically pleasing to onlookers. Even more influential in the development of an ideal beauty was the Greek sculptor Praxiteles. His work in the fourth century BC led to a depiction of ideal beauty that held for the next 100 years.[4] He sculpted the figure of Aphrodite, the goddess of love, in what is considered the first completely nude image of the goddess created. In his interpretation he crafted a female figure that appeared much more gentle than previous sculptures, in which females seemed more like males with breasts attached to their chests.[6] His Aphrodite showed human expression, and this figure, modeled after a well-known woman of his society, was to be imitated and revered for many years.

In the first century BC the Roman architect Marcus Vitruvius Pollio wrote that the proportions of humans should be used when creating sacred buildings. He reasoned that the human body is a model of perfect proportions; thus, architecture would benefit if buildings were modeled on nature. He described the proportions of humans that he felt created the most ideal figure. He also attempted the task of trying to contain the human figure within a circle and square by having the figure with arms and legs extended (later to be referred to as the Vitruvian man). Although his work was not appreciated in his time, he provided a great influence for several of the Italian Renaissance painters.

The late fourteenth century through the middle of the sixteenth century in western Europe was referred to as the Renaissance Period. During this time there was a renewed interest in Ancient Greece, and the ideals of classic beauty reappeared. Women were starting to receive formal education and were attaining some increased degree of independence. People were also regarding female intelligence as compatible with beauty.[4] This increased reverence for women was also met with new advances in artistic techniques. Masaccio (1401–1428) developed the artistic technique of perspective, allowing the creation of figures that appeared more realistic and human.[6] Artists during this time found that copying beauty was no longer the goal; they wanted to *perfect* beauty. Female faces would often be created with the combination of various features from different models.[4]

Leonardo da Vinci (1452–1519) devised a new version of the Vitruvian man and developed an obsession with the infinity of geometric transformation as exhibited by his attempt to square the circle (Fig. 9–1). The image he created,

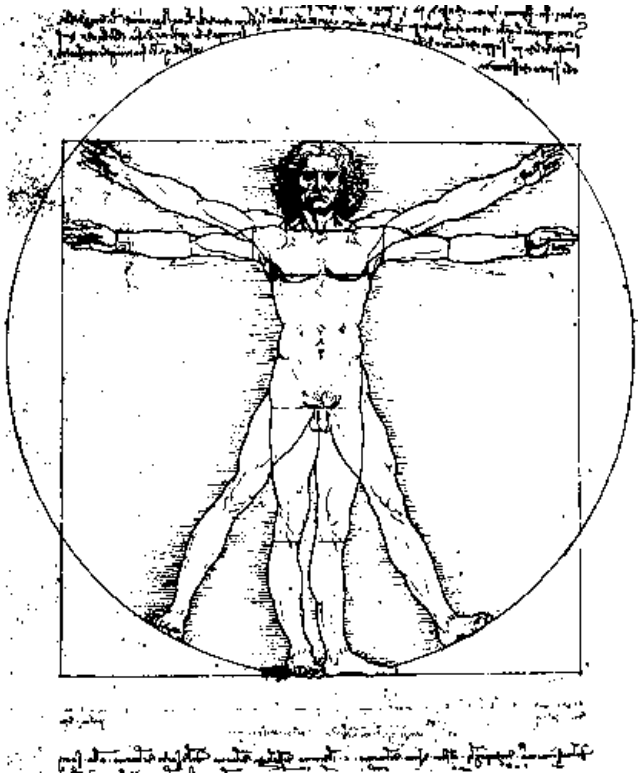

Figure 9–1 Leonardo da Vinci's proportions of the ideal human body. (Courtesy Historical Pictures Service, Chicago.)

recognizable to most people, was far more aesthetic in appearance than the original created by Vitruvius.[7] This figure uses the golden proportion (discussed later) prominently, as do many of da Vinci's other works.

Another artist who was inspired by the Vitruvian notion of perfect proportions was the German painter and printmaker Albrecht Dürer (1471–1528). He tested the human proportions devised by Vitruvius that would create the perfect body. By applying these principles, he created drawings of the female figure as described by Vitruvius. Unfortunately, the image that resulted was a round-bellied, drooping-breasted, large-hipped woman with gigantic feet. Without becoming discouraged, Dürer continued in his pursuit to define beauty by writing four books on human proportions. The Italian monk Agnolo Firenzuolo (1493–1543), also interested in defining ideal beauty, wrote a catalog of desirable female traits. Basically analyzing every feature of the female body, Firenzuolo describes the size, shape, and proportions of what he considered the ideal woman.[4]

Perhaps the artist most renowned for defining the Renaissance ideal of beauty was the Florentine painter Sandro Botticelli (1444–1510). In his art he was able to combine the social preferences of his time with the classic ideals of antiquity. His images of women show classical bodies, but they also have the Renaissance style of high foreheads and high coloring.[4] The women appear voluptuous but not cumbersome. In his most famous work, *The Birth of Venus* (c. 1480), the image of Venus appears to be floating, despite having her feet touching the shell beneath her.[6] Her face is long and angular rather than oval, as had been common. Although ideals change from generation to generation, this image of the female figure exhibits many of the traits still deemed ideal.

After the Renaissance period, the ideal of beauty changed to the long-fingered, long-necked, graceful female figures of the Mannerist period. Artists of this time tried to convey an unearthly beauty by greatly extending and distorting the natural proportions.[4] After this period, which lasted 75 years, the Baroque period, a Counterreformation response of the Catholic Church to Protestantism, inspired many splendorous works of art. Peter Paul Rubens (1577–1640) was one of the great artists of this period. His figures, recognized throughout the world, depict females as robust, round, pink nudes that were cheerful and playful in appearance. For a brief period of time Rubens' nudes were seen as the ideal beauty of women, perhaps due to the energy portrayed by the subjects rather than the appearance of the figures themselves.[6]

From the middle of the eighteenth century until early in the nineteenth century, the definition of beauty switched back and forth between the classical images of the Greeks to the Romantic images of the time. In the nineteenth century, doll-like females began to emerge as the epitome of beauty. These women, with pale, rounded faces, portrayed purity in addition to beauty. No longer did the ideal female possess certain physical traits, but the role of fashion in the determination of beauty came to the forefront.

The twentieth century has seen the concept of beauty change with each successive decade. The advent of motion pictures and later television facilitated the widespread dissemination of images of models and actresses who represented the beauty of their generation. The ideal beauty at the turn of the century was personified by "the Gibson girl," and later in the 1920s by the "flapper." The "pin-up girl" of the 1940s gave way to the "new look" of the 1950s. The "flower child" of the 1960s made the natural look, with long, flowing hair, no make-up, and simple clothing, popular. The 1970s brought excess in hair styles, make-up, and clothing, followed by an emphasis on a healthy, fit appearance at the end of the century. Undoubtedly, the look of beauty will continue to change at an even more rapid pace in the twenty-first century.

To perceive beauty is an emotional experience. The regard for beauty is perhaps one of the most precious of human qualities, and in its most basic form is intuitive or instinctive.[8] Recognizing and appreciating beauty in different forms and analyzing proportion and harmony can be learned. Even though tastes, fashions, and standards of beauty change from age to age, there appear to be certain facial proportions and relationships that provide a basis for diagnosis and planning in facial surgery.

CONSIDERATIONS IN FACIAL ANALYSIS

To form a basis for analysis of the facial components, several general considerations should be taken into account. These factors help shape our concept of beauty and therefore should be noted first. Performing a generalized analysis of the whole before considering the individual parts will create some general impressions on which a more detailed analysis can be constructed.

Age

Consideration of the patient's age is of primary importance in facial analysis. The effect of the aging process is often the main factor involved in the patient's desire for surgery. Although senescence of the facial structures is a normal physiologic process, there may be a discrepancy between chronologic age and perceived age because of an acceleration of these processes. Many patients desire to have their perceived age rolled back to have a facial appearance more appropriate for their actual physical and/or mental state.

Infants and children have a large amount of subcutaneous fat in their faces. Combined with highly elastic skin and a facial skeleton that is not yet fully developed, this imbues them with a round-faced, cherubic appearance. Growth of the facial skeleton during puberty and adolescence results in the characteristic curves and angles of the adult face.

The effects of senescence on the face have been described by Gonzales-Ulloa and Flores (Fig. 9–2).[9] The effects of aging begin to appear at about age 30. Skin laxity is first noted when the upper eyelids begin to overhang the palpebral lines. The inferior palpebral sulci and nasolabial folds become noticeable.

At about age 40 the forehead wrinkles and glabellar furrows begin to appear. Laxity of eyelid skin develops into noticeable excess, and crow's feet begin to appear at the lateral canthi. Sagging of the mandibular line also becomes detectable.

By 50 years of age the forehead and glabellar wrinkles have become permanent and may unite to form continuous lines. Upper-lid sagging may reach the level of the lashes. The outer canthi begin to tilt downward, and the nasal tip begins to droop. Fine wrinkles develop around the mouth and along the neck. Sagging of the cheek skin indicates early loss of subcutaneous facial fat.

At age 60 all skin wrinkles deepen and begin to coalesce. There is a perceived diminution in the size of the eyes resulting from progressive encroachment of the surrounding lid skin. Skin thickness begins to decrease, and the loss of subcutaneous adipose tissue accelerates, producing noticeable deficits in the temporal, orbital, and buccal areas.

By age 70 the nasal tip has descended even further, and the excess skin of the lower eyelids may have developed baglike deformities. Continued loss of subcutaneous fat makes the malar complexes appear quite prominent and the orbits more hollow.

At 80 years of age minute wrinkles coalesce about the face to produce the typical appearance of advanced senescence. Loss of skin thickness, absence of subcutaneous fat, and diminution in the size of the cranial vault combine to make the facial skeleton more conspicuous than at any other time in life.

Sex

Sex differences in facial appearance are the result of hormonal and cultural influences. In general, men tend to have stronger, more angular facial features. Women tend to have rounder, more curved lines defining the face. The gonial angle of the mandible is more defined and prominent in men. The chin is more prominent. Consequently, a receding chin in a man may cause him to be perceived as weak and ineffective. The forehead and zygomatic bones are more apparent in men. The eyebrows are thicker, straighter, and positioned at the supraorbital rim in men. Women's brows are usually

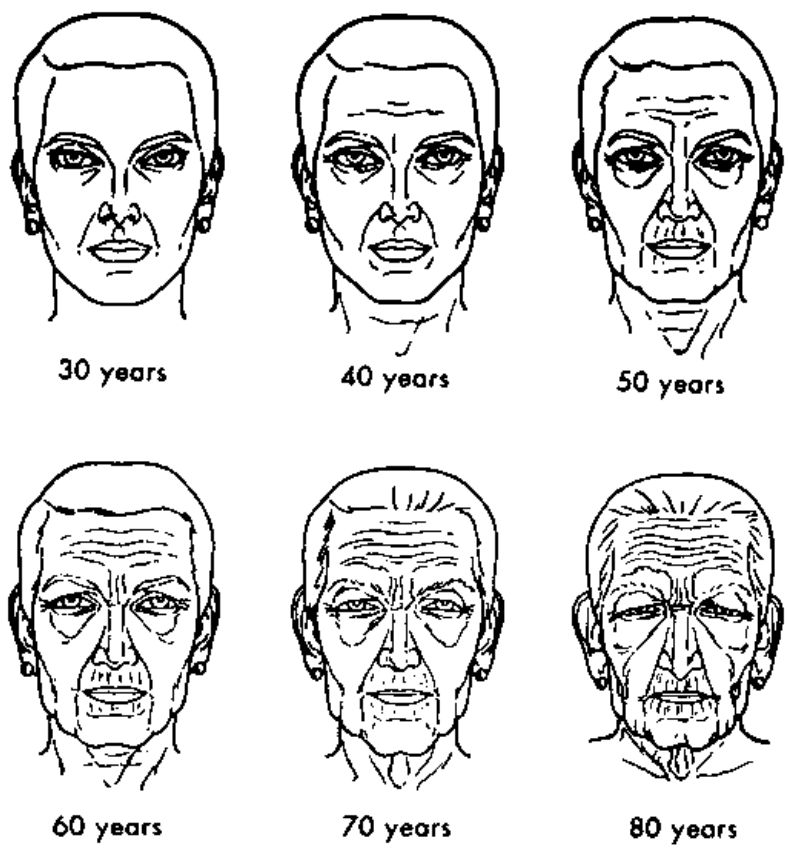

Figure 9–2 Progressive effects of senescence upon the face. (From Gonzales-Ulloa M, Flores ES. Senility of the face—basic study to understand its causes and effects. *Plast Reconst Surg* 1965;36:240. With permission.)

thinner, more arched, and positioned above the level of the supraorbital rim. Facial skin is usually thicker and more textured in men.

Numerous differences are noticeable regarding the ideal noses of men and women. Men usually have larger, broader noses with a dorsum that is straight to slightly convex. Women tend toward smaller noses with a slightly concave dorsum. Their nasolabial angle is preferably obtuse, whereas most men prefer a nasolabial angle of no more than 90 degrees. Overall nasal contour is strongly associated with sex identity. Individuals may wish to masculinize or feminize their facial features to better harmonize with their self-image (Fig. 9–3).[10]

Body Habitus

Just as the parts of the face cannot be evaluated independently, the face cannot be analyzed without regard for the body on which it rests. Different faces are right for different body types. In general, the overall body type is reflected in the face. Tall, slender individuals will usually have longer, thinner faces, whereas short, stout people tend to have rounder faces with less height and more width. Obviously, this type of body and face will tolerate a shorter, broader nose. However, a long, narrow nose would appear out of place on a short, stocky build. Overall, the individual aesthetic units of the face must be in proportion with the rest of the face and, likewise, the face with the rest of the body.

Ethnicity

Aesthetic value is strongly associated with ethnic, cultural, and social background. Facial structure and body habitus also depend on genetic background. Skin type, scarring, and the ability to camouflage facial incisions may vary widely among various ethnic groups. A clear understanding of the patient's desires is absolutely necessary to achieve a result that will please the patient and surgeon. It is ill advised to assume that all patients want westernization of non-Caucasian features. Many patients desire rejuvenative or reconstructive surgery yet wish to retain certain ethnic and cultural features that are important to their self-image.

Personality

Assessing personality traits is part of the general impression gained during the facial evaluation. These characteristics usually cannot be inferred from static photographs. While awake the face is in a perpetual state of movement and dynamic change. This facial movement allows expression of the spectrum of human emotion. Relative movement among the various components of the face provides an endless array of expressions through which a wealth of nonverbal information is communicated. A certain proportion or harmony among the parts gives the face a personality that is perceived to be a reflection of the individual's personality. Surgery should neither distort nor deceive in this regard. An extrovert with a bubbly personality fits well with upturned facial lines and features, whereas a more somber, serious person would most likely be unhappy with such an incongruous appearance.

Hair

Hair can be styled to manipulate the space around the face. Hairstyles can camouflage less attractive aspects of the face and draw attention to the more pleasing features. Although

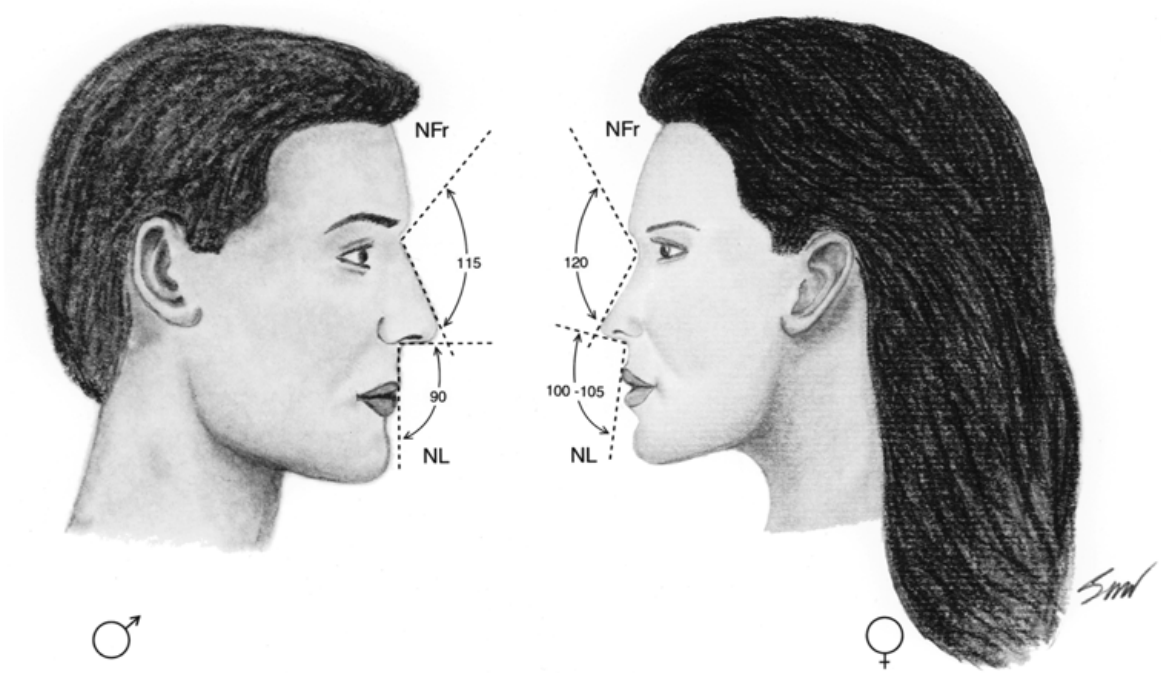

Figure 9–3 Differences between male and female ideals for the nasofrontal and nasolabial angles. *NFr*, nasofrontal angle; *NL*, nasolabial angle.

the forehead is the most difficult aspect of the face to alter surgically, it is easily camouflaged by the hair. Protruding ears and preauricular and postauricular scars can likewise be minimized by judicious use of hairstyling.

FACIAL PROPORTIONS

For facial harmony to exist there must be some degree of relative proportion of the various parts through which an overall balance is achieved. No individual component of the face exists or functions in isolation from the other integral parts. Any change in one part of the face will have a real or perceived effect on the other facial parts and on the whole.

The most basic facial proportions are those that are learned by beginning art students drawing the face. The ancient Greeks taught that the ideal human stature must equal eight times the height of the head.[11] The length of the neck is approximately one-half the length of the head. This distance is measured from the suprasternal notch to the chin and from the chin to the vertex of the skull.

Relative proportions of the hand to the face play an important role for the portrait artist in establishing facial proportions.[1] The length of the hand is three-fourths the length of the head or the length of the face as measured from the chin to the hairline. The width of the hand is one-half the width of the face. Placed transversely, the hand will cover one-fourth the length of the head or one-third the length of the face. Leonardo da Vinci described the relationship of the forehead, nose, and chin on the lateral view as lying along an arc produced by a radius based at the external auditory canal.[11]

The Golden Proportion

A mathematic phenomenon that was recognized at least as early as the fifth century BC by the Greeks and probably much earlier by the Egyptians is referred to as the golden ratio or proportion. This ratio is described by a line consisting of two unequal segments such that the ratio of the shorter segment to the longer segment is the same as the ratio of the longer segment to the whole line. The numerical value of this ratio is 1.61803 and is represented by the Greek letter phi (ϕ).

Numerous mathematic phenomena surround this proportion. The ratio of 1.0:1.618 is equal to the ratio of 0.618:1.0. It has the unique property of being the only number that, when reduced by 1, is its own reciprocal. If 0.618 is added to 1.618, the sum is 2.236, which is the square root of 5.[8]

The Egyptian rectangle was 8 parts long and 5 parts wide. The ratio of 8:5 is 1.6. Ancient Greek temples and statues are replete with examples of the golden proportion. The Hellenist Greeks found numerous proportions between the parts of the human body that corresponded to the golden proportion.[12] The golden proportion figures prominently in the paintings of Leonardo da Vinci and has even been called Leonardo's square, despite its origins in antiquity. This ratio has an intrinsic harmony or beauty, can be found throughout nature, and is particularly appealing to the human eye. Frequent examples of the golden proportion are also seen in the human face, including the ratio of the length to the width of the head and the ratio of the upper face (trichion to nasion) to the midface (nasion to nasal tip).

Figure 9–4 The width of the face is divided into five equal parts; each part is equal to the width of one eye.

Symmetry

Facial symmetry is assessed by bisecting the face through the midsagittal plane and comparing the halves. Although minor asymmetries will be noted in almost everyone, the midline points of the forehead, nose, lips, and chin should lie on this axis. Facial width is then divided into fifths and evaluated for balance among the parts (Fig. 9–4). The width of one eye should equal one fifth of the facial width or the intercanthal distance. Lines dropped from the outer canthi should approximate the width of the neck.[13] The lateral-most fifths of the face on frontal view extend from the lateral canthus to lateral-most point of the helical rim.

Reference Points

The Frankfort horizontal is the standard reference for patient positioning in photographs and cephalometric radiographs. A line drawn from the superior aspect of the external auditory canal to inferior aspect of the infraorbital rim is placed parallel to the plane of the floor to achieve this standardized position. Obviously, these points are more easily determined on lateral skull radiographs than photographs. When determining this position for patient photographs the hair must be pulled back sufficiently to reveal the tragus. The superior edge of the tragus approximates the superior aspect of the external auditory canal. The point of transition between the skin of the lower eyelid and the skin of the cheek is usually discernible and approximates the level of the infraorbital rim (Fig. 9–5).

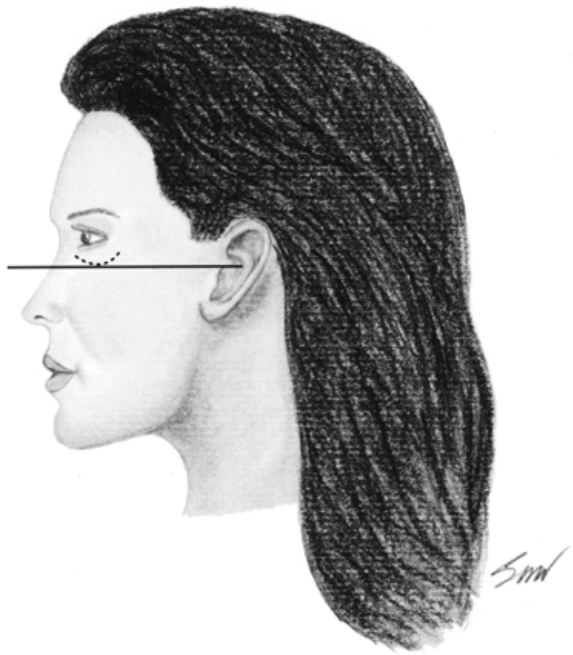

Figure 9–5 The Frankfort horizontal may be approximated on lateral photographs by constructing a line from the superior margin of the tragus to the junction between lower eyelid and cheek skin.

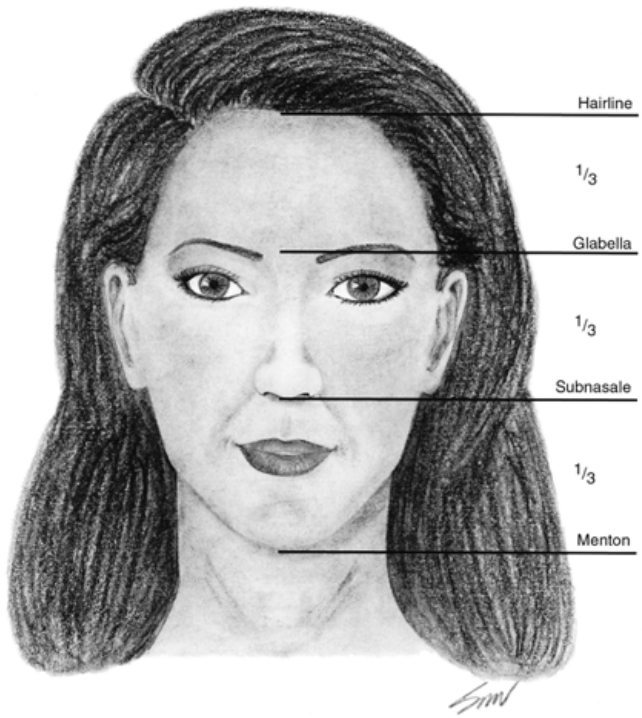

Figure 9–6 The length of the face is divided into three equal divisions at the levels shown.

For measurements of the face to provide meaningful information for communication with colleagues or for accurate records, standard reference points must be used. These have been standardized for use in facial surgery by Powell and Humphreys.[14]

AESTHETIC ASSESSMENT

The initial assessment of the face is to determine facial height. This is measured in the midline from the hairline (trichion, *Tr*) to the lowest contour point of the chin (menton, *Me*). In those with a receding hairline, the trichion *(Tr)* may be determined by the uppermost point of action of the frontalis muscle. The face can then be divided into thirds at the most prominent point of the forehead (glabella, *G*) and the point at which the nasal columella merges with the upper cutaneous lip (subnasale, *Sn*). The upper, middle, and lower portions of the face should be equal using this method (Fig. 9–6).

A second method for assessing facial height takes into account only the middle and lower portions of the face. The initial measurement is taken from the deepest depression at the root of the nose (nasion, *N*) to the menton *(Me)*. Midfacial height *(N-Sn)* should be 43% of the total, and lower facial height *(Sn-Me)* should be 57% of the total length (Fig. 9–7). The following are advantages of this method over the first: (1) the nasion *(N)* is a more reproducible landmark than the glabella *(G)* and (2) imbalance of the upper third of the face (forehead) is not easily amenable to surgical intervention.

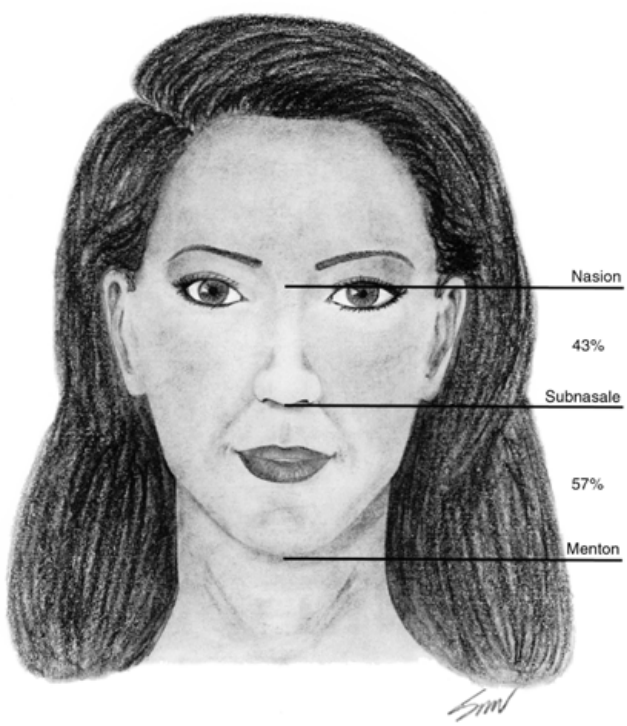

Figure 9–7 The lower face is divided into a 43:57 ratio as shown.

The face is then subdivided into the following five major aesthetic units for further analysis: forehead, eyes, nose, lips, and chin. In addition, the ears and neck should be considered separately and as they relate to the face as a whole.

Forehead

The forehead comprises the entire upper one third of the face. It forms a stable mass that is not readily modified. The aesthetically pleasing forehead produces a gentle convexity on profile with its most anterior point just above the nasion *(N)* at the level of the supraorbital ridge. Other possible forehead shapes include protruding, flat, and sloping.

The nasofrontal angle *(NFr)* is formed at the transition between the nose and forehead, where the nasal dorsum merges with the glabella *(G)*. The angle is determined by a tangent passing through the glabella *(G)* and the nasion *(N)*, and another tangent along the nasal dorsum. This angle should ideally be 115 to 135 degrees (Fig. 9–8).

The eyebrows separate the upper and middle portions of the face and frame the eyes. The medial edge of the eyebrow lies on a perpendicular that passes through the lateral-most portion of the ala nasi and approximately 1.0 cm above the medial canthus of the eye. The brow should begin medially with a slight clublike configuration and gradually taper toward its lateral end. In women the brow should rest just above the level of the supraorbital rim. An arch is desirable in women with its highest point at the level of the lateral limbus. The brow should end laterally at an oblique line that begins at the ala nasi and passes tangentially along the lateral aspect of the lower lid. The medial and lateral ends of the brow should lie on the same horizontal plane. In men the brow may form less of an arch and lie slightly lower at the level of the supraorbital rim (Fig. 9–9).[15]

Eyes

The eyes are perhaps the most expressive part of the face and have been referred to as the window of the soul. Nowhere else in the body are asymmetries more noticeable than in the eyes. The effects of aging become apparent in the eyes sooner than the other parts of the face. With increasing laxity of the skin of the eyelids, the eyes may project a tired, humorless expression that may be quite out of line with actual physical and mental state of the patient.

The width of the eye from canthus to canthus is equal to one-fifth the width of a well-proportioned face. This same measurement should approximate the distance between the medial canthi (Fig. 9–4). The distance between the midpoints of the pupils should equal the distance from the nasion *(N)* to the vermilion border of the upper lip (labrale superius, *LS*).

The supraorbital rim lies slightly anterior to the infraorbital rim when the head is in the neutral position. The lateral canthus is attached posterior to level of attachment of the medial canthus. The lateral canthi may lie on the same horizontal plane with medial canthi or slightly above.

The superior-most point along the arch formed by the free margin of the upper lid is at the level of a vertical passing through the medial limbus. The lateral portion of the free margin of the upper eyelid should parallel a tangent passing along the lateral vermilion border of the upper lip (Fig. 9–9).

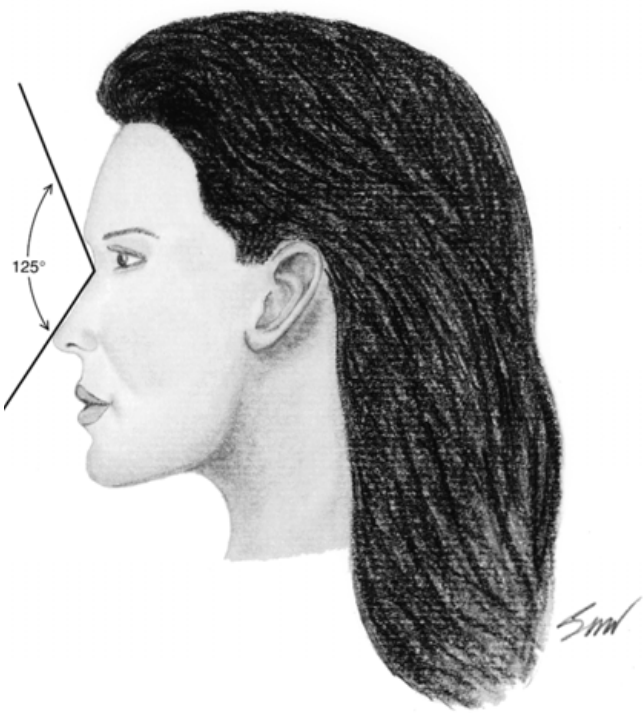

Figure 9–8 The nasofrontal angle *(NFr)*.

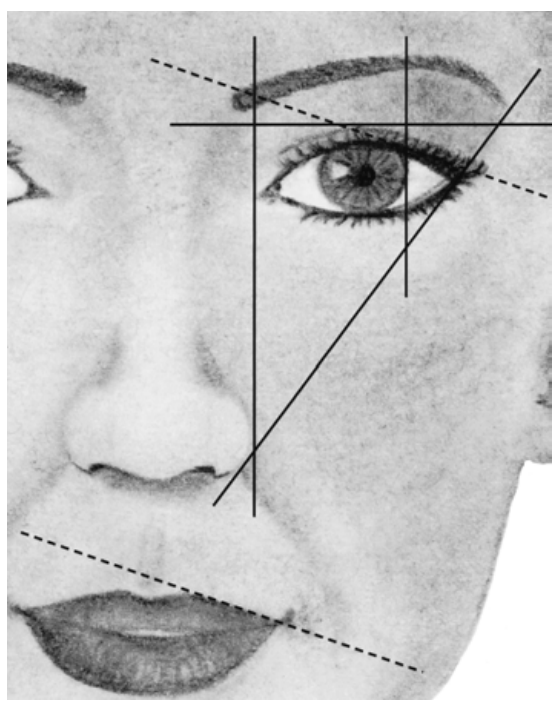

Figure 9–9 Relationships of the eyebrow, eyelids, limbus, nasal ala, and upper lip.

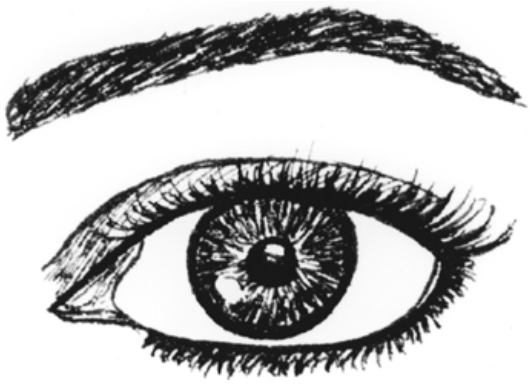

Figure 9–10 Lateral scleral show.

The inferior-most point of the curve of the lower lid margin is along a vertical passing through the lateral limbus. If the lateral one-third of the lower lid does not form a line rising steadily toward the lateral canthus, a subtle defect referred to as lateral scleral show may be present (Fig. 9–10). This may result from excessive excision of lower-eyelid skin during blepharoplasty.

The distance from the lash line to the lid crease in the upper lid varies from 7 to 15 mm and is related to body weight, skin thickness, and ethnicity. The upper eyelid normally covers a small portion of the iris but does not touch the pupil. The lower lid is within 1 to 2 mm of the iris on neutral gaze.[13]

Nose

The nose is the central focus of facial appearance by virtue of its position in the midline of the central third of the face. The tremendous significance of its form and function is reflected in the earliest writings of the Judeo-Christian tradition: "God formed man … and breathed into his nostrils the breath of life."[16] Slight changes in the structure of the nose can sometimes produce dramatic improvements in facial harmony and the perception of the surrounding aesthetic units. The ideal nose should appear natural and in harmony with its surrounding features and not draw attention to itself.[17]

The nose is the central aesthetic unit of the face. It can be further subdivided into aesthetic or topographic subunits. These include the dorsum, sides, tip, alae, and soft triangles.[18] The borders of these subunits allow for camouflage of scars resulting from reconstruction of nasal surface defects (Fig. 9–11). When incisions lie along the margins of these natural anatomic subunits, the eye is less apt to recognize the scar. Excising additional nasal skin to make the defect fit an aesthetic subunit before reconstruction will ultimately produce a less noticeable incision.

The issue of nasal measurement is made quite complex by the plethora of methods available in the literature and the lack of standardization. The various methods have been reviewed by Powell and Humphreys[14] and are summarized here.

Angle Measurements

The nasofrontal angle *(NFr)* has been described previously (Fig. 9–8), but a second angle measurement is necessary to define the proportions of the aesthetic nose. The nasofacial angle *(NFa)* is the incline of the dorsum of the nose in relation to the plane of the face (Fig. 9–12). On the lateral profile a line is drawn from the glabella *(G)* to the most anterior point of the chin (pogonion, *Pg*). The nasofacial angle *(NFa)* is defined when this line is intersected by the line of the dorsum of the nose. The dorsal line should intersect the nasion *(N)* and the tip *(T)* and should be drawn through any dorsal hump that exists.

The third angle measurement in the evaluation of the nose is the nasolabial angle *(NL)* (Fig. 9–3). Lines are constructed between the upper mucocutaneous border of the lip *(LS)* and the subnasale *(Sn)*, and between the subnasale *(Sn)* and the most anterior point on the columella of the nose *(Cm)*. This angle defines the relationship between the nose and the upper lip. It is susceptible to abnormalities of the facial skeleton and dentition. This angle should measure 90 to 95 degrees in men and 95 to 105 degrees in women. Shorter individuals tolerate a more obtuse angle, whereas taller people require a nasolabial angle at the low end of the range for their gender.

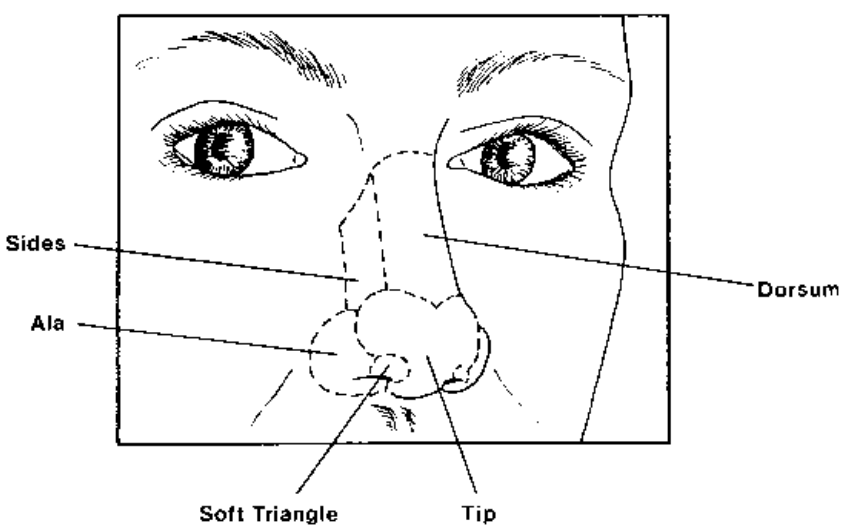

Figure 9–11 Aesthetic or topographic subunits of the nose. (From Burget GC. Aesthetic restoration of the nose. *Clin Plast Surg* 1985;12:463. With permission.)

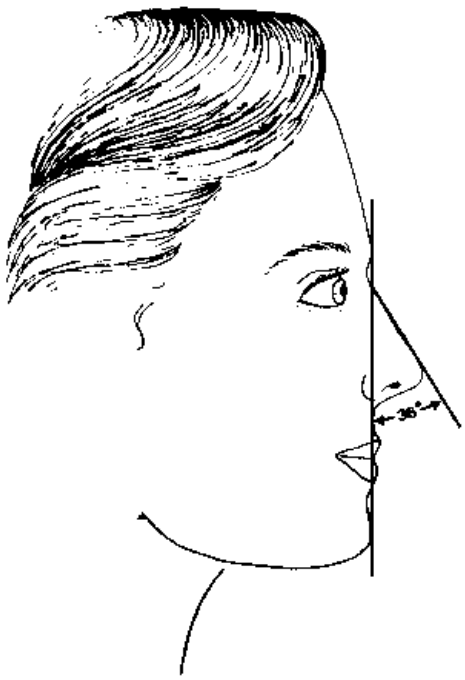

Figure 9–12 The nasofacial angle (NFa).

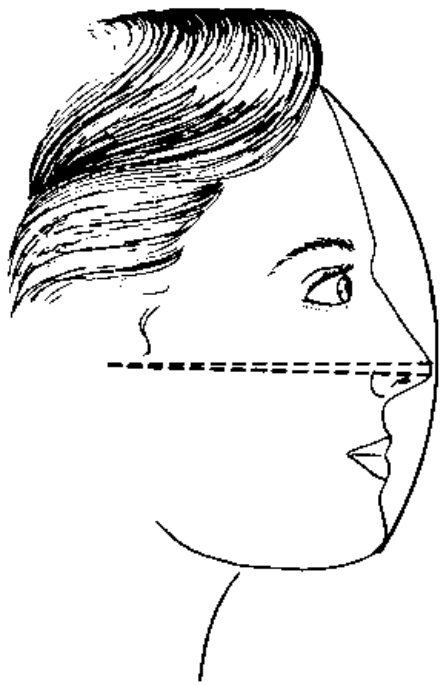

Figure 9–13 Nasal tip rotation occurs along an arc based at the external auditory canal.

Projection

It is necessary to differentiate between nasal projection and rotation. These two quantities are closely related perceptually. Cephalic movement of the lower lateral cartilages combined with lowering of the nasal dorsum can give the illusion of increased tip projection, even though actual projection has not changed. Tip rotation generally occurs along an arc produced by a radius based at the external auditory canal (Fig. 9–13).

Simons[19] prefers to measure tip projection in relation to the length of the upper lip. The upper lip is measured from the vermilion border *(LS)* to its junction with the nasal columella *(Sn)*. The length of the nasal tip *(T)* is measured from the subnasale *(Sn)* to the anterior-most point of the nose. The ratio of these measurements should be 1:1 (Fig. 9–14). Accurate measurement of these distances is difficult because of the complex topography of these structures, even when done on lateral photographs. The method also assumes that the length of the upper lip is normal. Given the variability of upper lip lengths and the difficulties encountered in changing this measurement surgically, this method does not address all circumstances related to the measurement of tip projection.

Figure 9–14 Relationship of nasal tip projection to the length of the upper lip.

Goode[14] uses a vertical line drawn from the nasion *(N)* to the alar groove and constructs a perpendicular line to the nasal tip *(T)* to evaluate tip projection. The ratio of the length of the perpendicular line to the nasal length as measured from the nasion to the tip *(N-T)* should be 0.55 to 0.60. This will maintain a nasofacial angle *(NFa)* of 36 to 40 degrees (Fig. 9–15).

Length

Nasal length has already been discussed in relation to facial proportions (i.e., glabella to subnasale is one-third of the height, and nasion to subnasale is 43% of the distance from the nasion to the menton). However, these methods do not take the nasal tip *(T)* into consideration. Any subjective assessment of nasal length demonstrates the importance of the distance between the nasion *(N)* and the nasal tip *(T)*. This measurement corresponds more precisely with the subjective impression of nasal length than do measurements taken to the subnasale *(Sn)*.

Width

Nasal width is proportional to the width of one eye at the nasal base. If the distance between the medial canthi is proportionate (i.e., one eye-width), verticals drawn from the medial canthi should pass along the lateral alae (Fig. 9–4).

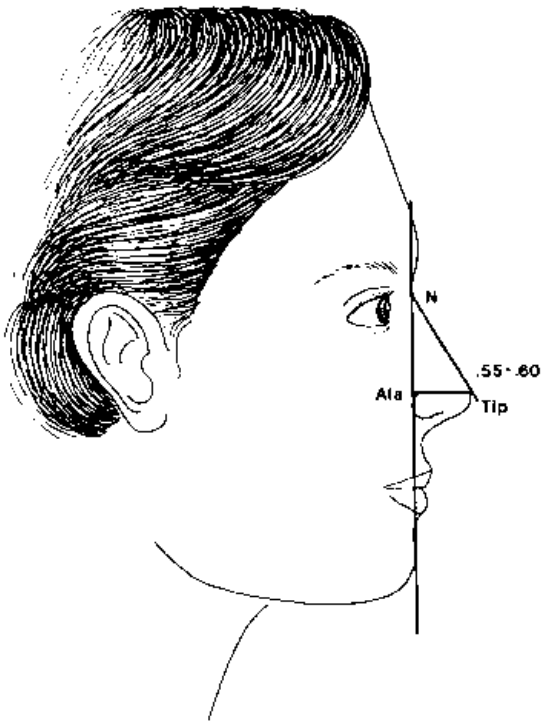

Figure 9–15 The Goode method of measuring nasal tip projection.

Another method for determining proportional nasal width is to measure the nasal length from nasion *(N)* to tip *(T)* and calculate a desired nasal width as 70% of this number.

Basal View

The tip represents about one-third of the total height of the base on basal view of the nose. The nares account for about two-thirds of this distance. When viewed from its basal aspect, the nares are ovoid and obliquely slanted toward the tip. The anterior end of the naris is narrow, whereas the posterior end is wider and rounder. On frontal view the nares are barely visible with the head in a neutral position. Close inspection will reveal the facets of the nasal tip that are a reflection of the underlying soft-tissue triangle of the rim. When viewed in profile, the columella is seen 2 to 3 mm below the level of the alae (Fig. 9–16).

Lateral View

On lateral view the ala-to-tip lobule ratio should be about equal. Tip lobular excess is more pleasing aesthetically than alar excess.[20] The nasal tip *(T)* in profile has a double break produced by the tip-defining point of the lobule anteriorly and the junction of the lobule with columella inferiorly. Just above the tip there should exist a slight depression in the line of the nasal profile known as the supratip break. A more pronounced supratip break is acceptable in women than in men. A straighter nasal dorsum is desirable in men.

Lips

The lips are a dynamic and expressive aesthetic unit of the face. Fullness of the lips and strong definition of the philtrum

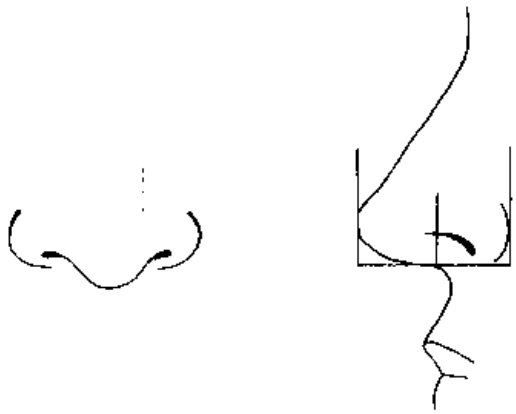

Figure 9–16 The nasal tip. **(A)** Frontal view. **(B)** Lateral view showing 1:1 tip-to-ala ratio.

are associated with youth. A thin vermilion, loss of lip highlights, and flatness are associated with aging.

The posture of the lips, designated as procumbent or recumbent, greatly depends on the underlying dental support. On frontal view the oral commissures are on a line vertical with the medial limbus. The lips are contained within the boundaries of the lower one-third of facial height. The upper lip is measured from the subnasale *(Sn)* to the lowermost point on the vermilion of the upper lip (stm_s). The lower lip is measured from the uppermost point on its vermilion (stm_i) to the menton *(Me)*. The length of the lower lip should be about twice the length of the upper lip, using these points for measurement.

Horizontal lip position can be determined by constructing a line between the subnasale *(Sn)* and the soft-tissue pogonion *(Pg)*. The distance along a perpendicular from this line to the most anterior point of each lip defines its horizontal position (Fig. 9–17). The upper lip should rest 3.5 mm anterior to this line and the lower lip 2.2 mm.[21]

A second method of assessing horizontal lip position is to construct a line between the nasal tip *(T)* and the pogonion *(Pg)* termed the *nasomental line* (Fig. 9–18). The lips should lie posterior to this line. The lower lip ideally falls 2 mm posterior to this line and upper lip 4 mm behind it. This concept was described by Ricketts as the *E-line* and has been incorporated into the aesthetic triangle by Powell and Humphreys.[14]

Chin

The chin is the aesthetic unit that confers strength to the face. The anterior limit is at a vertical dropped from the brow. For the chin to have pleasing form it must be well defined from both frontal and lateral views without appearing knoblike.[13] There should be a definite, but gentle, mentolabial sulcus separating the cutaneous lower lip from the chin.

The chin is included in measurement of the lower portion of the face (*Sn* to *Me*), as well as being part of the length of the lower lip (stm_1 to *Me*). The lower lip and chin compose two-thirds of the lower portion of the face.

When measured from a line drawn between the vermilion border of the lower lip (labrale inferius, *LI*) to the pogonion *(Pg)*, the deepest point of the mentolabial sulcus *(Si)* should lie approximately 4 mm behind this line (Fig. 9–17).

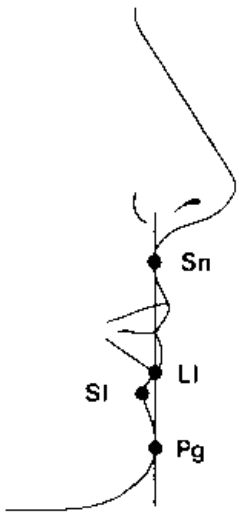

Figure 9–17 The horizontal position of the lips and the mentolabial sulcus relative to a line drawn from the subnasale to the pogonion. *Sn*, subnasale; *Pg*, pogonion.

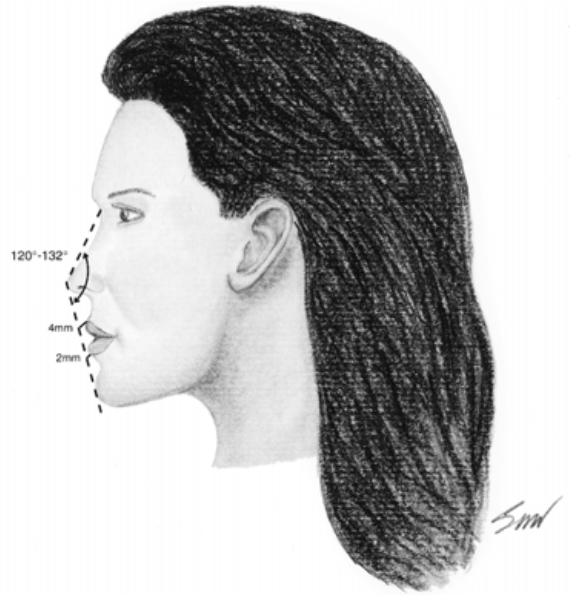

Figure 9–18 The nasomental angle is formed by the intersection of the line of the nasal dorsum and the nasomental line. The upper lip should fall 4 mm posterior to this line and the lower lip 2 mm behind it.

Ears

An additional facial feature to be considered is the ear. This flap-like, cartilaginous appendage has multiple convolutions and is attached to the scalp approximately one ear length posterior to the lateral brow. The superior aspect of the ear is at the level of the brow and its inferior aspect is at the level of the ala nasi.

The width of the ear is 55 to 60% of its length. The line of the posterior aspect of the auricle roughly parallels the dorsal plane of the nose.[22] The long axis of the ear is posteriorly rotated about 15 degrees from the vertical plane (Fig. 9–19). The auricle produces an angle of about 20 degrees with the mastoid posteriorly. The superior portion of the helix should rest at about 15 to 20 mm from the squamous portion of the temporal bone.

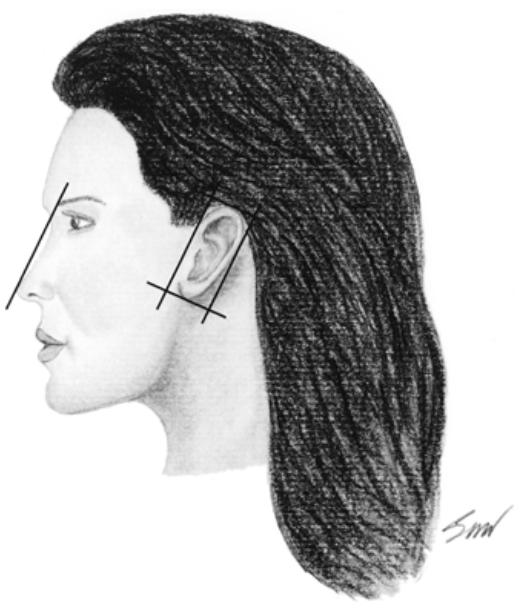

Figure 9–19 The long axis of the ear is parallel to the line of the nasal dorsum. Ear width should be 55 to 60% of its length.

Neck

Although the neck is not usually considered one of the major aesthetic units of the face, its shape, especially in the upper portion, can have a marked impact on the appearance of the chin and lower portion of the face. A low-lying hyoid bone, excessive submental fat, or laxity of the platysma can cause the neck–chin contour to be obtuse and create the perception of a chin deformity that does not exist.

Powell and Humphreys[14] have defined the mentocervical angle *(MC)*, which relates the line of the neck to that of the entire face. The angle is produced by constructing the facial plane from the glabella *(G)* to the pogonion *(Pg)*, and intersecting a line drawn from the menton *(Me)* to the innermost point between the submental area and the neck (the cervical point, *C*). This angle should ideally be between 80 degrees and 95 degrees (Fig. 9–20).

AESTHETIC ANALYSIS OF THE FACE

Gonzales-Ulloa[23–24] based his method of facial profileplasty on the relationship of the facial structures to the facial plane, which he termed the *zero meridian* (Fig. 9–21). In the ideal facial profile, the facial plane lies 85 to 92 degrees relative to the Frankfort horizontal when constructed through the nasion *(N)*. On the forehead, the glabella *(G)* lies just anterior to the plane and then slopes gently posteriorly. The alar crease is posterior to the plane. In the lower face the anterior-most point of the chin should lie within the plane. Using this concept a plane constructed approximately perpendicular to the Frankfort horizontal through the nasion *(N)* will indicate the

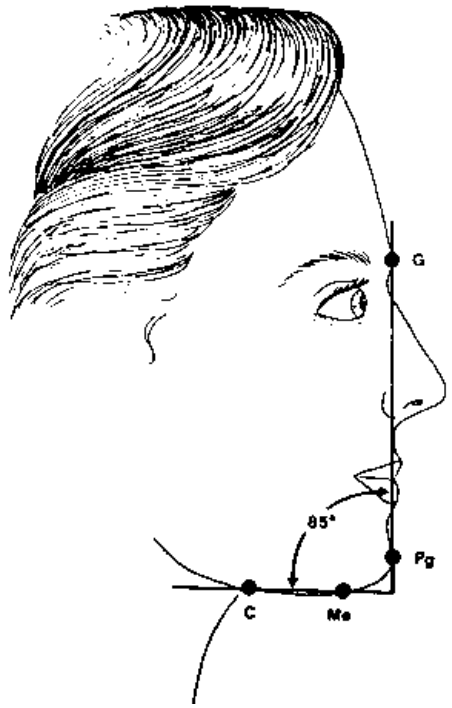

Figure 9–20 The mentocervical angle (*MC*).

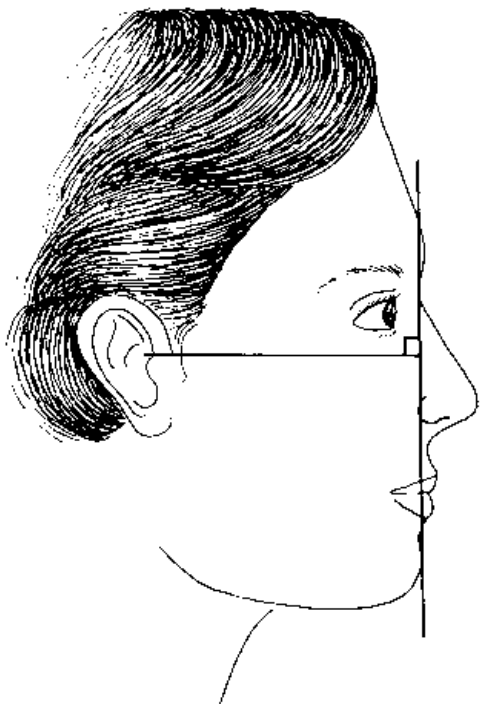

Figure 9–21 The zero meridian of Gonzales-Ulloa.

relative degree of upper, middle, and lower facial protrusion or retrusion. This method does not take into account the angle of the neck or the projection of the nose in the facial analysis.

The aesthetic triangle was described by Powell and Humphreys in 1984.[14] This method of facial analysis allows for consideration of all of the major aesthetic masses of the face and illustrates their interdependence. Angles that have been considered separately can now be assessed simultaneously to evaluate facial harmony. It is first necessary to define one additional angle that has not yet been considered. The nasomental angle is formed by the intersection of the dorsal line of the nose and the nasomental line (Fig. 9–18).

The analysis begins at the forehead, which is relatively stable and the least amenable to surgical alteration. The facial plane is constructed between the glabella *(G)* and the pogonion *(Pg)*. The facial plane determined by this method should intersect the Frankfort horizontal plane at an angle of 80 to 95 degrees. The glabella *(G)* is used as the reference point on the forehead rather than the nasion *(N)* (as used by Gonzales-Ulloa) because the position of the nasion *(N)* can be changed relatively easily by deepening the nasofrontal angle *(NFr)*.

The nasofrontal angle *(NFr)* is then drawn as described previously. This angle should ideally be between 115 degrees and 135 degrees. The nasofacial angle *(NFa)* can now be measured from these lines as well. This angle should lie in the range of 30 to 40 degrees (Fig. 9–22).

Ideal ranges for angles in the aesthetic triangle

Nasofrontal	115 to 135 degrees
Nasofacial	30 to 40 degrees
Nasomental	120 to 132 degrees
Mentocervical	80 to 95 degrees
Nasolabial	90 to 105 degrees

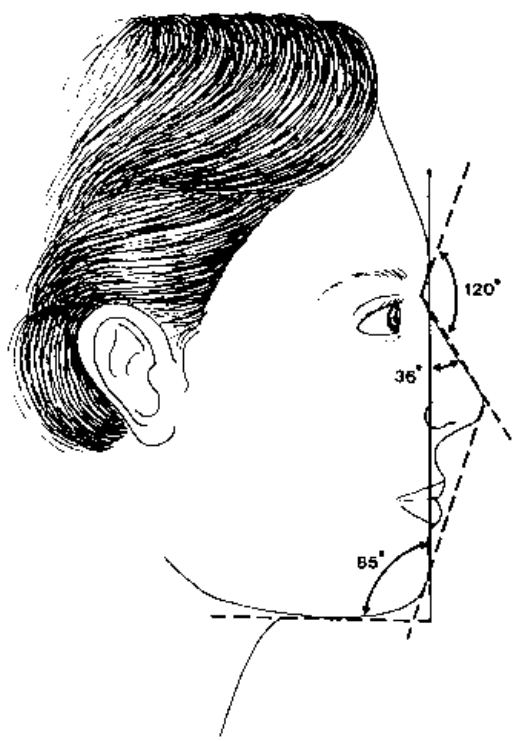

Figure 9–22 Facial analysis using the aesthetic triangle of Powell and Humphreys. Components include the following: (1) the facial plane, (2) the nasofrontal angle (*NFr*), (3) the nasomental angle, and (4) the mentocervical angle (*MC*).

The nasomental line is then constructed between the pogonion *(Pg)* and nasal tip *(T)*. This creates the most important angle of the aesthetic triangle, the nasomental angle. The ideal range for this angle is 120 to 132 degrees. The upper line of this angle, the dorsal line of the nose, is primarily dependent on nasal projection. The lower line, the nasomental line, is readily modified by the position of the chin. The nasomental line also allows horizontal position of the lips to be assessed. The upper lip should lie approximately 4 mm behind this line and the lower lip approximately 2 mm behind it (Fig. 9–18).

Finally, the mentocervical angle *(MC)* is measured. This angle evaluates the neck line and its relationship to the lower face. It is determined by constructing a line between the cervical point *(C)* and the lowermost point on the chin *(Me)* to intersect the facial plane. This angle should measure between 80 degrees and 95 degrees (Fig. 9–20).

The aesthetic triangle is therefore affected by the nasofrontal angle *(NFr)* or depth of the nasion *(N)*, the degree of nasal projection, and the position of the chin. Its appropriateness can be confirmed by the range of normal values for the primary, or nasomental, angle and by the relationship of its upper and lower lines to the facial plane (i.e., the nasofacial angle *[NFa]*) and to the horizontal position of the lips (i.e., 4 mm to the upper lip and 2 mm to the lower lip).

SUMMARY

Numerous methods have been presented for assessment of the individual aesthetic units of the face and for the determination of their relative porportions in evaluating the face as a whole. Other factors, such as age, ethnicity, body habitus, and personality, must also be taken into account in the aesthetic assessment of the face. Although no precise algorithm for the determination of facial beauty exists, preoperative facial measurements assist in the determination of which facial features need change to produce harmony with the face as a whole. Postoperative determination of the same measurements allows for assessment of the adequacy and appropriateness of the change.

GLOSSARY

alar groove junction of the ala nasa with the cheek.

cervical point (C) innermost point between the submental area and the neck.

columella point (Cm) anterior-most soft tissue point on the nasal columella.

dorsal line line passing through the nasion *(N)* and the nasal tip *(T)*; should be drawn through any dorsal hump that exists.

facial plane coronal plane passing through the face at the glabella *(G)* and pogonion *(Pg)*.

Frankfort horizontal line drawn from the superior aspect of the bony external auditory canal to the inferior-most aspect of the infraorbital rim on a lateral radiograph; approximated on photograph by a line from the superior tragus to lower eyelid–cheek skin junction.

glabella (G) most prominent point of the forehead on profile; usually at the level of the supraorbital rim.

gonion most inferior, posterior, and lateral point on the external angle of the mandible.

labrale inferius (LI) vermilion border of the lower lip.

labrale superius (LS) vermilion border of the upper lip.

mentocervical angle (MC) angle of a line drawn from the menton *(Me)* to the cervical point *(C)* relative to the facial plane.

menton (Me) lowest contour point of the chin.

nasion (N) point of deepest depression at the root of the nose.

nasofacial angle (NFa) incline of the dorsum of the nose in relation to the facial plane.

nasofrontal angle (NFr) angle defined by a tangent passing from the nasion *(N)* through the glabella *(G)* and the dorsal line of the nose.

nasomental angle intersection of the dorsal line of the nose and a line from the pogonion *(Pg)* to the nasal tip *(T)*.

nasomental line a line connecting the pogonion *(Pg)* and the nasal tip *(T)*.

nasolabial angle (NL) angle between the line of the nasal columella *(Sn-Cm)* and the line of the upper lip *(Sn-LS)*.

pogonion (Pg) anterior-most point of the chin.

stomion inferius (stm_i) uppermost point on the vermilion of the lower lip.

stomion superius (stm_s) lowermost point on the vermilion of the upper lip.

subnasale (Sn) point at which the nasal columella merges with the upper cutaneous lip.

tip, nasal (T) anterior-most point on nasal profile.

trichion (Tr) anterior hairline at the midline; may be determined in those with a receding hairline as the superior-most point of action of the frontalis muscle.

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Chapter 10

Computer Imaging for Facial Plastic Surgery

Ira D. Papel

Computer imaging in clinical practice has changed enormously since its introduction in the 1980s. Enhanced technologies in computer hardware and software, combined with extensive public information about facial surgery, have increased the popularity and availability of imaging systems in surgeons' offices. Imaging systems have been used for diverse purposes such as resident and fellow education,[1] patient–surgeon communication,[2] detailed facial analysis,[3] archiving of patient images, and marketing of surgical practices.[4] There are many practical, ethical, and legal issues that have been raised by the advent of computer imaging. In this chapter we will try to address the highlights of this interesting tool in facial plastic surgery.

HISTORICAL NOTES

The earliest forms of patient imaging involved free-hand sketches of anticipated surgical results by surgeons. Photographic techniques were not practical or affordable until the second half of the nineteenth century. As emulsion photography became more available, alterations of these images were used to communicate changes to the patient. Patient images in profile against dark backgrounds could be used to demonstrate reduction rhinoplasty or rhytidectomy procedures. In the twentieth century it became possible to print photographs on paper, and this made the above techniques more practical. Drawing on the back of 8 × 10 inch photographic prints could be used to envision profile changes against a background light. Instant photography provided another tool for demonstrating patient characteristics swiftly and could be drawn on to suggest changes.

Another method of demonstrating changes is to project 35-mm slides onto a white drawing tablet. This allows free-hand alteration of the projected image to demonstrate potential surgical changes. When computer imaging became available the relative ease and speed of the computer overshadowed all of these time-tested methods. Although the early computer graphic programs were cumbersome and required practice, the newer systems are much more user-friendly. The common element in any imaging system is that the surgeon must have a clear idea of what he or she would like the patient to see and understand. This requires that the surgeon have a well-developed sense of facial analysis and aesthetics, and the ability to express this with the computer tools available.

SYSTEM REQUIREMENTS

Modern imaging systems may be purchased from various vendors with a variety of features. The core of each system involves an image capture device, such as a video or digital camera. The image is then downloaded into a computer and archived for current or future use. Each imaging system utilizes special software developed for patient image modification. Graphics boards, digital drawing tablet, large hard drive, back-up tape system, monitor, and lighting system are essential. The computer should include at least 64 megabytes of RAM, an 8- to 10-gigabyte hard drive, and a central processing unit of at least 300 MHz speed to cope with the large memory and speed demands of graphic imaging. The equipment should be situated so that patient and surgeon may sit near the monitor and discuss proposed surgical techniques and anticipated changes. Many offices combine the lighting used for traditional photography and computer imaging in one multimedia room. A printer may be used to make hard copies of computer images if desired.

Many commercial systems are available for purchase in a wide range of prices. Those systems with purely digital image capture systems and sophisticated hardware can run as high as $30,000. Basic systems can cost a fraction of this. It is possible to assemble reasonable hardware and purchase software to reproduce these graphic systems for a much lower cost. This requires the ability to integrate computer software and hardware into a working unit.

The patient background should be a consistent color and shade to facilitate a fair comparison of images. A light blue background seems to be aesthetically pleasing and provide good contrast with natural skin tones.[5] Lighting should be provided that eliminates shadows but does not flatten out the details of the face and skin. Indirect modeling lights with umbrellas and/or diffusers from at least two directions will provide excellent images (Fig. 10–1).

Images are captured in the same patient positions as with conventional photography. Soft tissue reference points, such as the tragus, angle of mandible, and anterior hairline, should be visible to enhance analysis potential. It is recommended that all images be stored on the hard disk prior to initiating graphic changes. These will prevent loss of images if there is a computer failure. Each system should have an external back-up, such as a tape drive, to download files at the end of each day.

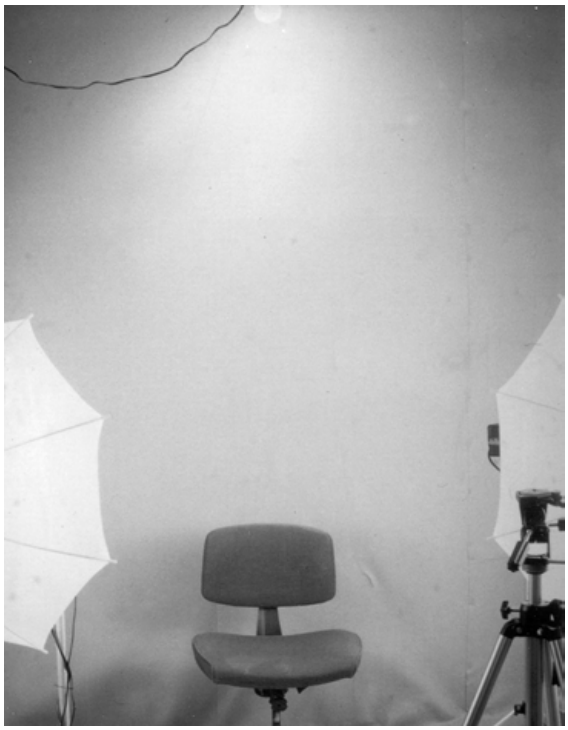

Figure 10–1 Demonstration of lighting system used for computer imaging.

In 1998 it was estimated that 8 to 10% of cosmetic surgery practices were utilizing computer imaging in some capacity. This number was expected to grow to 40% by 2001.[6]

ANALYSIS AND APPLICATIONS

Computer imaging provides an opportunity to assess patient characteristics in a quantitative fashion. These analytical data can be used in conjunction with aesthetic judgment to plan potential facial surgery. Imaging also gives the patient a chance to assess the surgeon's goals, thus creating a very important communication device that was lacking before sophisticated imaging systems were available. The surgeon may also assess whether the patient has realistic ideas of what facial surgery can attain. Based on this interaction either patient or surgeon may decide that surgery is not indicated due to patient–surgeon incompatibility. This is beneficial for surgeon and patient alike.

In planning facial surgery the relationship to quantitative facial ideals may be considered. With the imaging systems it is fairly easy to generate data based on quantitative facial measurements as defined by several authors to assist in facial analysis.[7–10] These techniques have been used for instruction in facial analysis for resident surgeons and fellows. The most common key points for facial analysis, definitions, and aesthetic norms are listed in Tables 10–1 and 10–2.

RHINOPLASTY AND MENTOPLASTY

As an example of quantitative analysis using the computer imaging system, consider the case of a 30-year-old man with a history of trauma resulting in septal and nasal deformity. The preoperative computer analysis is shown in Fig. 10–2. The measurement indicates that the nasal tip projection is adequate, and the Legan angle of 20 degrees indicates poor chin projection. All other parameters were within

TABLE 10–1 Definition of Key Analytic Points

Tragion	Most anterior portion of supratragal notch
Trichion	Hairline at midsagittal plane
Glabella	Most prominent portion of forehead in midsagittal plane
Nasion	Most posterior point at root of nose in midsagittal plane
Rhinion	Junction of bony and cartilaginous dorsum
Supratip	Point cephalic to dome
Tip	Most anterior projection of nose
Columellar point	Most anterior point of columella
Subnasale	Junction of columella and upper lip
Mentolabial sulcus	Most posterior point between lower lip and chin
Pogonion	Most anterior point of chin soft tissue
Menton	Lowest point on contour of chin soft tissue
Cervical point	Junction of tangents to neck and submental areas
Gnathion	Intercept of subnasale to pogonion line with cervical point to menton line

TABLE 10–2 Definition of Measurements

Frankfort and vertical planes	Intercept of tragion to infraorbital rim with glabella to pogonion line
Nasofrontal angle	Intercept of glabella to nasion line with nasion to tip line
Nasofacial angle	Intercept of glabella to pogonion line with nasion to tip line
Nasomental angle	Intercept of nasion to tip line with tip to pogonion line
Mentocervical angle	Intercept of glabella to pogonion line with menton to cervical point line
Nasal height	Nasion to subnasale
Lower facial height	Subnasale to menton
Legan facial convexity angle	Intercept of glabella to subnasion line with subnasion to pogonion line
Nasolabial angle	Intercept of columella point to subnasale line with subnasale to labrale superioris line
Columellar show	Midnares to subnasion
Goode nasal projection ratio	Alar point to tip divided by nasion-to-tip distances. Alar point defined by intercept of nasion-to-ala line with perpendicular line to tip.
Alarlobule ratio	Tip to posterior lobule divided by posterior lobule to ala
Mentolabial sulcus	Distance from labrale inferioris to pogonion line to mentolabial sulcus

normal range. A computer-generated revision is shown and compared with the preoperative image in Fig. 10–3. The patient elected to undergo septorhinoplasty and mentoplasty. The postoperative profile is compared with the computer–generated image in Fig. 10–4. The postoperative analysis is shown in Fig. 10–5, with all measurements now in the normal range. It is also important to use aesthetic sense to judge if the results are pleasing to the eye as well as statistically correct.

RHYTIDECTOMY

A 50-year-old woman is shown on the left in her preoperative appearance before rhytidectomy surgery (Fig. 10–6). The center image is the computer-generated anticipated result and the right the actual 1-year surgical result. Note that the jawline, neck, and midface can be addressed with computer imaging.

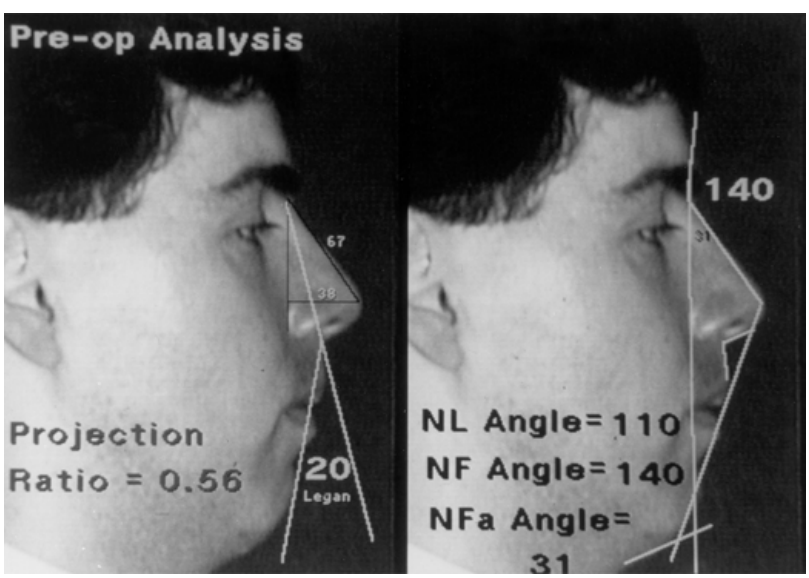

Figure 10–2 Preoperative analysis of patient with nasal and chin deformities.

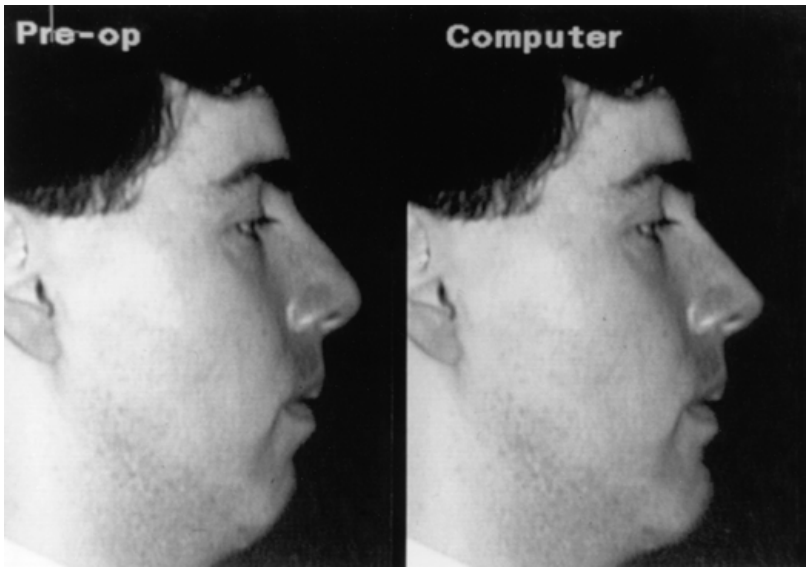

Figure 10–3 Computer-generated changes are compared with the preoperative image.

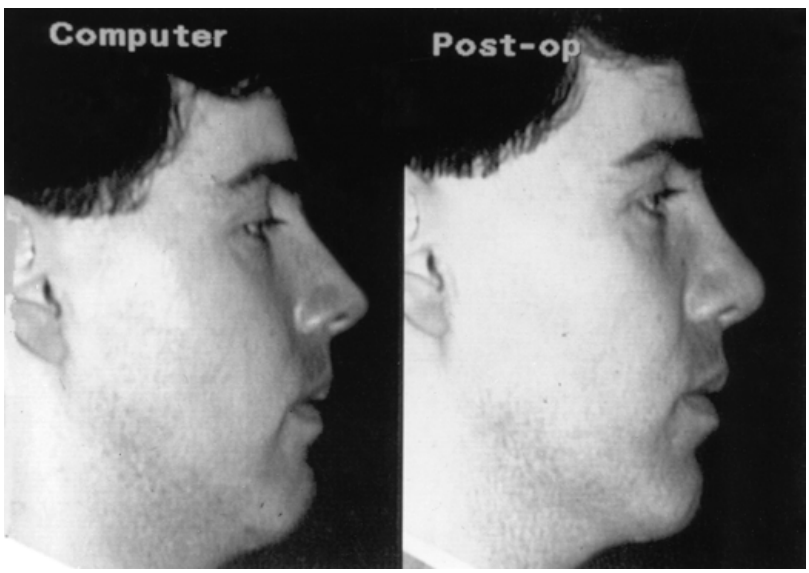

Figure 10–4 The computer image generated before surgery is compared with the actual postoperative image.

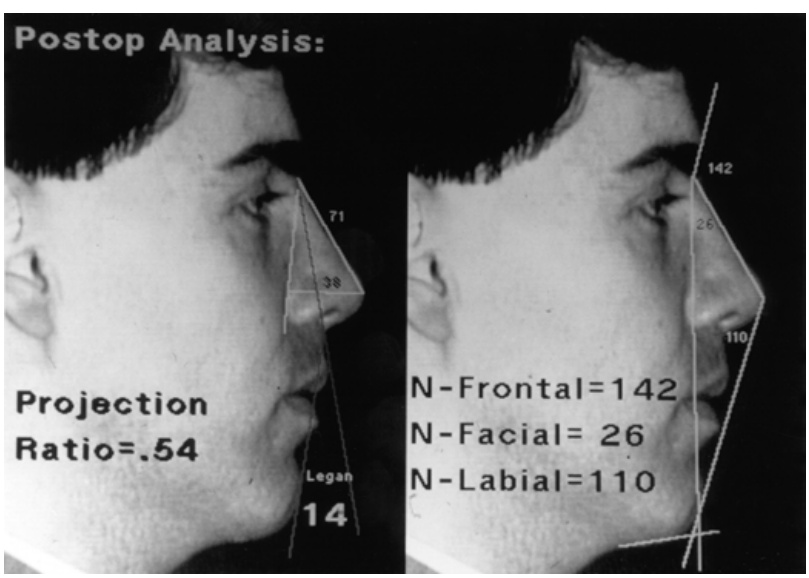

Figure 10–5 Postoperative analysis showing better relationship to aesthetic ideals.

Figure 10–6 A 50-year-old woman shown on the left before rhytidectomy. The center image portrays the computer-generated changes, and the actual postoperative image is on the right.

AUGMENTATION RHINOPLASTY

Figure 10–7 demonstrates a patient with previous rhinoplasty leaving an overresected dorsum and overprojected tip. The left image is the preoperative appearance, the center is the computer-generated changes, and the right the actual postoperative profile. This is an example of the actual postoperative profile not being exactly like the computer projection. It is not unusual for the patient to prefer the actual surgical result to the computer prediction.

Figure 10–8 demonstrates a 16-year-old girl desiring rhinoplasty. Analysis determined overprojection of the tip and shallow nasofrontal angle. The center image demonstrates computer-generated alterations. The right image shows the actual surgical result.

Figure 10–7 This patient has had previous rhinoplasty with a residual overprojected tip and shallow dorsum. Preoperative image is on left, computer-generated image in the center, and actual postoperative appearance on the right.

ADVANTAGES OF COMPUTER IMAGING

Computer imaging has several obvious and enviable advantages in a plastic surgery practice. Imaging has great appeal among prospective patients and has become an expected part of a consultation in some cities. The computer imager can also be used by the surgeon to market his or her practice with its "value-added" implications to potential patients.

The imaging system has tremendous potential for facial analysis and surgical planning. Surgeons in teaching situations can utilize this, as can residents and fellows independently to help develop better understanding of facial aesthetics. Imaging also is very useful for communication of anticipated surgical results to patients. Newer systems with digital cameras can also provide photographic archiving systems with reasonable image quality. Although not as sharp as standard 35-mm photography, digital imaging is improving rapidly and may match film emulsions in time. The cost factor of the imaging system then becomes more attractive when film purchase and processing in a busy surgical practice are eliminated.

DISADVANTAGES OF COMPUTER IMAGING

The major problems with computer imaging arise when a surgeon is overly optimistic about postoperative changes during the imaging session. Imaging must be approached with an honest and conservative attitude. There should be a direct and open discussion about the fact that computer imaging is not equivalent to surgery and never should be taken as a guarantee of a surgical result. The relative risks and benefits of demonstrating to patients projected surgical results have generated discussion related to medicolegal matters.[11] Chavez et al argue that a well-documented and honestly projected imaging session may actually reduce the risk of malpractice suits by better informing both the patient and surgeon of the other's outcome concepts.[6] Some surgeons require that patients read and sign a consent form prior to any imaging session. As in any consultation, overly optimistic

Figure 10–8 A 16-year-old girl with overprojected tip and shallow radix. The preoperative image is on the left, computer image in the center, and postoperative appearance on the right.

predictions and modifications will probably lead to patient dissatisfaction.

Additional disadvantages include the expense and time necessary to include computer imaging in a consultation. The hardware can occupy significant space but can be included in a photography room utilized by many surgeons. The time required to record the images, generate modifications, and consult with the patient about the images may add 30 minutes to a cosmetic consultation. The surgeon who performs all of these functions personally will experience a significant increase in time spent. Some surgeons employ their office staff to record and modify the images, followed by surgeon review and modification as needed.[12] This method does save some time at the initial consultation but requires a second visit and additional surgeon time.

In spite of the time and resource commitments, most surgeons who use computer imaging in their practices feel that the increased patient education, decreased anxiety, and easy demonstration of ancillary procedures make the investment worthwhile.

ETHICAL ISSUES

All surgeons who practice facial surgery are taught to be conservative in predicting surgical results. Computer imaging, especially in a young surgical practice, creates temptations for the surgeon to portray unrealistic results. The surgeon and his or her staff must resist this pattern and honestly communicate realistic outcomes. Although imaging can be used to market a practice in a tasteful and honest manner, care must be taken to stay within realistic limits in predicting surgical outcomes. To stray beyond this limit will create dissatisfied patients and possible legal complications.

One more issue raised by digital and computer imaging is the problem with truthful presentation at medical meetings. The advent of computer-generated lecture presentations with all-digital visuals creates the potential for altered images presented as postoperative results. This possibility may call into question conclusions about surgical techniques. Some imaging programs have built in icons, which identify altered images, but this is not universal and may be deactivated by a sophisticated computer user.

SUMMARY

Computer imaging is a valuable tool in facial plastic and reconstructive surgery. Through computer graphic technology the surgeon can project realistic-looking postoperative predictions to share with patients and fellow surgeons. The ability to measure and evaluate facial features is invaluable for surgical planning and outcome analysis. Discussions about legal and ethical issues will continue, guided by a growing practical experience.

TABLE 10–3 Aesthetic Norms for Facial Analysis

Profile Analysis	
Frankfort and vertical planes	80–95 degrees
Aesthetic triangle	
Nasofrontal angle	115–130 degrees
Nasofacial angle	30–40 degrees
Nasomental angle	120–132 degrees
Mentocervical angle	80–95 degrees
Anterior facial height	
Nasal height ratio	47%
Lower facial height ratio	53%
Legan facial convexity angle	8–16 degrees
Nasolabial angle	90–120 degrees
Columellar show	3–5 mm
Goode nasal projection ratio	0.55–0.60
Alar lobule ratio	1:1
Vertical lip ratio	1:2
Mentolabial sulcus	4 mm
Frontal Analysis	
Facial height:	
Nasal height ratio	47%
Lower facial height ratio	53%
Nasal width	Equal to intercanthal distance
Intercanthal distance	25.5–37.5 female; 26.5–38.7 male

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Chapter 11

Photography in Facial Plastic Surgery

Theda C. Kontis

Photographic documentation of patients is an integral component of cosmetic and reconstructive surgery. Consistent standard photographic technique allows critical analysis of aesthetic features of the patient before and after surgery. Occasionally, preoperative review of photographs will demonstrate an irregularity or an asymmetry that was not recognized during the patient encounter. A frequently quoted dictum is that demonstration of these irregularities to the patient preoperatively is considered "counseling," whereas postoperative explanations are viewed by the patient as an "excuse" for a less than perfect result.

Preoperative photographs are essential for all plastic and reconstructive procedures. Insurance companies frequently use photographs for preauthorization purposes. Patients may "forget" how they looked before surgery and some request to see their preoperative photos. Photographs are an important part of the patient record for medicolegal documentation. The surgeon also can refine and adjust technique from review of surgical successes and failures.

EQUIPMENT

The gold standard for photodocumentation has been the single-lens reflex (SLR) 35mm camera (Fig. 11–1A). Image standardization can be achieved with the SLR camera because the image seen in the view finder is identical to the photographic image generated.

Digital photography may soon make 35mm photography obsolete. Many surgeons are currently considering conversion to a strictly digital format (Fig. 11–1B).

35MM PHOTOGRAPHY

Camera

Although a high-quality 35mm camera body provides excellent imaging, the body need not be the top-of-the-line model with extravagant features. Medical portrait photography does not require the ability to perform special effects, so the simpler cameras often suffice. A motor drive for film advancement allows for a smooth and rapid photographic session with the patient and may permit automatic exposure bracketing (see later). One disadvantage of the motor drive is the tendency to snap photos without allowing enough charge recycle time for the flash units. A good rule of thumb is to wait 2 seconds after the camera flash ready light is illuminated before taking the next picture.

A "databack" accessory prints the date or other important data on the photograph. This feature is standard in a few cameras or can be added to many 35mm camera bodies. This can aid in patient identification and can be used to time the postoperative photographic sequence. A log book of patient photographs updated by a compulsive photographer can substitute for a databack.

A

B

Figure 11–1 **(A)** Typical 35mm camera used for portrait photography. **(B)** The digital camera may replace the 35mm camera for surgical photodocumentation. (Photographs courtesy of Nikon, Inc., Melville, NY.)

If the time required for film processing is not acceptable, a Polaroid (Polaroid Corporation, Cambridge, MA) camera is a good back-up to have in the office. Polaroid photography is used most commonly when photographs are sent to insurance companies for surgical preauthorization. In general, polaroid images lack the high resolution of 35mm slides with conventional processing.

Lens

The most important piece of photographic equipment (and often the most costly) is the camera lens. A 90mm or 105mm "macro" lens is recommended for portrait photography. The macro telephoto lens minimizes facial distortion by allowing a 1:1 representation onto the film.

An ultraviolet or skylight filter can be attached to the lens to protect it from dust, fingerprints, and scratches. Close-up filters can be purchased and provide an inexpensive way to obtain magnified views. However, magnifying filters are not required if a macro lens is used.

Aperture Setting (F-Stop)

The lens f-number determines the brightness of the image by adjusting the amount of light that enters the lens. The f-number series is equivalent to 1.4, 2, 2.8, 4, 5.6, 8, 11, 16, 22, 32. Changing to the next larger number decreases the image brightness by half. Lowering the f-stop to the previous number doubles the brightness of the photo. The larger the aperture (smaller f-number) the greater the maximum shooting distance, but the lower the depth of field (image sharpness). The larger the aperture, the shorter the flash recycling time.

In portrait photography, one must select the appropriate f-stop that maximizes image depth of field and shooting distance while keeping the image bright. Tardy[1] suggests determining the correct f-stop for a given studio setup by photographing a subject holding tongue depressors marked with the aperture setting used, developing the photos, then selecting the best image and using the f-stop labeled. One will find that this f-stop setting will generally work for most photography in the office studio, except on darker skinned patients. The f-stop should be lowered one-half to one f-stop when photographing these patients to open the lens aperture and brighten the image.

Because the surgeon cannot instantly view the photographs taken, it is often a safeguard to obtain photographs at different f-stop settings by using exposure "bracketing." This camera feature allows the photographer to select three to five different f-stops at one time, generally one-half to one f-stop above and below the recommended f-stop setting. With one depression of the shutter release button, three to five images are taken with a range of selected aperture settings. Exposure bracketing can be performed manually with any camera.

Lighting

A studio setup is the most desirable method for obtaining standardized portraits. Most studios use background lighting and soft umbrella lighting (Fig. 11–2). A slave-triggered light can be installed on the ceiling behind the patient to prevent shadows behind the subject and to increase depth of field (Fig. 11–3). This key light or "kicker" flashes when the primary flash is triggered.

Two umbrella flashes, one placed on each side of the patient, allow soft lighting for portrait photography. Umbrellas are available in two types: the "reflector" type with an opaque inner lining of white, gold, or silver, and the "shoot-through" umbrella, which is made of a translucent material. The reflectors bounce the flash light off of the umbrella onto the patient. The shoot-through umbrellas (Fig. 11–4) let the flash light through the umbrella. For small studios with low ceilings, shoot-through types are preferred because they allow the flash unit to be positioned close to the subject. The umbrella flash units should be positioned at the same level and equidistant from the camera. A cable

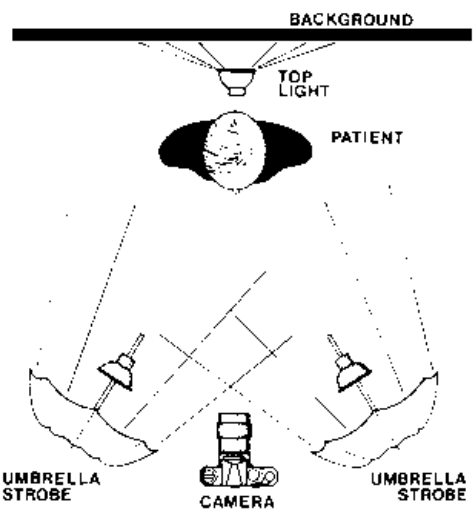

Figure 11–2 Suggested placement of patient, lights, and camera for in-office studio.

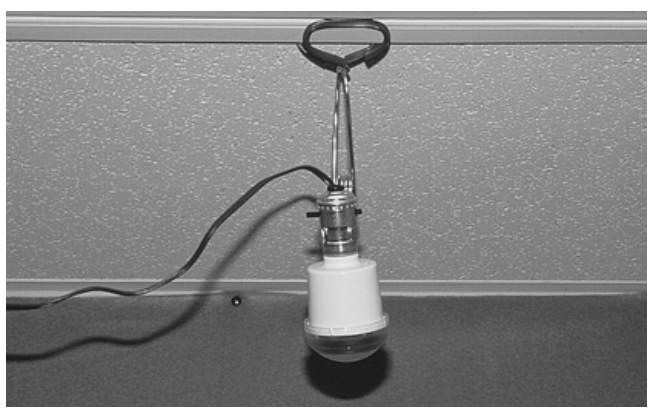

Figure 11–3 A slave flash unit is mounted on the ceiling behind the patient. This flash is triggered by the camera flash unit or umbrella flash, and it eliminates background shadows.

Figure 11–4 "Shoot-through" umbrella light produces soft lighting of the subject.

from one of the umbrella flashes is attached to the camera body accessory shoe.

Electronic flash units that attach to the camera body are required when patients are being photographed outside the studio setting. Because of the variability in flash units, it is recommended that trial photographs be taken using different f-stop settings to determine the optimal flash parameters. A "ring" flash is not used for portrait photography. These flash units provide shadowless lighting, which is optimal for photography of body cavities; however, the harshness of this lighting makes it unsuitable for portrait photography.

Background

The ideal color of the background in portrait photography is light blue or green. These colors do not overwhelm the subject, are appealing to the eye, and allow for a greater depth of field. A dark background appears to envelop the subject and diminishes the image's three-dimensional quality (Fig. 11–5). The background should be a single solid color, without folds or creases in the material. The background should be flat, not shiny, to avoid having light reflected back at the camera. Background materials include felt, window shades, or a papered or painted wall with a flat finish.

Film

The 35mm slide transparency (2 × 2 in.) is the most common format for cosmetic surgery photodocumentation. There are two general types of Kodak slide film: Kodachrome and Ektachrome (Eastman Kodak, Rochester, New York). Fuji (Elmsford, New York) also makes a film similar to Ektachrome (Fujichrome). Ektachrome and Fujichrome are more economical than Kodachrome because they can be developed quickly using the widely available E-6 process. Ektachrome slides have a sharp image but must be stored in a cool, dark environment to limit image degradation and color fading.

Kodachrome film has a more stable emulsion. Kodachrome 25 and 64 are used for portrait photography because they produce photographs with excellent image quality and resolution. Kodachrome film is processed at fewer laboratories than Ektachrome. The film is usually mailed to processing centers with turnaround time of up to 10 days.

Film speed (ISO number) refers to the film sensitivity to light: the higher the number, the greater the sensitivity. A film speed of ISO 200 is twice as "fast" or "sensitive" as ISO 100. Films with lower ISO numbers (25 and 64) are used for portrait photography to reduce image grain. The studio setting, with adequate artificial light, allows for the use of lower

A

B

Figure 11–5 The same patient is photographed using light blue **(A)** and black **(B)** backgrounds. A light blue background allows the patient to appear more three-dimensional and is aesthetically pleasing when printed in either color or black and white.

speed film. The fine grain of the lower speed films allows preservation of image sharpness for print enlargement or projection onto a screen during a presentation.

Slide transparencies are easily converted to color prints in the office using a Polaroid Daylab. These inexpensive units generate photographs that are better in quality than a standard Polaroid photograph. The cost for production of one photograph is approximately $1.50.

PORTRAIT PHOTOGRAPHY

Consent

Consent for photodocumentation should be obtained from patients prior to the photographic session. These photographs may be used to demonstrate surgical results to other patients and physicians. At the time of consent, one may also obtain permission for use in publications or transmission on the internet. Patient confidentiality must be maintained, of course.

Standardization

Standardization of pre- and postoperative photographic views is of paramount importance in facial plastic surgery because it facilitates image comparison. Identical views should be obtained for each type of surgery performed. Photography can be standardized by photographing the patient in the same studio, with the same equipment, using the same focal length distance from the patient, and using a set of standardized views (Table 11–1). The major photographic goals are consistency and reproducibility. These goals can be met by having a simple protocol that is always followed (Figs. 11–6 and 11–7).

The patient is seated on a stool that can swivel and roll. The patient's feet should touch the floor. Preferably, the stool should have a short back to help the patient assume a straight posture. The patient is asked to "swivel" in the chair or "roll" the chair to obtain optimal positioning.

A tripod reduces motion artifact and helps standardize patient images. A wall-mounted camera, with the camera mounted in the vertical position and perpendicular to the facial plane, can also be useful. Most physicians prefer to hold the camera, orienting it vertically or horizontally as needed. Motion artifact is minimal due to the short duration of the electronic flash.

Accurate and reproducible photographic techniques can be augmented by using a focusing screen with a grid pattern. This is a plate inserted into the body of the camera with lines for orientation of the subject. Focusing screens can be used in many of the more expensive SLR camera models. The grid is viewed through the view finder but is not printed onto the photograph. Multiple grids have been designed to assist in portrait photography.[2,3] A horizontal line aids in positioning the frontal and base views by preventing head tilt. It also helps with the lateral view by lining up the Frankfort plane (an imaginary line from the top of the tragus to the inferior orbital rim, parallel to the orbital floor). Vertical lines assist in correctly "framing" the image on the screen. The experienced photographer can achieve accurate and symmetric photographs without using a grid. The photographer can "imagine" the vertical and horizontal lines for proper patient positioning. In the base view, the tip of the nose would be seen between the brows (Fig. 11–6G, H). Surgeons often disagree about patient positioning for the oblique view. Some photographers line up the tip of the nose with the edge of the opposite cheek,[4] whereas others feel that this extensive rotation results in a "five-sixths" view rather than a "three-fourths" view. Lesser rotation, by aligning the medial canthus with the oral commissure, may better demonstrate the relationship of the nose to the opposite cheek[2] (Fig. 11–8).

One method of standardization of photographs uses permanent markers fixed on the walls of the studio. The patient is asked to swivel in the chair and look at each marker. This standardizes the position of the eyes and head for reproducible results. Patient positioning is the most difficult skill to master and is a common cause of unsatisfactory photographs.

Relevant anatomic details must be well visualized. Hair may need to be tied back or pinned back with bobby pins or hair clips, and glasses should be removed. Photographs of otoplasty and microtia patients are assisted by the use of a headband to pull hair away from the ears (Fig. 11–9).

TABLE 11–1 Recommended Standardized Photographic Views for Specific Procedures

Procedure	Views
Rhinoplasty	Frontal Base R/L lateral R/L oblique
Blepharoplasty	Frontal (full face) Frontal (close-up eyes) Eyes open Eyes closed Upward gaze R/L lateral
Rhytidectomy	Frontal R/L lateral R/L oblique
Otoplasty	Frontal Posterior R/L lateral R/L lateral close-up

R, right; L, left.

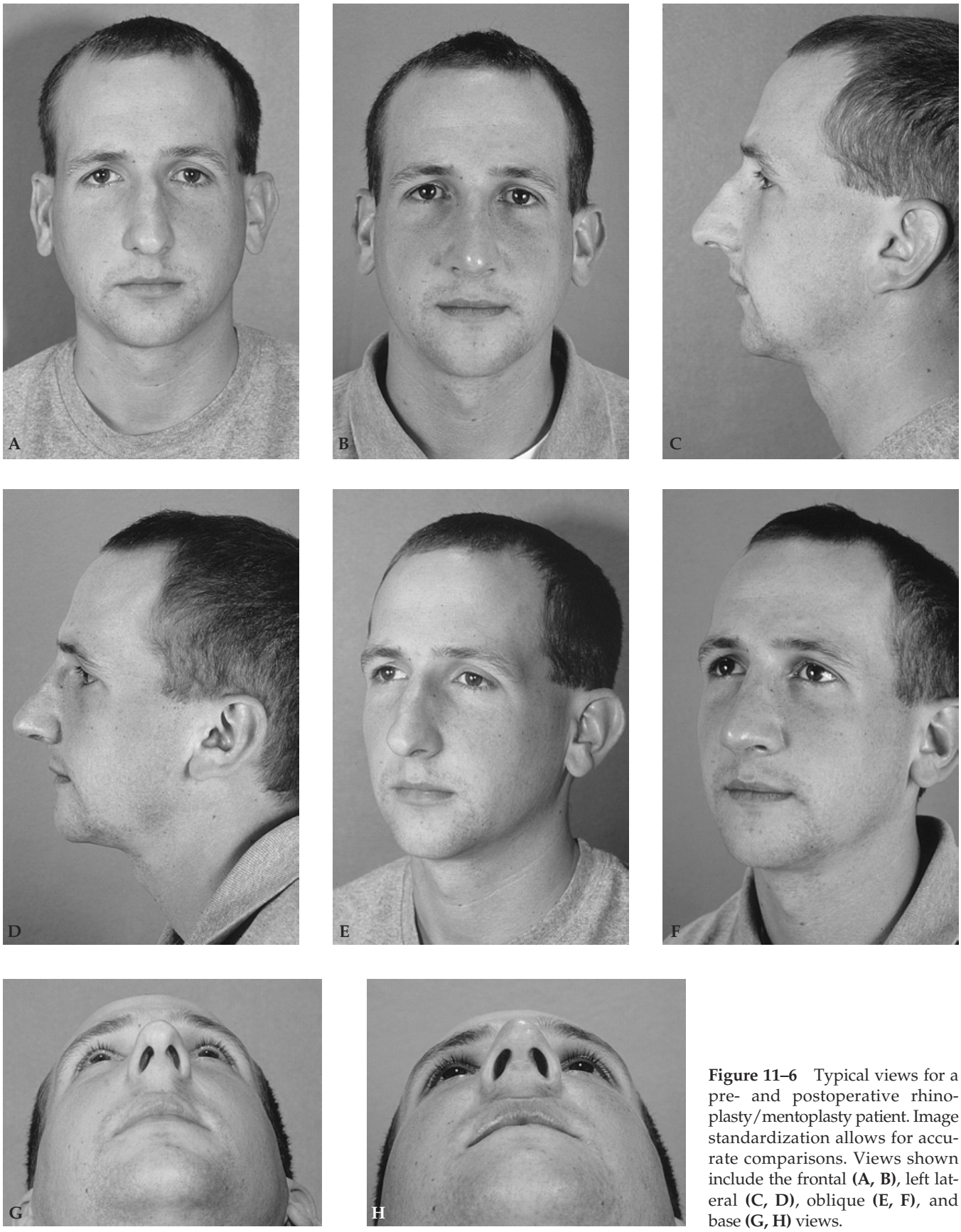

Figure 11–6 Typical views for a pre- and postoperative rhinoplasty/mentoplasty patient. Image standardization allows for accurate comparisons. Views shown include the frontal **(A, B)**, left lateral **(C, D)**, oblique **(E, F)**, and base **(G, H)** views.

Figure 11–7 Typical close-up views for a blepharoplasty patient. Eyes open frontal view **(A)** demonstrates right brow ptosis. Eyes closed view **(B)**. Eyes looking up view **(C)** accentuates the infraorbital fat pad prominence. Right **(D)** and left **(E)** lateral views demonstrate infraorbital fat pad prominence and upper lid hooding.

Figure 11–8 **(A)** The three-quarter oblique view places the medial canthus in line vertically with the lateral oral commissure. **(B)** The "five-sixths" oblique view aligns the tip of the nose with the edge of the cheek.

Figure 11–9 A headband can be used to pull hair away from the patient's ears when photographing otoplasty or microtia patients.

DIGITAL PHOTOGRAPHY

A Time of Transition

Digital photographic technology is rapidly improving and will likely become the standard for photodocumentation in the near future. One of the advantages of digital photography is the ability to view photographs in near–real time. The images can be saved or discarded, and retaken at the same sitting. The images are stored on a disk or other removable medium that can be loaded into a computer and saved indefinitely. Film purchasing and processing, along with issues of emulsion stability, are no longer relevant.

Camera

Digital photography, first developed in the 1970s, involves image capture onto a charged coupler device (CCD). This image is formatted by a digital signal processor into a digital code that

is translatable by computer. The data are then stored on a memory device, temporarily within the camera, and usually downloaded onto a computer.

All of the major camera manufacturers (Nikon, Canon, Olympus, Sony) market digital cameras. The qualities of a digital camera in which one should be interested include the resolution, lens quality, zoom capabilities, and price. Currently, most digital cameras suitable for portrait photography are priced at around $1000. Although digital cameras are becoming less expensive, they can become superseded by improved technology in as little as 6 months.

Resolution is one of the most important characteristics of a digital camera. Digital photographic resolution has not yet approached the fine resolution of 35mm photography. There are more than 35 million pixels (points of light with uniform color) in a 35mm photograph, but only about 2 million with a digital photograph. In general, 1.4 million pixels is required for a photograph to be acceptable. Higher resolution digital photography requires longer time for image loading and transfer and more memory for image storage. "Standard" resolution is actually "low" resolution, which is adequate for computer photography (i.e., e-mail and web sites, preferred because the image downloads quickly) but not for the printing and enlarging of photographs. The "medium" mode of resolution is referred to as "high" resolution, and the highest resolution is called "super fine" or "ultra-high" resolution. In general, the higher the resolution, the better the quality and usefulness of the photograph.

As in 35mm photography, the lens system is also important in digital photography. The lens should be made of optical glass and have macro capabilities for close-up photography. Focusing is generally automatic with the lower model digital cameras. The more sophisticated digital cameras possess capabilities for manual focusing, exposure settings, and flash settings.

Digital cameras consume considerable amounts of battery power for image capture, viewing, and flash photography. For office photography, it is suggested that the camera have rechargeable batteries using the latest battery technology, and have converters for use with 120 V ac.

Lighting

An acceptable digital photograph can be taken with ambient natural lighting. One or two umbrella flashes and a slave light for background illumination are probably still required in the studio setting. Software packages can eliminate shadows and manipulate shading after the photograph has been taken.

Image Storage

The number of images that can be stored in the camera itself can range from one to several hundred, depending on the size of the memory card. The higher the image quality, the fewer the number of photographs that can be stored on a card. Digital cameras currently have 8- to 64-MB removable media cards (occasionally referred to as "digital film" and "e-film"). Removable media cards currently available include SmartMedia (Olympus, Melville, NY), Memory Sticks (Sony, Park Ridge, NJ), and CompactFlash (Kodak, Rochester, MN; Canon, Lake Success, NY; Nikon, Melville, NY) cards. Media cards that can store larger numbers of images are becoming available as technology improves.

Hard drive storage of digital photographs on the personal computer requires adequate free disk space, usually at least 50 MB per photograph. The images can be compressed into a JPEG file, which allows 1 to 2000 images to be stored on one gigabyte of hard drive space. The images can also be stored onto a writable compact disc (CD). Approximately 100 high-resolution images can be stored on a CD. In the future, advances in image compression technology will allow about 10,000 images to be stored on one gigabyte of hard drive, or the equivalent of one CD. Although not yet available for digital photography, digital versatile disc (DVD) may be the storage modality of the future, allowing storage of 4.7 gigabytes of information on one disc.

Software

Digital cameras generally come with cables and software necessary for downloading images onto the personal computer. The software used is as important as, if not more important than, the selection of the digital camera. Digital file formats include JPEG, TIFF, and BMP. It is essential that the software used be compatible with these formats. Software packages are available, such as Adobe PhotoShop and Adobe PhotoDeluxe (Adobe Systems, Inc., Seattle, WA), which allow manipulation of the images once downloaded. Once digitized, there are numerous possibilities for image manipulation: shadows can be eliminated, photographs can be rotated, text can be added, photographs can be merged or added to the web, and so forth. The photos can also be placed into a slide format, such as Powerpoint (Microsoft, Redmond, WA), for presentations. Although most presentations at meetings still rely on 2×2 slides, the digitalization of images will probably result in more computer-driven "slide" presentations in the future.

Printers

A printer is required for conversion of a digital image to a photograph. A dye sublimation printer with three color ribbons offers the best quality, and photograph production costs on average about 67 cents per photo, or about half the cost of Polaroid prints. The cost of these printers is currently about $300.

Use of these printers is strictly limited to the generation of photographs. The office surgeon, who probably does not need to print many high-quality photographs, may not require this printer.

Making the Transition to Digital Photography

DeLange and Diana[5] compared the costs of digital versus 35mm photography. The conversion to digital photography requires the purchase of expensive equipment. The cost decreases dramatically after start-up because film purchasing and developing fees are not generated.

It has been suggested that before converting exclusively to digital photography one try scanning the 35mm slide images into the computer, thereby digitalizing a standard photograph. The image can then be manipulated and the surgeon can determine how digital photography can fit into his or her practice.

35mm versus Digital Photography: Advantages and Disadvantages

Digital photography will replace the 35mm camera as the medium of choice for patient documentation in the near future, and the personal computer will probably replace the slide projector for image display for presentations.[6] The advantages of the 35mm camera include its familiarity and ease of use. Disadvantages of traditional photography

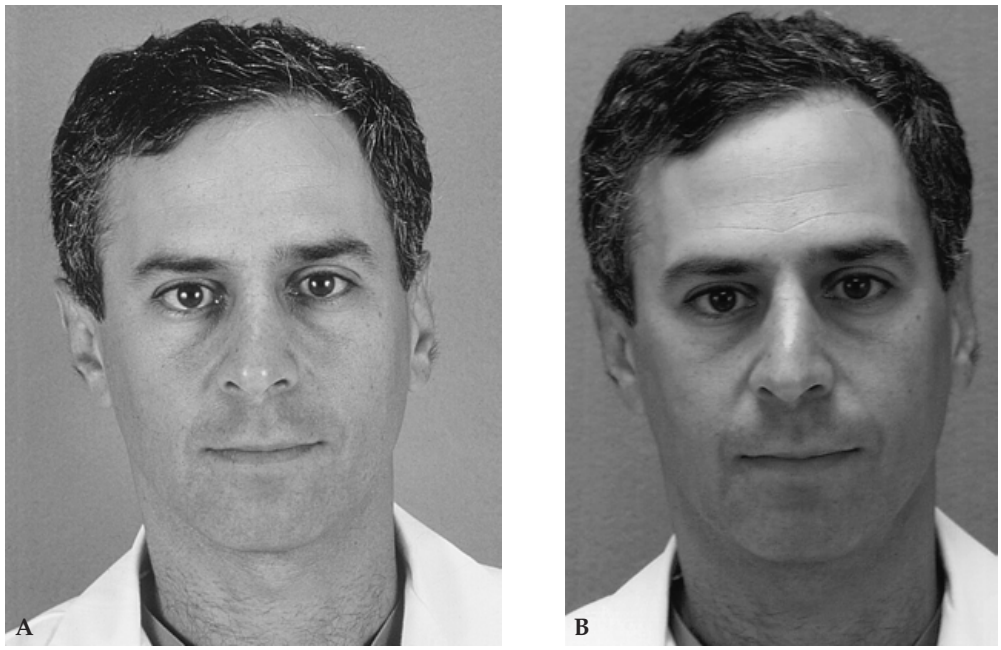

Figure 11–10 Comparison of 35mm **(A)** and digital **(B)** photos of the same subject in the same studio setting. (Equipment used: Nikon 6006 35mm camera with Kodachrome 64 film; Olympus D-620L digital camera, super high resolution. Digital photograph courtesy of Matthew Cooper.)

include the expense of film purchasing and developing, and the delay in film processing. The images are not viewed immediately, so mistakes in patient positioning, lighting, and aperture setting are not seen until the slide has been developed and the patient has left the office. Virtually all surgeons have at one time or another operated on a patient only to find that the preoperative photographs "didn't turn out." (More often that not, the postoperative result is superb!)

The storage space required for 2 × 2 slides is enormous. Slides can be stored in cabinets, boxes, notebooks, and so forth. The slides must be correctly labeled and cataloged accordingly so that they can be found with ease.

Pertinent information about the subject of the image must be transcribed onto a 2 × 2 slide or the date printed onto the slide using a databack accessory. Digital photographs have all the important information stored with the image, and the date or other information can easily be added or removed from the image.

Digital photography is more expensive than 35mm photography to initiate but much less expensive to maintain. The image capture, storage, and retrieval are instantaneous. The photograph, once taken, is viewed immediately, and can be deleted and retaken if necessary. There is no need for film purchase and developing, and no delay in image production. There is a learning curve with the use of digital photography and its software.

The resolution of digital images is still less than optimal. Although digital images are not as sharp and clear as 35mm photos, the high-resolution images are certainly acceptable (Fig. 11–10). Image resolution will continue to improve.

Image stability is superior with digital photography. Slide emulsions can degrade but a digital photograph is stored as computer data and will theoretically remain unaltered indefinitely. (The image data should probably be backed up every 5 to 10 years.) Storage on a CD, floppy disk, or hard drive takes little space, but one should be aware that new methods of image storage may make current disk drives obsolete and incompatible with the new hardware.

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Chapter 12

Ethics and the Facial Plastic Surgeon

"Doing the right thing professionally and personally"

Donn R. Chatham

THE FIRST ETHICS TRAGEDY

The Greek poet Pindar (474 BC) writes about the mythical physician Asklepios, who had an illustrious career in mending and healing:

> *"Those who came to him with flesh devouring sores,*
> *with limbs gored by gray bronze or crushed stones,*
> *all those with bodies broken, sun struck or frost bitten,*
> *he freed of their misery … some with medications,*
> *… others he set right through surgery." [11:47–53]*

But this comes to a tragic end:

> *"Even wisdom feels the lure of gain: gold glittered in this hand*
> *and he was hired to retrieve from death*
> *a man whose life was already forfeit;*
> *Zeus hurled flashing lightning and drove the breath,*
> *smoking from the breasts of savior and saved alike." [54–60]*

Perhaps this fable highlights the first case of medical ethics. A competent physician was induced by greed to perform a forbidden medical service. He violated devine law and paid the penalty. Medical ethics, then and now, is about the physician's attitude and dealings with the price of saving and healing life.[1]

DEFINITION OF "ETHICS" (OR, WHAT IS ETHICS ANYWAY?)

> *"Ethics is a subject that those colleagues beneath you need to be concerned with."*
> *Anon.*

What Is Ethics?

Although *ethics* is a word we hear often, we have a hard time defining it. It has been said that a man who is good in his heart is an ethical member of any group in society, whereas one who is bad in his heart is an unethical member. Ethics implies a state of goodness verging on saintliness to which we might aspire but which we are unable to achieve.[2] Random House defines ethics as "moral principles, philosophy of values dealing with the rightness or wrongness of certain actions and to the goodness and badness of the motives and ends of such actions." The fellowship pledge of the American College of Surgeons in part goes: "I pledge to pursue the practice of surgery with honesty, and to place the welfare and rights of my patient above all else."

Perhaps ethics is a personal expression of what one believes is right and one's capacity to give meaning to that belief. It often is associated with honesty and truthfulness. When one thinks about an ethical person, such as an ethical physician, one inherently believes that person will deal with patients in an honest and truthful manner, and not put his or her own needs first. In a simplistic way, ethics can be thought of as doing what is right.

Historically, ethical codes have evolved from the time of Hippocrates, through Roman influences, into the writings of Thomas Percival in the eighteenth century, which in turn had an influence on the Code of Ethics of the American Medical Association (AMA). (The original AMA ethics writings began as a set of admonitions to ensure peaceful relations between physicians!)

How do ethics relate to the facial plastic surgeon? Why is the existence of ethics important to all physicians? Who should decide what is ethical behavior and what is not? Ultimately, the most important ethical behavior involves the moral bond to which the physician commits in trying to help the patient. One of the goals of this chapter will be to better acquaint facial plastic surgeons with ethical concepts and guides.

SIMPLE ETHICAL QUESTIONS

A number of ethical questions come to mind when thinking about facial plastic surgery, both cosmetic and reconstructive. Here are some of them:

- Is cosmetic surgery inherently ethical or not?
- Is reconstructive surgery more ethical?
- Who should be performing cosmetic and reconstructive surgery?
- What is the difference between a revolutionary new procedure and experimental surgery?
- Who should be primarily making decisions about another person's health?
- How should information about plastic surgery be communicated to the public?
- What is "ethical advertising"?

- What is ethical conduct with regard to behavior with one's peers?
- What constitutes ethical behavior when running a viable business?

The ultimate ethical vanguard remains how the physician behaves with regard to patient care because the patient comes to the physician asking for help. In asking for help the patient presumes that ethical care will be delivered.

Surgeons generally have avoided issues of ethics, believing that if they work hard, study perennially, and do their best technically, all will be well, even though life's experiences teach us that such a notion is naive. But no longer can we just "do the best job that we can" and then move on, as we once did. What we have failed to do in the past, attorneys, insurers, governments, and hospitals now frequently do with ill-informed glee. For example, if we know that certain operations are unnecessary but perform them anyway, how can we protest when outside forces intervene?[3]

A MODERN FABLE

Here is a little story about a plastic surgeon and a patient:

Once upon a time, Jane made an appointment with a plastic surgeon. She had never felt very comfortable with her appearance; now she wondered if plastic surgery could help make her happier and add to the quality of her life. After all, she had been reading the paper and seeing ads on TV that talked of the "miracles of cosmetic surgery." The results showed beautiful people—real patients who were smiling, looked great, and seemed very self-assured.

Jane had chosen Dr I. M. ZeBest because he had a very nice ad that extolled his many credentials. He claimed experience and competency in many procedures, and she liked his ability to provide "no-scar surgery." In addition, she had heard that she should only see a doctor who is "board-certified" and Dr. ZeBest was that.

On the day of her consultation, Jane found Dr. ZeBest's office to be palatial, with ornate furnishings. She was asked to complete some paperwork and told that payment was expected that day before the consultation. One of the questions asked was, "Have you ever had any cosmetic surgery in the past and were you happy with the results?" She had had a dermabrasion procedure several years earlier, with modest results and no real problems.

After a 2 $\frac{1}{2}$-hour wait she was escorted into the private office of Dr. ZeBest. When she met Dr. ZeBest, he introduced himself as the "premier plastic surgeon in this part of the country" and asked her what she needed to change. "Nothing drastic, Dr. ZeBest," were her words as she began to describe her feelings about her face. She wanted some subtle improvements. Doctor ZeBest interrupted Jane after a minute or so, telling her that she needed lots of work on her face if she wanted to be really attractive and thus happy. He suggested she have several procedures done. Doctor ZeBest asked her if she was satisfied with the work done by the previous surgeon. He looked at her scars, whistled as he shook his head and muttered "um, um, umm."

One of the procedures Dr. ZeBest suggested was relatively new, but he had just returned from a seminar the previous week where he had heard about the technique. He felt that he knew just about enough to perform it. Certainly, after he had performed it a few times he would pick up the nuances, and some patient had to be first, after all. Jane asked about possible risks and complications. Doctor ZeBest told her not to worry, he "did not allow complications with his patients." He saw no need to worry Jane by revealing details about the three liability settlements that had been judged against him. Jane told him that she'd had some sort of "hepatitis thing once" but she believes she is over it now.

When it was time to discuss fees, Jane realized she did not have enough money to afford all of the procedures Dr. ZeBest recommended. He advised her to take out a short-term loan and told her that his staff would help her apply through a financing company with which he worked. Jane obtained the loan but later told Dr. ZeBest's receptionist that she had to sell some family jewelry to come up with the final amount.

Before Jane left Dr. ZeBest's office, his assistant told her about a "special personalized skin care regimen" to be started prior to surgery. "Doctor ZeBest wants all his patients on this and it is crucial you maintain this for the rest of your life." We have skin products that have been "developed especially for our patients, and can be purchased only through our office." Thirty minutes later, Jane left with a sack of several jars and bottles of skin rejuvenation lotions and creams and was $245 poorer.

Surgery was scheduled. Jane arranged with some difficulty to be off work for 10 days, and prepared herself. The day before her surgery, one of Dr. ZeBest's friends called him. "I. M., I have a tee time tomorrow at Augusta National for the two of us. Fly down with me in the morning and we will be back by nightfall." Being an avid golfer and Masters fan, Dr. ZeBest wanted to go, but doing so would involve postponing Jane's surgery, creating an inconvenience for her.

"What the heck," he reasoned, "patients change their plans all the time." So he decided to go. He asked his receptionist to call Jane to inform her about the "emergency surgery" he had to perform the next day. Because of her job commitments, it would be another 6 months before Jane could get back on the surgery schedule. She trusted Dr. ZeBest and didn't want to interview another surgeon, so she rescheduled despite losing some vacation time. The morning of surgery she wanted to speak with him one last time preoperatively, as he had promised. But the nurses gave her so much Versed she could barely keep her eyes open and she couldn't think of what she had wanted to say.

Doctor ZeBest was a bit tired that day. The previous day had been exhausting, and he had stayed out late having dinner and drinks at a friend's birthday celebration. This morning his headache was relieved with a Tylenol #3. "I can operate better when I'm tired than most other surgeons can on their best days," he boasted to himself. The surgery seemed to go well, except for a little extra bleeding. "All bleeding stops eventually," he chuckled to his assistant. He noticed a dark nevus on the back of the patient's shoulder that bothered him, even though Jane had never mentioned it, and he excised it for her and discarded it.

In the recovery room, the nurses paged the doctor to tell him that Jane's blood pressure was a bit high, about 200/150. He told them to either find the anesthesiologist or call one of the internists because hypertension was not his thing. Later Jane was discharged.

Jane called the office on postoperative day (POD) no. 4, a bit worried about some redness and swelling of one side of

her face. She asked to speak with Dr. ZeBest, and the nurse told her he was seeing patients all day and could not be interrupted. She told Jane to put heat on the swelling and see them at her one-week visit.

On POD no. 7 in the office, Dr. ZeBest said to Jane: "Darling, you look beautiful!" Jane thought she looked as if she had been hit by a train and she was depressed. There was an ugly dark blue swelling in her cheek, and one side of her mouth seemed not to move as well as it had. "Don't worry, dear, everything will heal perfectly," Dr. ZeBest said with a smile as he backed out of the door. She wanted to ask Dr. ZeBest several questions, but in 40 seconds he was gone, leaving his nurse to remove Jane's sutures. Jane asked when she was to see Dr. ZeBest again, and his nurse replied, "I will be the main person you will see, but we can make an appointment in about 6 months for the doctor to see you." At that moment, Jane did not feel very good about herself, or very beautiful.

COSMETIC SURGERY: INHERENTLY ETHICAL OR NOT?

"The creed of the cosmetic surgeon: if you're happy, I'm happy."

J. Goin and M. K. Goin[4]

"It is just as important to make patients happy as it is to make them well."

Sir Wm. Osler[5]

"The only contraindication to repeat plastic surgery is poverty of funds or tissue."

David Hyman[6]

Plastic surgery generates a great deal of interest and analysis on the part of the public, the medical community, and the payers of health care. Especially significant is the distinction between reconstructive ("to restore") surgery and cosmetic ("to enhance") surgery. The ethics of cosmetic surgery creates interesting viewpoints. Is cosmetic surgery inherently ethical? Is it possible that some procedures themselves are unethical or perhaps are performed sometimes for unethical reasons?

Psychological studies of beauty suggest that more attractive people are thought to be more "sensitive, kind, interesting, strong . . . sociable . . . exciting" and to "experience happier and more fulfilling lives than less attractive people."[7]

For example, let's take the subject of aging. What is the morality of treating the affliction of aging? Is aging an actual disease, and must it be treated as such? Is it ethical to classify aging, which most people would consider a normal process, as an abnormality to be treated? Is there a message that we as practitioners of cosmetic surgery are sending to society to the effect that looking older is undesirable and must be addressed? Or has society already decided this for us, and are we merely responding to a need? If our society valued aging and the people who age the most, then wrinkles would be considered worthy of praise.[8]

Let us also examine the goal of cosmetic surgery. Traditionally the goal of medicine has been health, and this remains the goal for most of medicine, both Eastern and Western. But the ideal outcome of many cosmetic procedures has become not health but happiness with the surgical result. Is it ethical to replace "health" with "happiness with the result"? So now the measure of a surgical outcome is not whether the patient is healthier but whether he or she likes what was done? For example, if a patient requests we make an ornamental scar on one cheek, we know that this does not promote physical health. Would we hesitate to perform such a surgery? Yet the creation of a scar as a by-product of a cosmetic procedure (say, tightening of a sagging face) is a routine event.

What if a patient were to request removal of an organ because the person believes this would improve his or her self-esteem? Most surgeons probably would not agree. However, we routinely remove sections of skin from the face and lids (portions of the largest organ) solely in the hope that the new appearance will help the patient to feel better.[9]

If one decides that surgery performed solely for beautification is unethical, then other questions arise. Are cosmetic dental procedures ethical? Do procedures designed to simply whiten teeth or to position shiny veneers over existing teeth violate this prohibition against beautification? No one would argue that haircuts are in themselves unethical. Is the application of skin tattoos unethical? And what about application of ultraviolet radiation to skin for the purpose of darkening it? After all, one can make the case that this is inherently unhealthy, promoting a myriad of health problems.

On the other hand, is the application of nonionizing radiation to skin (i.e., laser "skin resurfacing") more ethical than the services of tanning centers? After all, a second-degree burn is intentionally created for the skin to take on a "more desirable" texture and color.

Today's medical model has the surgeon as a cafeteria worker, displaying the various therapies to patients and allowing them to choose on the basis of risk, price, benefit, or whatever else the patient considers to be important.[9]

And what of the question, Is reconstructive surgery more ethical than cosmetic surgery? One could argue that it may be. Or one could argue that surgery that ends up being mutilative (some head and neck cancer extirpations) perhaps is not as ethical as it could be. What of nasal surgery? Is reduction of a nasal fracture (reconstructive) more ethical than a pure rhinoplasty (cosmetic)? What about septorhinoplasty? Just what is unethical surgery and who is responsible for defining it?

PHYSICIAN QUALIFICATIONS: WHO SHOULD BE PERFORMING PLASTIC SURGERY?

"Cur'd yesterday of my disease
I Died last night of my physician."

Matthew Prior

Much has been made of the qualifications surgeons must hold before being allowed to call themselves "plastic surgeons" and perform procedures defined as "plastic surgery procedures." Who should the practitioners be? Should they all come from the ranks of a certain specialty, board, or society? Does the completion of a certain training program or board certification confer to a surgeon special qualities and qualifications that can only be obtained in this manner? Certainly a patient seeking plastic

surgery should expect the surgeon to be well trained in the performance of that procedure and capable of handling any complications that might arise.

Some surgeons disparage the training, education, or skills of other surgeons. Is this ethical? On the other hand, if a surgeon knows that another physician is not trained to perform certain procedures and has seen serious complications arising from that physician's past surgeries, is there a moral obligation to warn the patient against surgery? Then there are those surgeons who masquerade as the knight in armor riding the white steed, whose mission in life is to save society from the surgeons who have invaded the others' turf. Some of these champions have been guilty of defending their own financial coffers while demonstrating little altruistic concern.

Today's plastic surgeon stands on the shoulders of giants who emerged from general surgery, orthopedics, otolaryngology, ophthalmology, maxillofacial surgery, and dermatology—so he or she should grumble least of all about territorial disputes.

Another issue is the development and use of new surgical procedures and devices. As no surgeon is born with the innate knowledge of how to perform a surgical procedure, all must be learned. Some are more complicated than others. Once in practice, the surgeon may learn of a new procedure while attending a medical conference or perusing a journal. When is it ethical to introduce a new and perhaps partially unproved procedure on one's patients? And is there anything wrong with that surgeon promoting her- or himself as the "first surgeon in this area" to become trained in this implicitly improved procedure?

Also along the lines of training and proficiency, is it possible for every surgeon to become an "expert" in every procedure related to his or her specialty? The standard of care does not say that any procedure must be "perfect" or the outcome guaranteed. But society does expect a certain baseline of competency from its physicians, including surgeons. The moral issue here is the competence of the surgeon.

Another question we must ask is, should physicians be performing procedures in their own office or office surgical suite if they cannot gain privileges to perform the same procedure in an accredited surgical facility or hospital, which is subject to strict peer review? Should prospective patients be told that their surgeon does not have credentials to perform certain procedures in an outside licensed medical center? One could also argue that due to the imperfect system of credentialing, which is subject to local politics and sometimes the personal agendas of competing surgeons, it may be impossible in some institutions for a given physician to ever obtain credentialing by that body. Or one could argue that a lack of peer credentialing exposes the patient to excessive risk.

But who can disagree that the foremost goal of our profession should be the issue of competency. Don't all patients deserve a competent physician, and certainly a competent facial plastic surgeon? It would seem that rules, regulations, admonitions, and efforts that point in the direction of enhanced competency would be worthwhile goals.

It has been stated that "most surgeons have a defect, congenital or acquired, of exaggerating the number of operations they do and of underestimating the failures. Some may call this lying; the more forgiving might say that it is evidence of rampant optimism."[10]

So our final prayer may become, "God, please provide me with a surgeon who knows what he or she is doing."

HEALTH CARE DECISION MAKING: WHO SHOULD DO?

"From the poetry of Lord Byron they drew a system of ethics, compounded of misanthropy and voluptuousness."

Lord Macaulay

At first glance, this may appear to be a simple question. But in today's world, there are many players vying for center stage when surgery is contemplated.

First, of course, there is the *patient*. We assume the patient is competent to make an "informed decision." But is the patient always properly informed? Can we assume that the patient has heard all the pros and cons about the proposed surgery, even if the surgeon tried his or her best to delineate them? Are patients always of sound mind and judgment to make this sort of decision? Who should decide if they are or aren't? Isn't the advice of a physician implicitly coercive because the surgeon is the "powerful one" and the patient in the lesser position of seeking advice? Or, if a patient adheres to a set of aesthetic beliefs different from those of the surgeon, how does one reconcile the difference?

Then there is the *surgeon*. Is the judgment of the surgeon always sound? Can it be influenced from time to time by extraneous forces, sometimes without the surgeon's conscious understanding? If the surgeon is having a particularly good day or not-so-good day, does his or her own mood play an important role? Does the promise of money sometimes seduce the surgeon into scheduling an inappropriate surgery? And who decides if the surgeon has sufficient skill to perform a certain procedure, especially if it is a relatively new procedure?

Then there are other players. If a *third-party health insurer* is involved, should they decide if a procedure is medically necessary or should the surgeon? Should the surgeon withhold information or exaggerate symptoms if it helps the patient achieve precertification? Or, if the surgeon knows that a plan he or she participates in will likely pay for a surgery but at a greatly reduced rate, then should he or she file for insurance in the first place?

Let's presume that certain materials or medical devices are to be used in the surgery. Does the existence of a business relationship between the surgeon and the company that manufactures the devices matter? If the surgeon financially profits from use of this material, does this interfere with impartial judgment? What if a material or drug is FDA-approved for use in a certain anatomic site but the patient requests use in an entirely different site? What if the patient requests volumes that greatly exceed the usual amount? Should the patient be the one to decide if a certain implant should be used or not? Is the patient capable of deciding?

What if the patient has a potentially communicable disease? What if the patient has some form of viral hepatitis history? What if he or she is HIV-positive? Should cosmetic surgery still be done? What if a patient desires surgery but the surgeon refuses to operate because of HIV history? Should the surgeon have the right to refuse the patient? Does this violate constitutional rights of the patient? Conversely, does an HIV-positive surgeon have an obligation to inform the patient prior to surgery?[10]

It is clear that medical decision making can be very complex. And when the directions become unclear, what shall serve as the "ethical compass" that sets us back on the correct course?

CAVEAT EMPTOR: ETHICAL ADVERTISING

"Some forms of advertising are economical with the truth."[11]

Once upon a time, physicians did not engage in advertising, at least in the sense of paid use of the media to exhort their virtues and skills. It was assumed that medicine was a profession above those of trades people and that a surgeon who was "able, affable, available, and affordable" would have patients knocking on his door.

Yet a student of medicine can find examples of early advertising. The hawking of potions and elixirs was common. Consider the following example by a nineteenth century "medical salesman" taken from the *Saturday Evening Post* on September 13, 1760:

> *A prolifick elixir, the cure of barrenness in women, of imbecility in men, by promoting the cheerful curricule of the blood and juices, raising all the fluids from their languid state, to one more florid and sparkeling, increasing the animal spirits, restoring the juvenile bloom, and evidently replenishing the crispy fibres of the whole habit with a generous warmth and balmy moisture . . . and even seems to keep back the effects of old age itself.*

It is interesting to compare the previous example with a more recent ad from a plastic surgeon:

> *Lines and wrinkles smoothed away naturally. Being unhappy with lines and wrinkles that are making you look older than you feel is a problem you don't have to live with any more. We have also developed an exclusive skin care treatment program which, in addition to our long established collagen replacement therapy service, represents the most important advance in skin care by any cosmetic surgery group.*[11]

In recent times, there has been rapid growth of physician advertising. This was preceded in many parts of the United States by advertising produced by other medical groups, including hospitals, health insurers, and other health-related organizations; dentists; chiropractors; and others. Advertising by attorneys can be viewed as a separate phenomenon. (One could write another treatise on "truthful advertising by the legal profession.") So many physicians and surgeons have joined the ranks of advertisers and marketers of their skills.

The question begs to be asked: Is advertising itself inherently ethical? Is it unethical? Shouldn't advertising be truthful and helpful? Just what is ethical advertising and who should decide?

For instance, does plastic surgery advertising target a more vulnerable population? Is it moral to create a desire for procedures (unnecessary markets) that carry morbidity and risk, especially when presented to susceptible patients with lower self-esteem? In advertising cosmetic procedures, how can the self-esteem of a prospective patient be enhanced by a procedure that carries the message that he or she is basically unacceptable? For example, by promoting younger faces, do we not promote the "cult of youth"? Are we creating an unnecessary market for our surplus surgical skills? Although we know the importance of having realistic expectations, are we not advertising "perfection" in the quest for the perfect face?

When it comes to the advertising world, who should monitor and decipher boundary disputes between competing specialties? Should advertising be regulated and subject to certain government statutes, or should the "free market" decide who should say what about themselves? Should there be limits on what advertising should say or not say? Should paid testimonials from patients be permitted? Should there be a limit on use of terms like "exclusive," "specially trained," "first to be certified," and other pronouncements of special competency? Should words like "advanced" and "superior" be allowed to be used without proof of validity?

Do consumers and society as a whole benefit from increased advertising? Do plastic surgeons contribute to the betterment of their communities by print ads promising a new face or by infomercials describing the benefits of certain procedures? For that matter, does knowledge of the newest version of the "Ronco Vegematic" help us or does it really matter?

After all, shouldn't society have access to all kinds of information? We cannot ban certain types of services and allow promotion of others, can we? But how do we know when we are actually seeing accurate and truthful information?

PROFESSIONAL CONDUCT: OUR BEHAVIOR WITH PATIENTS, PEERS, AND THE PUBLIC

With Patients

"Ethics are the only guarantee we have in doing what we think is best in helping our patients—in the end this must prevail."
"Postoperatively each surgeon must ask himself, What did the operation accomplish?"

John Conley, MD[12]

"God has given you one face and you make yourselves another."

Shakespeare[13]

What is the primary duty of the physician in the doctor–patient relationship? Ultimately, how we treat our patients defines the state of our ethical development. Ideally, we listen to learn about the patient's needs, we try to communicate about possible treatment options, we help patients to become adequately informed, we use our skills to try to achieve the best possible surgical results, we guide our patients through the healing process, and we try to be there for them afterward, hopefully as they enjoy their improved faces and spirits.

But things aren't always ideal.

Is it ethical to spend 20 minutes with a new prospective patient and then decide to perform procedures that carry potential health risks and cost thousands of dollars? In the

initial consultation, sometimes the surgeon does not develop a rapport with the patient. Is it best to choose not to pursue the doctor–patient relationship at this point? As the consultation develops, isn't the doctor's advice somewhat coercive? Is it not weighted by the lure of increased income made possible by offering more and more procedures? How does a surgeon communicate enthusiasm to the patient about a procedure without appearing to be "selling" the patient something that may not be wanted or needed?

Sometimes the patient's expectations are not met. Does this constitute treatment failure? Sometimes the surgeon may feel no compassion for the patient. Should compassion be faked? Or is that dishonest? If there really exists no human empathy for the patient, how should this be handled? What if the surgeon just does not like the patient at all? Does this mean that the patient–doctor relationship should be terminated? If so, what is the best ethical (not to mention medicolegal) way to terminate the relationship?

And what constitutes unethical surgery? When is surgery "experimental" and when is it "breakthrough" surgery? What is the difference between performing "research" on your patients and offering them the "latest advances" in plastic surgery? Is it ethical to try a new procedure on a patient after just hearing about it at a meeting? What of new devices or materials that have not been investigated in terms of their long-term consequences to the patient? Is it ethical for the surgeon to use a drug or material (i.e., collagen) in a patient for a non–FDA-approved use or at an anatomical site for which it was not intended?

Remember that the surgeon is running a business, and the patient is the consumer who requests goods or services in exchange for money. The success of the transaction, like all business transactions, is whether or not the customer is happy with the services. Correct? Or is there more to it than a mere business comparison? Does not the physician have a greater moral responsibility than the typical business person?

For example, if a typical business with a product or service to sell is approached by a consumer who has a lot of money, the business owner is interested in making a business transaction. Let's suppose the consumer offers a lot more money for some special deal or more services. For example, at the end of a routine consultation, the patient says: "I want all six procedures we discussed, I want surgery tomorrow, and I will double the quoted fee in exchange for your additional trouble, doctor." In most businesses, it would be considered smart to find a way to satisfy the customer and make the financial exchange. But what about our situation? Can one separate business from ethics?

There are many other questions one must answer in terms of how to deal ethically with patients who walk into the surgeon's office.

With Peers

"A good name is more desirable than great riches; to be esteemed is better than silver or gold."

Proverbs 22:1

The early codes of professional conduct dealt primarily not with proper care of patients but with rules of conduct between physicians. For example, turf battles are not new, and physicians have traditionally had trouble in dealing with each other. Certainly when well-educated, ambitious individuals with large egos find themselves competing with others of like mind, conflicts and disagreements ensue.

In the realm of ethical behavior, how should physicians best deal with members of their own profession who violate the most commonly agreed on ethical principles? There exist state and national licensing boards, hospital committees, and ethics panels that can, and sometimes do, investigate questionable behavior. But in day-to-day living, how does one physician deal with another physician who appears to be transgressing beyond certain boundaries? How does one deal with an incompetent surgeon? If a surgeon sees evidence of poor work on a patient, is it ever ethical to openly criticize the offending surgeon?

On another matter, is it ethical for the specialist plastic surgeon to not inform or confer with the primary care physician about a mutual patient? What if the primary care physician recommends that a patient not undergo an elective surgery? Is it ethical for the plastic surgeon to suggest a second opinion or even to disregard the advice and proceed with the surgery?

And what of a new procedure that has been "invented" by a surgeon? If it helps people, should it be made available to all interested surgeons? Or is it ethical to "patent the procedure" so that no one else will steal it? Or should the inventor surgeon just market it to others if they agree to pay some money for the right to learn the technique?

Finally, is it ethical for a surgeon who has a financial relationship with a company to encourage use of that company's products to other surgeons?

If plastic surgeons were asked, "How do you wish your medical colleagues to remember you?" what would be the likely answer?

With The Business Community: The Surgeon as Businessperson

Physicians of the utmost fame
were called at once, but when they came
they answered, as they took their fees,
there is not a cure for this disease.

Hilaire Belloc

A successful surgeon must become a successful business person or the surgery services will not be available for long. Can this be done in an ethical manner, or is "successful business" incompatible with "good ethical standards"? How does the surgeon balance being a responsible business person and a compassionate caregiver? In today's world, we have situations where a physician who is a member of a health maintenance organization must make medical decisions for his or her patients that may sometimes affect the final reimbursement rates for the physicians in that group. By denying certain tests and treatments, their financial reward increases. The question is obvious: Do the financial interests of the organization outweigh the health interests of the patient?

Additional questions we must answer in today's climate are as follows: Is the sale of such products as skin care potions, nutritional supplements, and vitamins for profit in one's office ethical? Is the patient not being somewhat coerced to buy what the doctor recommends?

Is it acceptable for a surgeon with a financial relationship with a company to support use of that company's products by other surgeons? Is it okay to accept gifts from companies? Is it ethical for the plastic surgeon to align with lay "beauty businesses" and salons to sign up patients, exchanging reduced costs for exclusive referral of potential patients? Is it ethical to raffle a cosmetic surgery procedure at a fund-raising benefit event?

The necessity of coexisting with other businesses is a reality. How best to relate to such businesses is the question.

NEW BIOTECHNOLOGY, MATERIALS AND PROCEDURES: BREAKTHROUGHS OR EXPERIMENTS?

"New procedures and devices are good if the patient is benefited and the new ideas are significant, practical and successful. But the patient is harmed if the procedure is based on premature presentation, inaccurate information, unrealistic hopes and unprepared surgeons."[3]

Although "plastic" is rarely used in plastic surgery procedures, there is never a dearth of other alloplastic or homograft materials available for implantation in patients. We know that medical devices and preformed implants sometimes vary not only between countries but between training institutions. There exists a large cache of "legal" cosmetic and reconstructive materials that may find their way into human bodies on any given day. Who should be responsible for ensuring that these implants and materials are safe for human consumption? Should the FDA assume ultimate responsibility? Should it be the manufacturer or supplier of the device? Should it rest with the surgeon recommending the surgery? Or should it rest with the patients themselves?

For those who think it might not matter, please consider recent history and the ongoing morass featuring the silicone breast implants. In 1992 the FDA and its General and Plastic Surgery Devices Panel concluded that, after years of use, not a single entity involved in the use of silicone-filled breast implants could meet the statutory requirements for safety and effectiveness.[14] After years of retrospective clinical studies, emotional rhetoric, and ongoing legal battles featuring unhappy patients accompanied by hungry plaintiff jackals, and as we view the billion dollar spoils, we pause to assess the emotional, legal, and financial costs. The question begs to be asked, was this an abrogation of responsibility on the part of surgeons to not insist on answers from the companies that develop and sell such devices?[15]

Congress long ago decided that caveat emptor is not an acceptable standard for medical devices used in this country. A review of the literature (refer to the history of pacemakers and spine appliances) will reveal that plastic surgery is not alone in its confusion.

And what of new procedures? Sometimes there is a fine line between a revolutionary new procedure and experimental surgery. How does one judge the competency of surgeons to perform the "latest procedure?" We can test automobile drivers and airline pilots, along with others trusted with performing in the public realm. Can we test a surgeon's skill out of the operating theater before it is applied to a living face? Can patients have any real assurances of the competency of the person to whom they entrust their face?

MEDICAL MISSIONS: HAVE SCALPEL, WILL TRAVEL

"So when you give to the needy, do not announce it with trumpets."

Matthew 6:1

It is not uncommon for surgeons to volunteer their services in locations far from the communities in which they practice. Apart from the career medical missionary, there seem to be numerous venues where plastic surgeons can serve as short-term, intermediate-term, and even "very brief"-term itinerant surgeons. Most of the volunteer work being performed in domestic and foreign communities is likely altruistic and provides a very positive service for those patients who are the beneficiaries. So what possible ethics problems might arise?

Well-meaning surgeons from developed countries visit less endowed countries briefly to operate on indigenous patients who do not have access to certain types of elective surgery. The motivation can be mixed: to improve the quality of life is noble, but to improve one's skills by practicing on others is something else, as in an "overdoctored country" they might not have the chance to perform a cleft lip repair. To gain experience at the expense of a disadvantaged community implies that the patients are of lesser worth than those living in the doctor's own country.[16]

Relatively few are helped unless the visiting surgeon is also there to instruct local surgeons in the techniques. This also emphasizes the shortcomings of the host country.[4] After the trip is complete, the physician has the opportunity to parlay it into a public relations experience. One might ask, who becomes the beneficiary of this latest media exposure? Is the resultant media attention "just news," produced for the benefit of the local community. Or is it "savvy marketing," which positions the surgeon as the latest Dr. Albert Schweitzer? I know a number of generous and committed physicians who tirelessly tend to the needs of impoverished patients in very difficult conditions overseas. I have seen surgeons who participate in regular foreign "medical missions" state in newsletters to their patients that they don't really enjoy traveling every year to those exotic lands to render their skills; rather, they do it out of a sense of "calling" as a self-sacrifice.

But do motivations really matter if a good deed is offered to a person who otherwise might not have benefited? Is this colonial paternalism or a mission of mercy?

TEACHING AND TRAINING: "PRACTICING MEDICINE"

"Doctor, will you be the one actually performing my surgery?"

A modern patient

As no physician is born with medical wisdom or possesses innate surgical technique, all doctors must learn and be trained. All physicians, including surgeons, learn by their

experiences in treating live patients. Sometimes the practice of medicine is actually that—practice. How do we balance the rights of the novice surgeon to learn and of society to replenish its surgical force against the rights of the patient who seeks care in a "teaching institution"? What rights does the patient in a teaching and training institution have? For example, if the senior surgeon is "supervising" the case, does this mean that the senior member is helping guide the novice's hand, carefully positioned in the operating suite? Or is he or she "present" but in another operating room, or the lounge, or via cell phone from the golf course? If a patient agrees to a trainee doing the surgery under the supervision of the senior physician, then what role has the senior physician agreed to take? What if the patient is a member of the surgeon's given the patients immediate family? Should the care given the patient be different from the care given another?

We encounter other questions as well. Is it ethical for a resident surgeon to perform a procedure requiring thoughtful judgment and technical dexterity while extremely fatigued, often secondary to a long on-call stint?

FINAL THOUGHTS

As we endeavor to excel in facial plastic and reconstructive surgery, we realize that it is fairly easy to teach surgical techniques and to acquire new information. What is more difficult is to teach judgment and to develop advanced skills in ethical decision making. Although many surgeons developed a sense of ethics as they grew from childhood to mature adult, and from novice surgeon to accomplished master surgeon, unfortunately not all have done so. We need to improve on the process whereby we screen candidates who apply for facial plastic surgery residencies and fellowships, as well as continue to emphasize the importance of ethical behavior in our practices. Let us not forget, too, that there are many as yet undescribed ethical dilemmas to come.

We have asked many questions but find it difficult to provide all of the answers. Nevertheless, it is important that the questions be stated. We will end with a few words of wisdom by others:

> *Professionals without ethics are merely technicians who know how to perform work but who have no capacity to say why their work has any larger meaning.*[17]
>
> *What we need is to construct and maintain a way of life of which we are not ashamed and which we shall not, on reflection, regret or despise, and which we respect.*[18]
>
> *As a stream cannot rise above its source, so a code cannot change a low-grade man into a high-grade doctor, but it can help a good man be a better man, and a more enlightened doctor. It can quicken and inform a conscience, but not create one.*[19]
>
> *In the final analysis, honesty in all matters is the keystone to our ethical arch. We must follow our instincts, offering to those in our care only the operations we would wish for our own wife or daughter or mother, advising with the truthfulness and kindness that we would hope our own loved ones would encounter.*[3]
>
> *The most ethical position is that which helps the patient and family most, under the advice and counsel of the physician.*[20]

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Aesthetic Facial Surgery

Section

II

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Chapter 13

Aesthetic Facial Analysis

R. James Koch and Matthew M. Hanasono

Facial aesthetic surgery requires the surgeon to have a clear vision of the final outcome prior to any intervention. Therefore, the preoperative analysis of the face is as critical to the end result as careful surgical technique and thoughtful postoperative care. Facial surgery requires a deep familiarity with the "normal" face. Comprehensive assessment of the facial plastic surgery patient also depends on knowledge of the aesthetic ideal as it is influenced by age, sex, and body type, as well as cultural and contemporary trends in facial aesthetics. When the goal is to restore a youthful appearance, the surgeon also needs to understand the facial changes associated with aging.

Equipped with an appreciation for what makes a face attractive, the surgeon must then identify problem areas and determine priorities for surgery. In the preoperative facial analysis, thickness and texture of the skin and subcutaneous tissues, bony structure, and wrinkle patterns caused by the mimetic actions of the facial musculature must be considered. Changes caused by aging must be both assessed and anticipated. The preoperative analysis is unique to each patient, and solutions to problems must be fitted to specific needs.

Key concepts in facial aesthetics include balance, proportion, symmetry, and harmony. It is the combination of facial features in balance and proportion rather than any one specific characteristic that we equate with facial beauty. It should be remembered during facial evaluation that exceptions to the rules of facial proportion are sometimes encountered in beautiful faces that demonstrate unique and pleasing disproportion. Asymmetries should be pointed out to the patient prior to any intervention so that the patient understands that they were not caused by the surgery. The patient should be advised that some asymmetries cannot be surgically corrected. Harmony is achieved when the features of the face are congruent with each other and the rest of the body habitus. The challenge to the surgeon is to modify the facial appearance, sometimes in major ways while effectively hiding incisions, and to alter the patient's features without creating an "operated on" appearance.

Figure 13–1 The head of Queen Nefertiti, ca. 1365 BC. (Courtesy of the Berlin State Museum, Berlin, Germany.)

HISTORICAL PERSPECTIVES

Since ancient Egyptian times, the aesthetic facial ideal has been portrayed in art (Fig. 13–1). Modern facial analysis, however, began in Greece. Greek artists and philosophers analyzed the perceptions of beauty and established standards for ideal facial proportions and harmony (Fig. 13–2). Strongly influenced by the Greeks, artists and anatomists of the Renaissance Period continued the study of aesthetic proportions (Fig. 13–3). Leonardo da Vinci's work is well known for its portrayal of ideal facial proportions. His study of facial anatomy included the concept that facial balance exists when the face can be divided into equal thirds from the frontal hairline to the nasal root, the nasal root to the nasal base, and the nasal base to the bottom of the chin.

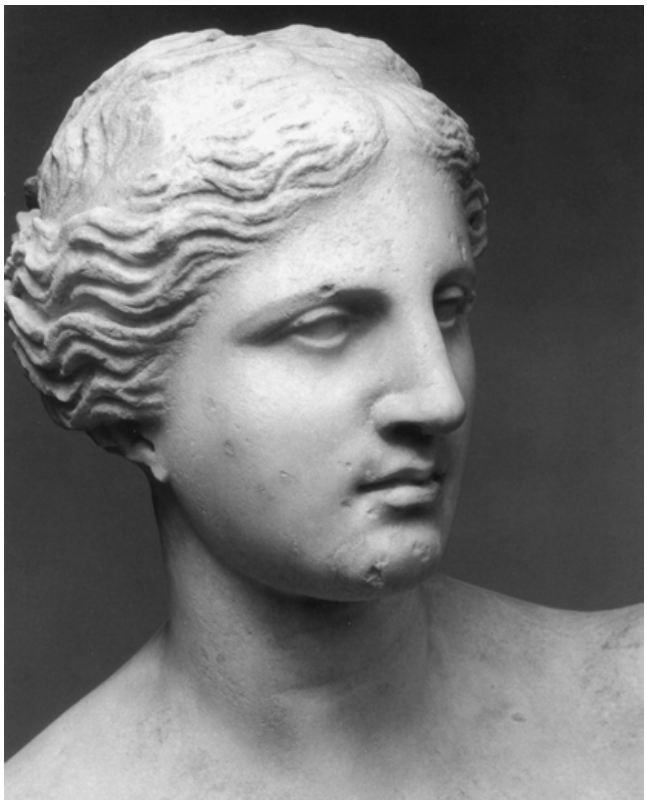

Figure 13–2 Venus De Milo, Circa 100 BC. (Courtesy of the Louvre, Paris, France.)

Figure 13–3 The birth of Venus, Botticelli, ca. 1480. (Courtesy of the Uffizi Gallery, Florence, Italy.)

MODERN CONCEPTS

Whereas some concepts of facial beauty endure across time and culture, others vary. In our culture, television, magazines, and motion pictures appear to have the greatest impact on our perception of beauty. Temporal differences in the aesthetic ideal can be appreciated by observing popular media from recent decades.

Various sociologic studies suggest at least some cultural differences in aesthetic tastes. Martin[1] conducted one such study in 1964. In that study, photographs of black female magazine models were ranked with respect to facial features considered to be most black and least Caucasian, to those felt to be least black and most Caucasian. These models were then ranked in terms of beauty by 50 college age white American males, 50 college age black African American males, and 50 college age black Nigerian males. The beauty rankings of American whites and African American blacks both showed a positive correlation with models displaying more Caucasian, less black features. The beauty rankings of Nigerian blacks correlated with more black, less Caucasian features. Martin's study suggests that there is, or was at that time, a single cultural standard of beauty in American society, despite its multiracial composition, different from that of an African society that is predominantly based on the black facial model. Other studies show high interrater reliabilities in cross-cultural beauty, suggesting that some features are perceived as attractive regardless of the racial and cultural background of the viewer.

Recent research has sought to define facial beauty in terms that are more objective. It has sought to define preferences that appear to be biologically predetermined and cross-cultural. Langlois et al.[2] showed that infants, whose inclinations presumably do not reflect culture-specific standards of beauty, prefer to look at adult faces that were perceived as more attractive. In a later study with adults, Langlois and Roggman[3] showed that a computer-generated face that was a composite of many faces was favored over any singular face of actual male and female subjects. This study suggests that "average" features (those that deviate least from the norm in terms of size, shape, location, and proportion) are the paragon of facial beauty.

More recently, Perrett et al.[4] found that subjects preferred a computer-generated composite of attractive female faces to a composite of average female faces. Male subjects preferred a caricature in which the differences between the attractive composite and the average composite were increased by 50%. This preference was observed in British subjects judging British faces, Japanese subjects viewing Japanese faces, and British subjects viewing Japanese faces. British and Japanese women preferred an "attractive" male composite to an "average" male composite as well, but had no preference for a caricature over an attractive composite. Qualities found to be more attractive in female faces included large eyes, high cheekbones, narrow jaw, and smaller vertical third of the face.

Whether beauty is preprogrammed or exists only in the eye of the beholder, the most important goal for the facial plastic surgeon is to create a result that portrays beauty and contributes to a positive self-image in the mind of the patient. Certainly, one can accept that a face that is beautiful beyond a certain level is likely to be universally accepted as beautiful, transcending racial, cultural, and temporal preferences. In addition, in the present world with well-developed communications, frequent travel, and globalized media, beauty does not exist in a culture- or race-specific vacuum.

HISTORY AND PHYSICAL EXAMINATION

A complete and systematic medical history and physical is as important in facial plastic surgery as any other surgical discipline. History taking should include information about medical problems, prior surgeries, medications, and allergies as well as smoking, illicit drug use, and drinking habits. As hematoma is among the most common complications of facial aesthetic surgery, risk factors for postoperative bleeding, such as hypertension and use of nonsteroidal anti-inflammatory drugs, should be elicited. Smoking history is pertinent to concerns for skin slough and flap necrosis.

Questions regarding dryness or irritation of the eyes should be posed to patients undergoing surgery in the periorbital region. Vision in each eye is assessed, and tests for adequate tear production are performed if the history is suggestive of decreased lacrimation.

Patients with rare skin disorders may present to the facial surgeon with premature aging or skin laxity. These conditions include Ehlers–Danlos syndrome, progeria, Werner's syndrome, cutis laxa, and pseudoxanthoma elasticum. The underlying pathologic process must be taken into account in determining whether such patients are candidates for aesthetic surgery. Ehlers–Danlos is a genetic disease of connective tissue associated with thin, hyperextensible skin, hypermobile joints, and subcutaneous hemorrhages. Rhytidectomy is contraindicated due to high risk of postsurgical bleeding and poor wound healing. Plastic surgery is contraindicated in progeria, a disorder characterized by growth retardation, craniofacial disproportion, baldness, prominent ears, pinched nose, micrognathia, and shortened life span. Due to associated microangiopathy, cosmetic surgery is also contraindicated in Werner's syndrome, or adult progeria, a condition that also presents with scleroderma-like skin changes, including baldness, aged facies, pigmentation defects, short stature, muscle atrophy, osteoporosis, premature atherosclerosis, and diabetes. Cutis laxa, in which there is a degeneration of dermal elastic fibers, is associated with chronic obstructive pulmonary disease, cor pulmonale, hernias, as well as urologic and intestinal diverticula. Facial rejuvenation is generally safe in these patients as long as their overall health status is satisfactory. Finally, pseudoxanthoma elasticum is a degenerative disorder of elastic fibers resulting in premature skin laxity for which facial rejuvenation surgery is beneficial.

PREOPERATIVE PHOTOGRAPHY

Preoperatively, the surgeon should photograph the patient in standard views specific to each operative procedure. These photographs should include, at the minimum, a frontal view, left and right lateral views, and left and right oblique views, as well as close-up views of the regions to be addressed surgically. The photographs should be taken with the head in the Frankfort horizontal position. In the Frankfort horizontal, the supratragal notch is level with the infraorbital rim. Photographs assist in preoperative planning and intraoperative decision making, and postoperatively as a way of assessing results. They assist preoperatively in discussion with the patient as well as postoperatively during the counseling of patients who may not remember their exact preoperative appearance. Photographs are also necessary for medicolegal documentation. The reader is referred to Chapter 11, Photography in Facial Plastic Surgery.

COMPUTERS IN FACIAL ANALYSIS

There is no doubt that the use of preoperative computer imaging is an excellent tool to increase communication with patients. It allows the surgeon to visualize what the patient desires as a final result. The patient can articulate any desired modifications. It allows the surgeon and patient to compare their own aesthetic interpretations.

For procedures such as profile changes in rhinoplasty, it allows patients to view themselves from a different perspective, one that they normally do not see. Many times their self-image is not congruent with what others see. Also, the computer imager shows how different manipulations can yield very different results. This is important with procedures such as rhinoplasty where subtle or dramatic changes can be achieved by single maneuvers. It also shows the illusionary or secondary effects of a singular change. For example, apparent nasal tip rotation can be increased by removing a dorsal hump or augmenting the premaxilla. Such secondary effects can be visualized on the imager and are valuable in the planning of that procedure. The reader is referred to Chapter 10, Computer Imaging for Facial Plastic Surgery.

SKIN TYPES

Due to the key role of skin in the facial appearance, evaluation of the skin deserves special mention. The texture, thickness, elasticity, and degree of sun damage to the skin of various facial regions should be evaluated by inspection and palpation. A gentle touch during this stage of the exam communicates to the patient the surgeon's technical delicacy. Skin lesions, scars, rhytids, and pigmentation should be noted and pointed out to the patient.

Fine, light skin with minimal subcutaneous tissue will tend to show even minor subcutaneous soft and bony tissue irregularities. Facial implants in such skin may prove problematic or unacceptable. Even minor abnormalities in contour require careful attention during surgery. On the opposite end of the spectrum, thick, oily skin tends to heal with scars that are more obvious. It also may conceal underlying structural changes. Somewhere between these two skin types lies the ideal skin for facial aesthetic surgery. Men tend to have thicker skin in the region of the beard, with an increased blood supply due to a richer subdermal plexus.

Figure 13–4 Dermabrasion for chicken pox scarring. (Courtesy of Dr. John R. Hilger.)

Textural imperfections, such as deep acne and chicken pox scars, may subtract from the desired result. Ice-pick acne scars penetrate through the dermal layer and fixate in the subcutaneous tissues, thus tethering the skin surface. Correction with injectable fillers or punch excision of depressed scars and sequential laser resurfacing/dermabrasion may be required (Fig. 13–4). Rhytidectomy frees scars from their underlying tethering and allows rotation and elevation of facial skin to an improved position.

Skin aging is variable and depends on multiple intrinsic and extrinsic factors. Genetics, sun exposure, smoking history, radiation exposure, and amount of use of the facial mimetic musculature all play major roles in the development of facial rhytids. It is important to differentiate dynamic facial lines from true wrinkles. Dynamic furrows are caused by the repeated pull on the skin of underlying facial mimetic muscles and require that the underlying muscle(s) be addressed (Fig. 13–5). They are differentiated from wrinkles (sagging skin), which are caused by age-related laxity of the skin. Aging is also associated with a progressive decrease in the elasticity and thickness of the skin.

With age, the development of benign, malignant, and premalignant skin lesions may occur. It is important to biopsy any suspicious lesions. Keratoses, epitheliomata, and other hyperpigmented lesions may appear on the face. Environmental damage from both ultraviolet radiation and trauma may take a toll on facial skin. Actinic damage and regions of pigmentary change may occur. The presence of facial hypertrophic scars and keloids should be noted, as they may be a relative contraindication to certain types of surgery.

Figure 13–5 Mimetic activation of facial musculature. (Courtesy of the Montreal General Hospital, Montreal, Canada.)

When planning skin resurfacing, it is important to ascertain the patient's sun reactive skin type (Fitzpatrick) (Table 13–1). Those with type IV or type V skin (such as persons of Asian or Hispanic descent, respectively) or in anticipation of a hyperpigmentation problem are pretreated with hydroquinone topically.

TABLE 13–1 Fitzpatrick's Sun-Reactive Skin Types

Skin type	Skin color	Tanning response
I	White	Always burns, never tans
II	White	Usually burns, tans with difficulty
III	White	Sometimes mild burn, tan average
IV	Brown	Rarely burns, tans with ease
V	Dark brown	Very rarely burns, tans very easily
VI	Black	No burn, tans very easily

HAIR

Men tend to have recession of the frontal forehead hairline, with loss and thinning of hair, much earlier in life than women. The position of the hairline, temporal recession, and density of hair follicles should be taken into account when planning surgical incisions. For example, one may consider a coronal lift with a low forehead and Norwood classification type I hair pattern, a mid-forehead lift with androgenic baldness or thin, light hair, and a pretrichial lift with a high forehead and Norwood type I or II hair pattern.[5] When performing the pretrichial lift, a trichophytic incisional technique should always be used. An endoscopic browlift can be performed with most hair patterns, yet incision modifications may be necessary.

FACIAL AESTHETIC UNITS

When all of the general considerations have been taken into account, a regional evaluation of the face is conducted. A practical method of doing this is by proceeding with a systematic evaluation of the individual facial aesthetic units. These units consist of the forehead and brow, the periorbital region, the cheeks, nose, the perioral region and chin, and the neck. However, one must remember to appreciate how the features of the various units interact with each other to produce a balanced or unbalanced appearance.

Forehead

Perhaps no other facial region has so many varied surgical approaches as the aging brow and forehead. A knowledge of the anatomy and aesthetics of the upper third of the face is necessary to select and perform the proper rejuvenation procedure. The layers of the forehead are in continuity with those of the scalp. The mnemonic SCALP describes the five layers of the forehead: S (skin), C (subcutaneous tissue), A (galea aponeurotica), L (loose areolar tissue), and P (pericranium). The skin (S) is adherent to the subcutaneous tissue (C). The galea aponeurotica (A) surrounds the entire skull. The galea divides to surround the frontalis and occipitalis muscles. Below the superior temporal line, the galea becomes the temporoparietal fascia. The loose areolar tissue (L) (subgaleal plane) is between the galea aponeurotica and the pericranium (P). This is an avascular layer that allows sliding of the other layers over the pericranium. The pericranium is a thick layer of connective tissue (periosteum) that is adherent to the outer table of the calvarium. At the temporal fusion line of the skull (where the superior and inferior temporal lines meet) the periosteum becomes confluent with the temporalis fascia. The periosteum also becomes continuous with the periorbita at the level of the supraorbital rims.

The movements of the forehead and eyebrows are due to four muscles: frontalis, procerus, corrugator supercilii, and orbital portion of the orbicularis oculi muscles. The paired frontalis muscles have a distinct midline separation. The frontalis originates from galea aponeurotica and inferiorly interdigitates with the procerus muscle, corrugator muscle, and the orbicularis oculi muscle. The frontalis muscle has no bony attachments. It is connected to the occipitalis muscle through its galeal attachments, and these two muscles act together to move the scalp. The function of the frontalis is eyebrow elevation. Transverse forehead creases result from chronic frontalis contraction. Loss of frontalis innervation results in brow ptosis on the affected side.

The paired corrugator supercilii muscles originate from the frontal bone near the superomedial orbital rim and pass through the frontalis and orbicularis muscles before inserting into the mid-eyebrow dermis. They pull the eyebrows medially and downward, and overuse (frowning) causes glabellar vertical furrows. The procerus is a pyramidal muscle that originates from the surface of the upper lateral cartilages and nasal bones, and inserts into the skin in the glabellar region. Contraction causes the medial aspect of the brows to descend and produces horizontal lines over the root of the nose. The orbicularis oculi muscle surrounds each orbit and extends into the eyelids. It originates from the periosteum of the medial orbital margin and inserts into the eyebrow dermis. It is divided into orbital, palpebral (preseptal and pretarsal), and lacrimal portions. The medial superior fibers of the orbicularis depress the medial brow. These fibers are called the depressor supercilii muscle. The corrugator, procerus, and orbicularis oculi muscles act together to close the eyes, are antagonistic to the movement of the frontalis, and their overuse creates horizontal and vertical glabellar lines.

The classically described brow position in a female has the following criteria[6]: (1) the brow begins medially at a vertical line drawn perpendicular through the alar base; (2) the brow terminates laterally at an oblique line drawn through the lateral canthus of the eye and the alar base; (3) the medial and lateral ends of the eyebrow lie at approximately the same horizontal level; (4) the medial end of the eyebrow is club-shaped, and this gradually tapers down laterally; and (5) the apex of the brow lies on a vertical line drawn directly through the lateral limbus of the eye. Some feel that the apex or highest portion of the brow should ideally be in a more lateral position; that is, the apex set along a vertical line through the lateral canthus, as opposed to the lateral limbus.[7]

For males some of the classical criteria apply, including the apex lying on a vertical line through the lateral limbus, yet the entire complex is minimally arching and positioned at or just above the supraorbital rim. Overzealous lateral elevation, producing a high or arched brow, can feminize the male brow. Overzealous medial elevation produces a "surprised" look. Compared to the male, the female forehead is smoother and more rounded with a less developed supraorbital ridge and a less acute nasofrontal angle.

The two main age-related changes of the upper third of the face are brow ptosis and hyperdynamic facial lines. Brow ptosis is primarily a result of gravity and loss of elastic tissue support from collagen changes in the dermis. It can give a crowded or angry appearance to the eye and brow complex. The brow should be examined for any asymmetry accompanying bilateral ptosis. Also, any underlying etiologic factors (such as temporal branch paralysis) should be sought in unilateral ptosis. What at first appears to be excess upper eyelid skin (dermatochalasis) may in fact be ptotic forehead skin. Clinically, this most dramatically presents as "lateral hooding" over the upper eyelids. This may be severe enough to result in a superiolateral visual field defect, producing

a functional indication for brow surgery. Attempts to excise the hooded skin via a blepharoplasty alone will only pull the lateral brow inferiorly, thereby worsening the brow ptosis.

In addition to brow ptosis, the aging brow and forehead may display hyperdynamic facial lines. These furrows are caused by the repeated pull on the skin of underlying facial mimetic muscles. Chronic contraction of the frontalis muscle in an upward effort leads to transverse forehead creases: the frontalis essentially performs its own nonsurgical browlift. Repeated frowning overutilizes the procerus and corrugator supercilii muscles. This, respectively, causes the development of horizontal creases at the root of the nose, and vertical interbrow furrows.

The need for ancillary procedures, such as blepharoplasty for upper eyelid dermatochalasis, should be recognized, as this will yield a potential camouflage incision site for the brow component. The height of the forehead should also be evaluated because some approaches will not only accomplish the lift but will secondarily improve (raise or lower) forehead vertical height. In general, whereas all forehead procedures elevate the brow as well as the forehead, browlifting procedures vary in their effects (if any) on the forehead.

Periorbital Region

The periorbital region includes the upper and lower eyelids, the medial and lateral canthal regions, and the globe. Again, the size, shape, position, and symmetry of the individual components should be assessed. The assessment should take into account the features of the remainder of the face. The intercanthal distance should be approximately equal to the width of one eye. In the Caucasian patient, the intercanthal distance should also be equal to the interalar width of the nasal base. In the Asian and African American patient, this rule does not necessarily apply due to typically greater interalar widths.

The primary muscle in this region is the orbicularis oculi. This muscle is innervated by the temporal and zygomatic branches of the facial nerve. The orbital portion of this muscle encircles the orbits and contracts as a sphincter to cause blinking. This portion of the muscle has lateral attachments to the anterior temporal and malar skin. This creates fine lines and wrinkling, known as crow's feet, as the face ages.

The eyelids often show the earliest signs of aging. The problems are mainly due to skin laxity (dermatochalasis), pseudoherniation of the orbital fat through the orbital septum, and orbicularis muscle hypertrophy. For the upper eyelids, dermatochalasis, followed by prominent fat pads, is the most common problem. The traditional skin–muscle upper eyelid blepharoplasty with fat removal addresses these problems well.

For the lower eyelids, problems with skin, fat, and muscle are often seen alone or in combination. Isolated lower eyelid pseudoherniated fat is commonly seen in younger patients and is managed by transconjunctival blepharoplasty. Mild dermatochalasis can be concurrently addressed by skin pinch excision, chemical peel, or laser resurfacing. Many younger patients also have isolated orbicularis muscle hypertrophy, usually secondary to frequent squinting. This is frequently observed in people who smile for a living, such as newscasters and politicians. This may appear as a firm roll along the margin of the lower eyelid and requires muscle excision or debulking.

Malar bags must be differentiated from festoons. Malar bags are edematous, sagging regions bordering onto the cheek aesthetic unit that accumulate fat or fluid with age. They sometimes require direct excision. Festoons, on the other hand, typically contain muscle and skin invaginations. They may be addressed via extended lower eyelid blepharoplasty.

Other periorbital problems, such as lid ptosis, enophthalmos, proptosis, exophthalmos, lower lid laxity or malposition, and lateral hooding, should be assessed. As noted previously, lateral hooding develops because of the descent of the brow as well as presence of redundant eyelid skin. The snap test, in which the lower lid is grasped between thumb and forefinger and pulled away from the globe, is routinely used to assess lower lid laxity. An abnormal result is delayed return to the globe surface or return only after blinking. Lower lid scleral show or ectropion (eversion of the eyelid margin) is also noted. Approximately 10% of the normal population have scleral show unrelated to aging. Enophthalmos may suggest prior orbital trauma and may require orbital reconstruction. Exophthalmos may suggest Graves' orbitopathy and requires endocrine evaluation. Globe malposition or extraocular muscle dysfunction requires ophthalmology consultation and orbital imaging studies.

Ptosis, entropion (inversion of the eyelid margin), ectropion, and excessive lower lid laxity can be corrected at the time of blepharoplasty. Hyperdynamic lines, such as crow's feet, cannot be eliminated except through alteration of the facial musculature. This may be achieved by paralysis or destruction of the facial nerve branches that supply the muscles. A practical method is chemical muscle paralysis with botulinum toxin.

Cheek

The cheeks form an aesthetic unit that extends from the preauricular crease laterally, to the nasolabial fold medially, as well as the zygomatic arch and inferior orbital rim superiorly, and to the inferior border of the mandible inferiorly. The most noticeable landmark on the cheek is the malar eminence. The malar eminence is composed of the zygomatic and maxillary bones. A prominent malar eminence is a sign of youth and beauty. The malar eminence lends form, strength, and shape to the facial appearance. Malar hypoplasia may be due to deficiency of the anterior face of the maxilla or, laterally, due to deficiency of the zygomatic prominence.

The muscles of the cheek can be divided into three layers. The deepest layer consists of the buccinator, which arises from the deep fascia of the facial area and blends with the orbicularis oris at the oral commissure. The next layer consists of the caninus, which originates at the canine fossa, and the quadratus labii superioris, which has three divisions that originate from the upper lip area. Both the caninus and quadratus labii superioris insert on the orbicularis oris. Finally, the zygomaticus and risorius interdigitate at the lateral commissure. All of these muscles originate from a bony landmark on the maxilla or the pterygomandibular raphe. They terminate in either the superficial fascia of the perioral skin or the deep musculature of the upper lip. They are innervated by the zygomatic and buccal branches of the facial nerve. These

muscles cause an upward and lateral movement of the middle third of the face associated with expressions of happiness.

The buccal fat pad is a consistent component of the masticatory space. Interestingly, it does not vary with the overall degree of adiposity of the individual. It is composed of a main body and three main extensions: temporal, buccal, and pterygoid. Significant jowling may be due in part to ptotic buccal fat. Clinically, ptotic buccal fat may present as inferior cheek volume or as a jowl with fullness in the midportion of the mandibular body.

The buccal fat pad is located through an intraoral incision above the third maxillary molar. The two surgically vulnerable structures are the parotid duct and the buccal branch of the facial nerve. It is therefore prudent not to chase buccal fat but to remove only that which buoyantly protrudes.

Deepening of the nasolabial crease and accentuation of the nasolabial fold, the portion of cheek lateral and adjacent to the crease consisting of the malar fat pad and overlying skin, are changes associated with aging. The nasolabial crease is perhaps the most noticeable crease on the face. It is a result of direct attachments of the mimetic muscles to the skin or forces of motion transmitted by the superficial musculoaponeurotic system (SMAS) to the skin by vertical fibrous septa. With age, there is atrophy of fat in the middle and upper face as well as deposition in the submental area. Development of submalar concavity associated with aging results in a hollow-cheeked look.

The malar eminence may be augmented with implants, which can be placed with an intraoral approach. Rhytidectomy with the appropriate vector of force in combination with malar augmentation may assist in diminishing the prominence of the nasolabial fold. The nasolabial crease may be directly addressed with implant augmentation or extended rhytidectomy. Complete eradication of this crease is not possible; neither is it probably desirable as it is an important facial landmark dividing the cheek aesthetic unit from the nasolabial unit. In extreme cases, direct excision of the nasolabial fold may be performed. Rhytidectomy may also improve the definition of the inferior mandibular border and can reposition the buccal fat pad.

Nose

The nose is the most noticeable of the facial aesthetic units owing to its central position in the coronal plane and its prominence in the sagittal plane. Minor asymmetry and variations are more conspicuous here than in other facial regions. Proportions of the nose should be in harmony with the rest of the face and the body habitus. A long, thin nose on a short, stocky person with a wide face appears out of place, as would a short, wide nose on a tall, thin person with a long face.

The muscles of the nasal pyramid are rudimentary in nature and have little influence on the static or dynamic appearance of the nose. Exceptions are the dilator muscles of the nostril and the depressor septi nasali, which extends from the upper lip to the floor of the nose and the nasal septum.

The nose is typically described in terms of its length, width, projection, and rotation. Numerous angles and measurements have been used to describe the nose and its relationship to the face.[8] In general, the dorsum follows a smooth curve downward from the medial aspect of the brows to the supratip region. A slight hump at the bony–cartilaginous junction is acceptable in either sex but is probably better tolerated in the male. The tip should show a double break, and 2 to 4 mm of columellar show is ideal. In the Caucasian, the base of the nose approximates an equilateral triangle. Wider interalar distances are normal in Asian and African American patients. Shorter people may be able to tolerate greater tip rotation than taller people.

With time, the cartilaginous skeleton of the nasal tip weakens causing broadening, tip ptosis, lengthening, and, potentially, airway obstruction. The nostrils may widen, and the columellar–labial angle may become sharper and more retruded. Thickening of the nasal skin may also occur, as in rosacea, for example.

A prominent nose associated with a hypoplastic mandible is aesthetically disagreeable and can usually be much improved when reduction rhinoplasty is combined with augmentation mentoplasty (Fig. 13–6). Conversely, nasal reduction should be conservative in patients with a prominent mandible and chin to preserve balance and facial harmony, and to prevent aggravation of a prognathic appearance, especially when viewed in profile.

Perioral Region and Chin

The perioral region includes the region of the face from the subnasal and nasolabial folds to the menton, the lower border of the soft tissue contour of the chin. The contour of the chin is determined by the shape and position of the mandible, as well as overlying soft tissues in the case of chin ptosis. Next to the nose, the chin is the most common site of abnormality in the profile view.

Muscles responsible for the mimetic actions around the mouth include the quadratus labii inferioris, mentalis, and triangularis muscles, which lie in a plane deep to the platysma. This group of muscles blends with the orbicularis oris in the lower lip. Nerve supply to this group of muscles comes from the marginal mandibular branch of the facial nerve. This muscle group serves to contract and depress the lower lip. All of the muscles of this group insert on the bony inferior rim of the mandible.

Figure 13–6 Augmentation mentoplasty with reduction rhinoplasty. (Courtesy of Dr. John R. Hilger.)

Microgenia literally means "small chin." In a patient with normal occlusion (Angle's class I: mesiobuccal cusp of the first maxillary molar aligns with the mesiobuccal groove of the first mandibular molar), microgenia is diagnosed by dropping a vertical line from the vermilion border of the lower lip to the chin. If this line falls anterior to the soft-tissue pogonion, then the patient has microgenia. Specific preoperative analysis should focus on the lateral view, with the surgical goal being to extend the mentum to the vertical lip line. Slight overcorrection in men is acceptable, whereas undercorrection in women may be appropriate.

Overall facial balance on profile is best assessed by also considering the nasal dorsum projection. Many times the computer imager is helpful in illustrating the possible positive contribution of chin augmentation to the results of a rhinoplasty. The primary surgical choices for correction of microgenia are implant augmentation and genioplasty. The most commonly used alloplastic mandibular implants are silastic.

Mandibular hypoplasia is an acquired condition secondary to varying degrees of bony resorption of the mandible. Adequate retained dentition can help combat overall loss of mandible size, especially that of alveolar height. With aging there is also specific progressive soft tissue atrophy and bone reduction in the region between the chin and jowl. The resulting groove has been termed the prejowl sulcus. This is of significance because although a well-performed facelift can improve the jowl area, it will leave this conspicuous groove behind.

Assessment of the patient with mandibular hypoplasia is similar to that of the microgenia patient, with attention to the presence of normal occlusion. One must not confuse mandibular hypoplasia with retrognathia. The latter condition demonstrates Angle's class II occlusion and benefits most from a bony advancement technique, such as sagittal-split osteotomy.

The surgical approach to mandibular hypoplasia is the same as that described for microgenia. The main difference is in the type of silastic implant used. An extended implant is selected if there is significant mandibular body hypoplasia. The implant design can also secondarily correct microgenia, if indicated. Certain patients lack mandibular definition in the region of the angle (usually congenitally), and may benefit from augmentation.

As with mandibular hypoplasia, dentition plays a major role in determining the shape of the lower face. Orthodontic correction can restore normal lip relationships in addition to restoring normal occlusal relationships of the teeth. Changes in dentition, specifically due to bone resorption in the edentulous mandible, may alter the proportions of the middle and lower thirds of the face. Absorption of alveolar bone, collapse of the vertical distance between the mandible and maxilla, and significant soft tissue disturbances may occur. These changes can only be partially compensated for by prosthetic dentition.

With aging, there is lengthening of the upper lip, thinning of the red lip portions, and midface retrusion. Perioral rhytids, which are vertical and extend from the vermilion borders of the upper and lower lips, also develop. Another phenomenon is the appearance and deepening of "marionette" lines, which are the bilateral inferior extensions of the nasolabial crease that resemble the vertical lines on the lower face of a ventriloquist's dummy. The chin as well as the malar eminences may become relatively underprojected as a result of redistribution of the overlying skin and subcutaneous tissues. The middle and lower facial skeleton also show a decrease in height with age.

Most procedures directed at lip alteration are for augmentation or reduction. Currently, full lips are favored. The upper lip should be fuller and project slightly anterior to the lower lip in profile. Lip augmentation has been performed with a number of various materials, including autogenous dermis or fat, homograft or xenograft collagen, and expanded polytetrafluoroethylene.

Neck

Restoration of cervicomental definition is an important component of rejuvenation surgery. The neck in youth has a well-defined mandibular line that casts a submandibular shadow. The skin of the submental triangle is flat and tight. The platysma muscle is smooth and has strong tone. In addition, the muscular attachments of the hyoid bone create a cervicomental angle of 90 degrees or less. These factors give the neck a youthful contour and appearance.

The unattractive neck may be the result of hereditary or acquired anatomic factors. Hereditary factors include a low-positioned hyoid–thyroid complex and accumulation of cervical fat both superficial and deep to the platysma. With aging, there are expected acquired changes in the lower face and neck. These include submandibular gland prolapse, platysmal banding, and skin redundancy. Microgenia, mandibular hypoplasia, jowling, chin ptosis, and prejowl sulci, all discussed previously, also have a great impact on the appearance of the neck.

Patients should be routinely assessed for the previously mentioned conditions. A standardized preoperative approach to the lower face and neck regions will ensure that the appropriate technique(s) is used.[9] Assessment for surgical rejuvenation of the neck follows a systematic approach: (1) assessment of skeletal framework adequacy, (2) need for management of the SMAS–platysma muscle complex, (3) need for fat contouring, and (4) need for skin tightening.

The hyoid bone is ideally positioned at the level of the fourth cervical vertebra. Patients with an anatomically low hyoid have an obtuse cervicomental angle, and this limits the surgical efforts. For cervical fat, the primary surgical approach is liposculpture using a suction cannula or direct lipectomy. The surgical correction of platysmal bands entails limited anterior horizontal myotomy with excision of the raised hypertrophic muscular edges. The newly defined anterior borders of the platysma are then reapproximated with sutures. Platysmal sling tightening will also help correct submandibular gland prolapse.

The preferred method to eliminate redundant neck skin is by superior lateral flap advancement during facelift. This bidirectional pull tightens the skin component of the sling. If persistent redundancy remains in the anterior neck, then a submental incision with local skin excision is necessary. Overzealous skin excision must be avoided as this produces standing cones at the lateral aspects of the closed incision. Excessive skin excision can also produce an acute cervical line that obliterates a youthful cervicomental contour.

Certain patients with cervical fat and youthful, elastic skin with minimal redundancy may require only liposuction of the fat. This type of skin is not lax and still retains its memory. These patients do not require local skin excision, as the neck skin will draw superiorly and hug the submental contour.

Ears

Some patients with prominent ears can benefit from aesthetic surgery. The top of the auricular helix should be at the level of the lateral eyebrow. The inferior attachment of the ear lobe should be at the level of the alar–facial junction. The ear is posteriorly inclined on the lateral view, with its vertical axis offset slightly from the horizontal. This is important to remember during rhytidectomy to prevent creating a pulled-forward look that discloses surgical intervention. The width-to-length ratio of the ear is about 0.6:1. The ears should protrude from the posterior scalp about 20 to 25 degrees, and the midear should be no more than 2 cm from the head.

With age, there is an increase in lobe size. There is also increased prominence due to an increase in the concho-scaphoid angle, and there may be partial loss of the antihelical fold. An increased concho-scaphoid angle and loss of the antihelical fold can emphasize prominent ears. Changes to the ear lobe may also result from prolonged earring use.

FACIAL ANALYSIS AND THE ASIAN PATIENT

Facial aesthetic surgery specific to the Asian patient usually focuses on changing two aspects of the Asian face. This includes surgery to modify the upper eyelid to create a supratarsal fold, so-called double-eyelid surgery, and rhinoplasty with augmentation of the nasal dorsum.

The typical Asian periorbital region differs from that of the Caucasian in several ways. The first is the presence of a persistent epicanthal fold. The epicanthal fold is present in all normal fetuses between the third and sixth fetal month but usually disappears in Caucasians by birth or by adolescence at the latest. Asians usually retain at least some trace of the epicanthal fold after maturity. Prominent epicanthal folds can be addressed with medial epicanthopexy. Another difference is that, unlike the Caucasian eye, the Asian eye is not deep-set. Surgical management is not commonly pursued for this feature.

The third prominent feature is the presence of the so-called double eyelid in Caucasians that is lacking or less well developed in most Asians. The double eyelid in the Caucasian eye is attributed to a fold in the skin of the upper eyelid that is present when the eye is open, that is, the supratarsal fold, which is nearly parallel to the lid margin. Anatomically, this corresponds to the distal fibers of the levator aponeurosis, which run through the orbicularis oculi muscle above the tarsal plate to insert on the eyelid dermis near the ciliary margin. In the typical Asian eyelid, the levator aponeurosis terminates at the septum orbitale, with few or no fibers penetrating the orbicularis oculi and attaching to the dermal layer of the eyelids. As there are no connections between the levator and the dermis, the preseptal fat deep to the orbicularis oculi is able to drift anteriorly which may further obscure the landmarks of the upper eyelid. In addition, the Asian tarsal plate tends to be shorter (4 mm versus 10 mm in the Caucasian eyelid).

Several anatomic studies document the presence of a double eyelid in at least 50% of the Japanese population, so it is a misunderstanding that double eyelids are a uniquely Caucasian feature. Often this crease is prominent only in the central to lateral portion of the lid. The double eyelid is more common and better defined in Asian females than males. It is not uncommon for the double eyelid to be asymmetric, with one eyelid possessing a more prominent fold than the other.

The typical Asian nose differs from the Caucasian nose in that it is smaller and somewhat differently shaped. The dorsum is wider and rounder. The Caucasian depression at the nasal root followed by a dorsal hump are features rarely seen in the Asian nose. In comparison with the Caucasian nose, the tip is broad and drooping. In the Asian nose, the ala are flared, and sometimes overhanging with a thicker nostril wall. Likewise, the nasal aperture is horizontally ovoid rather than vertically ellipsoid.

The nasal dorsum is the most common anatomic site for placement of alloplastic facial implants in Asian countries. A more defined nasal dorsum is considered to be aesthetically desirable in many Asian societies. The goal of the surgery is not necessarily to create an ideal Caucasian nose but to create a more well-proportioned nose that is in harmony with the patient's other facial features.

FACIAL ANALYSIS AND THE AFRICAN AMERICAN PATIENT

The African American patient is often seen in consultation by the facial plastic surgeon for a number of somewhat specific issues and procedures, including rhinoplasty, central face rhytidectomy, cheiloplasty for enlarged lips, and scarring problems. The anatomic features of the nose and aging face are distinct from those of Caucasians. Again, the goal is not necessarily to create ideal Caucasian features but to create balanced features in harmony with the rest of the face and the body habitus.

Common complaints regarding the typical African American nose include a wide nasal dorsum that lacks anterior height, flared alae with a wide interalar distance, and poor tip projection and definition. Thick skin, abundant subcutaneous fat, and wide, flat crura all result in poor tip projection. These problems are addressed with dorsal augmentation, alar base resection, interalar reduction, and tip defatting, respectively.

The aging-related changes to the facial hard and soft tissues in African Americans are different from those in Caucasians. Male pattern baldness is common. Preauricular skin excess is uncommon, as is fine wrinkling, including periorbital crow's feet. Skin laxity is most common in the central face, along the nasolabial folds and submental area. Skin and fat along the infraorbital rim droop with age and contribute to nasolabial fold fullness, exaggerating malar hypoplasia.

Facelift procedures may help but do not directly address the problems in the central face. Excision of the nasolabial folds and submental lipectomy may be performed, usually with good results for central face and submental skin and subcutaneous tissue redundancy.

Lip size is a concern among many African American patients. Central upper and lower lip heights of greater than 1 cm each are not uncommon. Visible pink vermilion on otherwise brown lips is felt by many to be undesirable. Optimally, the lower lip central height should be 50 to 75% greater than the upper lip central height. Dental assessment is part of the appropriate workup prior to offering cheiloplasty for reduction of lip size.

Excessive scarring, with the formation of hypertrophic and keloid scars, is seen with increased frequency in African American patients. Aberrant wound healing is most common on the chest, arms, and ears. Hypertrophic and keloid scars are rarely found on the eyelids, the nasolabial folds, the internal and external nose, the lips, and the submental area. Location of the incision, suture material, and surgical technique all play a role in prevention of hypertrophic and keloid scars.

CONCLUSIONS

Facial analysis is a critical element in successful facial aesthetic surgery. The surgeon must have a good grasp of contemporary facial ideal proportions, which must be put into perspective with the rest of the face and body habitus. Thorough anesthetic facial analysis allows the surgeon to select the appropriate procedures, and approaches to those procedures, for a specific patient. Baseline evaluation consists of a standard comprehensive history and physical, preoperative photography, appraisal of overall facial symmetry and balance, and systematic evaluation of the facial aesthetic units. Computer analysis is effective in conveying realistic expectations of surgical results to the patient and allows the surgeon and patient to compare their own aesthetic interpretations. Attention is paid to the quality of the skin, underlying bony landmarks, and contraction patterns of the facial musculature. Asian and African American patients may present specific concerns or areas they wish to address.

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Chapter 14

Anesthesia in Facial Plastic Surgery

Mark Fletcher

Anesthesia for facial plastic surgery covers a gamut of techniques from local anesthesia without sedation to general anesthesia. The first sections of this chapter deal with the drugs we have at our disposal to perform anesthesia. The next section deals with deep-sedation anesthesia, also known as monitored anesthesia care, or "The Big MAC." The final sections deal with how anesthesia influences blood loss, monitoring standards, and a discussion of anesthetic costs.

LOCAL ANESTHETICS

The first naturally derived local anesthetic was cocaine, isolated from the coca leaf in 1860. The first reported surgical procedure performed using local anesthesia was in 1884 when Koller reported using topical cocaine to facilitate ophthalmic surgery. The first synthetic local anesthetic, procaine, was synthesized in 1904. Lidocaine, the prototypical amide local anesthetic, was first synthesized in 1943.

All local anesthetics inhibit the inward flow of sodium ions that initiates a neural action potential. By progressively attenuating this inward current, they dampen and then totally eliminate neural conduction.

There are two classes of local anesthetics, esters and amides. The distinction is important for two reasons. First, an allergic response to amide local anesthetics is virtually unknown, whereas it is possible with the ester group. Second, all amide local anesthetics are metabolized in the liver, whereas all ester local anesthetics except cocaine are metabolized by pseudocholinesterase, a plasma enzyme.

Cocaine is unique among the local anesthetics in that it is the only ester local anesthetic partially metabolized in the liver and it is the only local anesthetic with vasoconstrictive properties. Both its psychoactive properties and its vasoconstrictive effect are due to blockade of norepinephrine reuptake. Thus, the combination of exogenous epinephrine and cocaine when administered nasally can result in significant tachycardia and hypertension in some patients. Pretreatment with a β-blocker can be beneficial.

Toxicity of local anesthetics is related to the peak plasma levels of the local anesthetic in the blood. The peak will be influenced by the following factors: quantity of drug injected, site of injection, presence or absence of a vasoconstrictor, and duration of administration.

Clearly, the more drug administered the higher the peak plasma concentration will be. In fact, there is a linear relationship between administered dose and plasma level.

The site of injection has tremendous impact on plasma concentrations. Obviously, injection into the vascular system itself results in a rapid rise in plasma level. Most toxic reactions to local anesthetics result from accidental intravascular injection. The differences between sites of injection are determined by their respective blood flows. The greater the vascularity, the sooner the peak is achieved and the higher the resulting concentration. The face has some of the highest cutaneous blood flow in the body. In particular, the nose and the mucous membranes of the mouth yield particularly rapid absorption.

Clinicians often add a vasoconstrictor, such as epinephrine, to a local anesthetic in an attempt to slow the rate of absorption of that anesthetic. This allows a higher total dose of local anesthetic without violating the safe plasma level. A second benefit of vasoconstrictor use is reduction in bleeding during surgery. When using epinephrine for vasoconstriction in facial surgery, the same quantity of drug should be used whether a local anesthetic is the primary anesthetic or a general anesthetic is used. The addition of local anesthesia with a vasoconstrictor to general anesthesia simplifies blood pressure management and ensures even and maximal vasoconstriction.

Maximal doses for local anesthetics are quoted as milligram per kilogram and are given as with and without epinephrine. Clinicians should consider both where the drug is injected and the time interval over which the drug is given. The toxic limit for a local anesthetic will be one quantity if the drug is given all at once and something quite different if the administration is stretched out over several hours. The redose intervals given in Table 14–1 specify how often the maximal dose may be repeated.

TABLE 14–1 Dosage Limits for Local Anesthetics (mg/kg)

Anesthetic	Plain	With epinephrine	Redose interval (min)
Lidocaine	4.5	7	90
Bupivacaine	2.5	3.2	180
Etidocaine	6	8	120–180

Data taken from 1999 *Physicians Desk Reference.*

Cocaine has poorly established maximal dosage limits. Cousins and Bridenbaugh give a limit of 150 mg in a typical adult,[1] whereas Goodman and Gilman are more liberal with 200 mg.[2] Many references do not publish a limit.

Ropivicaine is a newly introduced, long-acting, local anesthetic that is comparable to bupivacaine in duration and has a similar toxic limit of 3 mg/kg without epinephrine. In contrast, ropivicaine has a greater margin of safety for cardiotoxicity.

The two organ systems that manifest local anesthetic toxicity are the central nervous system (CNS) and the cardiovascular system. Fortunately, most patients express CNS toxicity with minimal to no cardiovascular toxicity. The earliest signs are a mild sedation, which then can progress to agitation, focal tics, and, finally, grand mal seizures. Patients will often report tinnitus, perioral numbness, and a metallic taste in the mouth.

Management of the early signs of CNS toxicity involves intravenous administration of a drug that will raise the seizure threshold. Benzodiazepines, such as midazolam and diazepam, or barbiturates, such as thiopental and methohexital, will suffice. Care must be taken not to sedate the patient to the point of airway compromise and hypoxia.

If the patient is seizing, the primary focus is on airway and oxygenation to prevent cerebral hypoxia. Termination of the seizure can then be accomplished as previously stated. Oxygen is indicated until the patient demonstrates normal blood oxygen saturation on room air.

Local anesthetics can also target the cardiovascular system, causing dysrhythmias, heart block, and reduced contractility. Fortunately, with most local anesthetics cardiovascular toxicity occurs at plasma levels twice those necessary to produce seizures. The one exception to this is bupivacaine whereby cardiac and CNS toxicities occur at similar blood levels. Bupivacaine toxicity should be greatly respected as a number of fatalities have occurred. When treating cardiovascular toxicity with bupivacaine, prolonged resuscitation may be required as the drug binds tightly to the myocardium.

Epinephrine toxicity is also possible, manifesting as dysrhythmias, tachycardia, as well as increased contractility and blood pressure. Awake patients will often complain about rapid and forceful heartbeat, palpitations, and a sense of extreme anxiety. A common story from patients who have experienced this is that they are allergic to epinephrine or local anesthetics and that they "almost died" when they received them. More often than not this experience occurred in a dental chair with either rapid tissue absorption or accidental intravenous administration.

The most specific therapy for epinephrine toxicity is β-blockade. Sedatives may also help resolve the anxiety. Doses of less than 7 μg/kg of epinephrine are unlikely to cause dysrhythmias.[3,4]

SEDATIVE HYPNOTIC DRUGS

Simply stated, the ideal sedative hypnotic drug for outpatient facial cosmetic surgery would be inexpensive, free from side effects, and equally effective in short and long surgical cases. The commonly used hypnotic drugs for outpatient facial plastic surgery include propofol, thiopental, methohexital, and etomidate. Ketamine is also used, but much less frequently due to its unique properties. All of these drugs are capable of rapidly inducing complete unconsciousness in less than 1 minute. All of these drugs are used to induce general anesthesia and some are used for sedation. They differ in cost, side effects, and pharmacokinetics.

Propofol

Propofol infusion has revolutionized the administration of outpatient, deep-sedation anesthesia. Propofol is very poorly soluble in water and is solubilized in a milky white suspension of soybean oil, glycerol, and egg lecithin. The suspension is responsible for the pain on injection noted with propofol, particularly when injected into a more distal, smaller caliber vein. The pain can be avoided or greatly diminished by immediately preceding the propofol with 20 to 30 mg of intravenous lidocaine and slowing the administration of propofol to 10 mg/s. There is a less than 1% risk of thrombophlebitis despite the potential for pain on injection, and both subcutaneous extravasation and accidental arterial injection are generally without sequelae.

Some practitioners have been concerned about the use of propofol in patients who report an allergy to eggs. Egg allergy develops to albumin, a component of the egg white. Egg lecithin used in the lipid suspension is a component of the yolk. For this reason, allergy to eggs is not a contraindication to the administration of propofol.

Propofol is a powerful sedative hypnotic with a rapid onset of action. Serious clinical effects include apnea, airway obstruction, loss of airway reflexes, and hypotension. When administered with other drugs, such as narcotics and benzodiazepines, cardiac output can be significantly reduced. Practitioners using this drug should be experienced in its use and be expert at airway management and resuscitation.

Propofol when used as an infusion has two distinct advantages for outpatient facial plastic surgery. First, it is rapidly and reliably titratable to a variety of anesthetic depths. Second, it is cleared rapidly from the patient's circulation. The clearance of propofol occurs by two mechanisms. The drug is conjugated by the liver and excreted by the kidney as inactive metabolites, and the drug is redistributed to more poorly perfused parts of the body. In the short term, these two mechanisms share the burden equally, but as infusion times lengthen, the plateau plasma concentration seen during recovery increases as redistribution sites are filled[5] (Fig. 14–1).

Propofol has other advantages, such as a reduced incidence of nausea and vomiting compared with thiopental. It also usually induces a euphoric state, which gives the patient a sense of well-being and affection for the surgical team.

Thiopental

Thiopental was the first ultra-short-acting sedative hypnotic brought into clinical practice. It is a thiobarbiturate whose activity is terminated not by metabolism but by redistribution to more poorly perfused tissues. Even after single doses of thiopental, there is a residual serum level that persists for hours. This makes the drug inappropriate for continuous infusion. Its only clinical use in outpatient surgery is as a single dose to induce general anesthesia. Thiopental has two advantages in clinical practice: its long clinical history and its

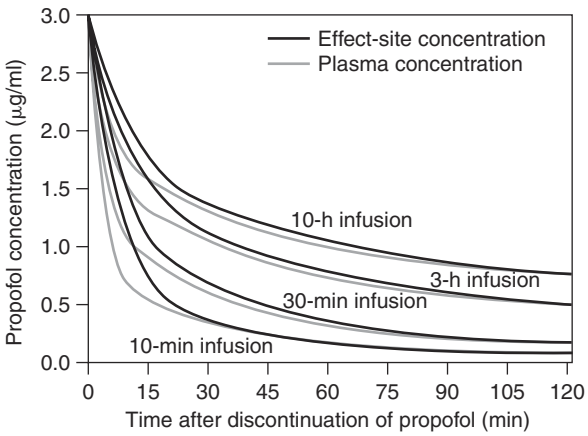

Figure 14–1 Predicted plasma and effect site concentrations of propofol after various infusion times (10 min to 10 h). (From Kazama, T, Ikeda K, Morita K, Sanjo Y. Awakening propofol concentration with and without blood–effect site equilibrium after short-term and long-term administration of propofol and fentanyl anesthesia. *Anesthesiology* 1998;88: 928–934, with permission.)

low cost. Where cost is not the limiting factor, propofol offers a number of advantages in the outpatient setting.

Methohexital

Methohexital is an oxybarbiturate with a pharmacologic profile similar to that of thiopental. Its chief advantage is a shorter terminal elimination half-life. Patients will awaken somewhat more quickly with methohexital and will notice less of a hangover after 30 to 60 minutes. Patients managed with a methohexital infusion will develop a residual sedation secondary to accumulation in the redistribution sites, but this is less noticeable than with thiopental.

Etomidate

Etomidate is an imidazole derivative that is used as an ultrashort-acting sedative hypnotic for the induction of general anesthesia. Etomidate causes little or no depression of the patient's cardiovascular system and is often used to induce anesthesia in the sickest patients. Ideally, there would be little need for etomidate in a facial plastic surgery practice.

Initially, there was enthusiasm for using etomidate in a continuous infusion as a sedative for intensive-care patients. This ended when it was discovered that etomidate suppresses the pituitary adrenal axis.[6,7] Transient suppression is noted after even a single dose of etomidate.

Like propofol, etomidate is insoluble in water and is therefore solubilized in propylene glycol. Pain on injection is prominent with etomidate unless a small quantity of lidocaine is injected immediately before the drug is given.

Ketamine

Ketamine is a unique anesthetic that is fast-acting but not classified as a sedative-hypnotic. It functions as a dissociative anesthetic such that patients do not react to stimuli in an expected fashion. For example, painful stimuli may elicit a vocal response but not a withdrawal reflex. A portion of the drug effect is due to stimulation of narcotic receptors.[8] Ketamine is in the same drug classification as phencyclidine, better known as PCP or angel dust.

Ketamine is also unique among other sedative drugs in that it causes an increase in CNS sympathetic outflow, resulting in tachycardia and mild increases in blood pressure. This effect is blocked by prior administration of benzodiazepines or barbiturates. Its use in adults is limited by dysphoric reactions. These dysphoric episodes can also be prevented by a benzodiazepine effect that outlasts the ketamine effect. Children do not seem to be troubled with the dysphoric effects, thus making the drug very useful for short pediatric sedation cases, particularly as the drug is very effective when given intramuscularly. There is a tendency to excessive salivation, which can be treated with a low dose of an anticholinergic, such as glycopyrrolate or atropine.

The drug is a potent anesthetic and should only be used in the presence of oxygen, suction, and the ability to manage the airway should upper airway obstruction occur. The proper dose is 0.5 to 1 mg/kg intravenously or 3 to 5 mg/kg intramuscularly.

NARCOTICS

Sedative-hypnotics work well only in the absence of painful stimulation. The patient will continue to move in response to pain despite deep hypnosis. The solution is to include a narcotic in the sedation regimen.

Narcotics are poor sedatives when given alone. They are powerful analgesics and respiratory depressants, but poor amnestics and only mild sedatives. When the combination of narcotic and sedative-hypnotic drugs is given, profound synergism results. The patient will sleep, be amnestic, and have little to no response to moderately painful stimuli, such as local infiltration or tissue manipulation. The analgesic properties of narcotics make them the critical component of a successful deep-sedation regimen.

There are many different narcotics from which to choose. Cost and pharmacokinetics are the most important factors in choosing a narcotic. In general, it is cost-effective and efficient to choose a narcotic whose duration of action is similar to the length of the surgery. Long-acting narcotics, such as hydromorphone, for short, less painful surgical procedures is ill advised, particularly in the elderly patient. On the other hand, using a short-acting narcotic such as fentanyl for a 4-hour case will require multiple redosing. This has two effects. First, the cost rises in proportion to the number of redoses and second, the drug accumulates in the body, filling up the redistribution sites, converting the drug from a short-acting one (dependent on redistribution) to a long-acting one (dependent on hepatic elimination).

Longer acting narcotics include morphine, meperidine, and hydromorphone. There is probably little difference in efficacy and side effects when equipotent doses are given. Recently, attention has been paid to normeperidine, a metabolite of meperidine, which tends to accumulate and can predispose to seizures.[9] This is of no consequence in the limited doses that patients undergoing facial plastic surgery would receive.

ANTIEMETICS

Postoperative nausea and vomiting (PONV) is one of the top patient complaints with all anesthetics. Often PONV occurs later in the day or evening of surgery and disturbs both the patient and the on-call surgeon. When it occurs in the immediate postoperative period it can delay or prevent discharge from the postanesthesia care unit. At the minimum, this may increase overtime payroll, and at worst it may necessitate transfer of the patient from an outpatient facility to an inpatient one.

In keeping with the axiom "less is more," the less that is done to a patient the less likely he or she is to experience PONV. A patient who receives only local anesthetic with minimal or no sedation is very unlikely to suffer any ill effects.

Modern sedatives, such as propofol, and inhaled anesthetics, such as desflurane and sevoflurane, have less potential to cause PONV than older drugs with longer elimination times. In addition, we have new antiemetics—ondansetron and dolasetron—which have been shown to inhibit nausea without the problems of sedation or extrapyramidal side effects. The major drawback to the newer antiemetics is cost.

Traditional antiemetics, such as chlorpromazine, promethazine, and droperidol, are inexpensive and effective, but they are sedating and have the potential to cause muscular rigidity, akathisia, and torticollis as the most common extrapyramidal side effects.

As a routine, we administer promethazine 50 mg and metoclopramide 10 mg orally to all adult patients before administering general anesthesia or sedation anesthetics. Because of its high cost, ondansetron is reserved for patients with a strong history of PONV.

INHALATIONAL ANESTHETICS

Inhalational anesthetics have come a long way from the days of diethyl ether, methoxyflurane, and even halothane. As newer agents have been developed, there has been a constant effort to reduce side effects and toxicity. The ideal volatile agent would certainly have one property—speed. It would exhibit both rapid induction and emergence. Speed is quantified in volatile anesthetics by measuring the blood gas solubility coefficient. The lower the coefficient, the faster the onset and offset of the drug.

Halothane with a blood gas solubility coefficient of 2.54 was a great improvement over methoxyflurane and diethyl ether with a coefficient of 13 and 11, respectively. Isoflurane (coefficient = 1.46) was even better, but sevoflurane (coefficient = 0.69) and desflurane (coefficient = 0.42) have rivaled nitrous oxide (coefficient = 0.46). These properties are nicely illustrated in Figures 14–2 and 14–3.[10]

The first graph demonstrates the impact of blood gas solubility on anesthesia induction times. The more rapid the rate of rise of the alveolar concentration, the more rapid the induction. This information is critical to the anesthesiologist but less so to the surgeon.

The graph illustrating the recovery times is of greatest importance when considering outpatient surgery. Considering the logarithmic scale, desflurane and sevoflurane enjoy a 1.6-fold faster recovery than isoflurane. In this study, the duration of anesthesia was 30 minutes. With longer anesthesia times, the recovery difference becomes even more dramatic. At 1 hour postoperatively, both desflurane and sevoflurane levels are approximately 2% of full anesthetic levels. At 2 hours into recovery, levels have fallen to 1%. In comparison with propofol infusion, only infusions of 1 hour or less can match this recovery profile. The longer the infusion of propofol, the longer the recovery. Recovery from agents like desflurane and sevoflurane are essentially independent of duration of anesthesia. Short recovery times reduce personnel costs by reducing overtime and perhaps decreasing the number of staff needed in the postanesthetic care unit. Postoperative nausea and vomiting are also reduced.

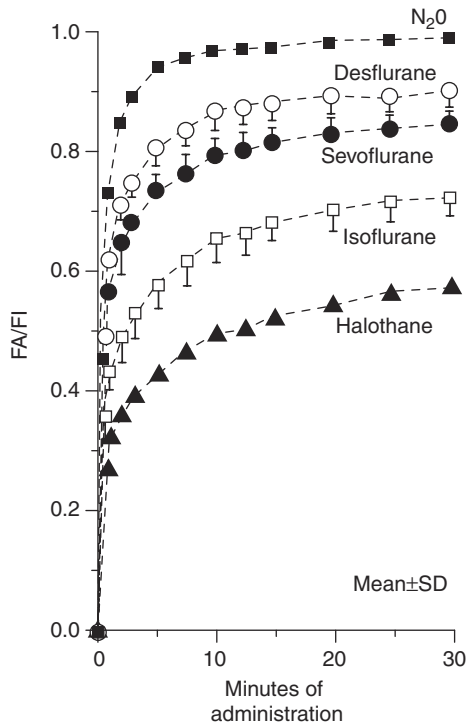

Figure 14–2 The pharmacokinetics of sevoflurane and isoflurane during their administration are defined as the ratio of end-tidal anesthetic concentration (F_A) to inspired anesthetic concentration F_I (i.e., F_A/F_I). (From Yasuda N, Lockhart S, Eger EI II, et al. Comparison of kinetics of sevoflurane and isoflurane in humans. *Anesthesia Analg* 1991;72(3):316–324, with permission.)

ANESTHESIA TECHNIQUES

Before the successful public demonstration of ether anesthesia on October 16, 1846, sedation and a speedy surgery were the only comforts surgeons could offer their patients. Deep

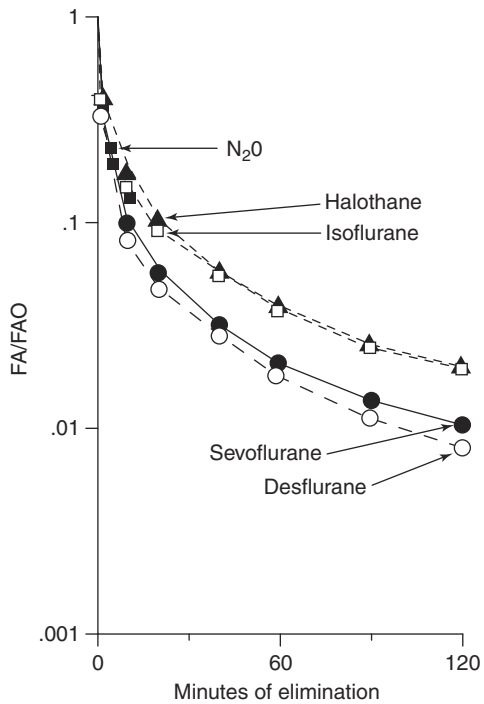

Figure 14–3 Elimination of each anesthetic is defined as the ratio of end-tidal anesthetic concentration (F_A) to the F_A immediately before the beginning of elimination (F_{A0}) (i.e., F_A/F_{A0}). (From Yasuda N, Lockhart S, Eger EI II, et al. Comparison of kinetics of sevoflurane and isoflurane in humans. *Anesthesia Analg* 1991;72(3):316–324, with permission.)

sedation was provided by one of two regimens: a near-toxic dose of alcohol or a near-toxic dose of opium. The outcomes were unpredictable and often unpleasant for both surgeon and patient. Today we are fortunate to have a variety of anesthetic regimens. For the purpose of this chapter these have been separated into four categories:

1. Minimal sedation
2. Moderate sedation/analgesia (also called conscious sedation)
3. Deep sedation/analgesia
4. General anesthesia

Any physician with appropriate training and facilities can administer the first two. The last two require specialty training in anesthesia. All may be supplemented with the use of local anesthetics to alleviate pain. The line between sedation and analgesia and deep sedation is a critical one. As published by the American Society of Anesthesiologists (ASA), moderate sedation/analgesia is defined as "a drug-induced depression of consciousness during which patients respond purposefully to verbal commands, either alone or accompanied by light tactile stimulation. No interventions are required to maintain a patent airway, and spontaneous ventilation is adequate." In contrast, deep sedation/analgesia is defined as "a drug-induced depression of consciousness during which patients cannot be easily aroused but respond purposefully following repeated or painful stimulation. The ability to independently maintain ventilatory function may be impaired. Patients may require assistance in maintaining a patent airway, and spontaneous ventilation may be inadequate."[11] The key difference is the patient's response to verbal command and his or her ability to maintain a patent airway without assistance.

Practice guidelines for sedation and analgesia by nonanesthesiologists have been published by the ASA.[12] These include standards for preoperative assessment, intraoperative care, and postoperative management. A discussion of relevant standards is included in the section on monitoring.

THE BIG MAC

Monitored anesthesia care (MAC), the newest name for what used to be called local standby, comes in many different forms. In the simplest sense, there is a continuum of sedation from minimal to a level that approaches that of a light general anesthetic. Minimal sedation is used when the patient is critically ill and the primary role of the anesthesiologist is as a vigilant monitor of vital signs and an expert in resuscitation.

At the other end of the spectrum lies The Big MAC. The patient is profoundly sedated to the level of unconsciousness and is unresponsive to moderately painful stimuli. To many facial plastic surgeons, this is the Holy Grail of sedation anesthesia. The use of deep sedation is in many ways more difficult and nerve wracking than use of a garden variety general anesthetic would be. Not every anesthesiologist is comfortable with this technique. A good working relationship between the plastic surgeon and the anesthesiologist should be cultivated. Deep-sedation anesthesia is viewed with skepticism by many anesthesia training programs where there is a strong emphasis on airway control with an endotracheal tube or laryngeal mask airway. They refer to it as an uncontrolled general anesthetic or "unconscious sedation." When deep sedation is utilized without a controlled airway, most anesthesiologists become anxious. With experience, they can develop a repertoire of techniques as well as a level of personal comfort.

There are certain elements of a successful Big MAC. These are narcotics, airway management, and supplemental oxygen.

All deep-sedation anesthesia involves the use of sedatives, often benzodiazepines such as diazepam or midazolam. Anesthesiologists add such drugs as propofol or thiopental. Sedating an operative patient without the addition of narcotics will be unsatisfactory when the patient experiences a painful stimulus. The patient will be amnestic but will grimace or move purposefully during painful events, such as local anesthetic infiltration, nasal osteotomy, and so on. If a sufficiently high dose of sedative alone is given to prevent reaction or movement, the patient will be apneic and will almost certainly lose his or her airway and become hypoxic, in spite of supplemental oxygen.

If proper doses of narcotics are used, the dose of sedative drug can be greatly decreased, reducing the duration of

any apneic period and motion in response to stimulation. Airway management and supplemental oxygen are still critical to the successful deep-sedation anesthetic. It is a rare patient who can be sedated to a level of unresponsiveness and still not require airway support. In short-duration anesthetics, neck extension and anterior jaw displacement may be all that is required. For longer cases and when the head and neck must be abandoned as part of the surgical field, nasal airways, oral airways, or laryngeal mask airways may be used. Nasal oxygen is often quite successful, and oxygen can often be jetted down the airway to preserve oxygenation.

At the Meridian Plastic Surgery Center, where the author practices, the anesthesiologists have been quite successful using a short nasopharyngeal airway as an oral airway. If the length is adequate to reach around the tongue to the glottic area without stimulating the glottis itself, this is ideal. The soft nasal airway is far better tolerated by the patient than a more rigid plastic oral airway and has the advantage of allowing jetted oxygen to be administered to the airway.

What follows are typical dosages for doing monitored anesthesia care during facelift or rhinoplasty on a typical adult patient:

Preoperatively:

- Promethazine 50 mg orally.
- Metoclopramide 10 mg orally.
- Midazolam 1 to 2 mg IV for sedation.

Preinduction:

- Oxygen supplementation by nasal cannula

At induction:

- Hydromorphone 1 mg IV.
- Propofol 60 to 150 mg IV.
- Airway support during local anesthetic administration, usually leading to insertion of nasal or oral airway with oxygen jetted at distal tip of airway.

Maintenance:

- Propofol infusion at 50 to 150 μg/kg per minute.
- Patient may require one or two additional doses of hydromorphone of 0.25 to 0.5 mg.

ANESTHESIA AND BLOOD LOSS

Some surgeons have a strong preference for sedation over general anesthesia because they believe that general anesthetics are vasodilators that will increase blood loss. Multiple studies confirm that volatile anesthetics are indeed vasodilators, particularly of skeletal muscle.[13] There is no evidence in the literature to support that these agents will counteract the vasoconstricting effect of subcutaneous epinephrine on blood vessels. Although different patients appear to undergo vasoconstriction to a greater or lesser extent in response to injected epinephrine, this is not related to the choice of sedation or general anesthesia.

Blood loss is profoundly affected by systemic blood pressure. A sudden elevation in pressure is clearly reflected in increased bleeding at the surgical site. This is particularly noticeable where large cutaneous flaps are elevated or in nasal surgery. The best therapy is to address the cause of the hypertension. Appropriate measures to reduce blood pressure include deepening of the sedation or general anesthesia, extension of the local anesthetic to cover surgical areas incompletely anesthetized, or administration of vasoactive drugs.

MANAGEMENT OF HYPERTENSION

The use of subcutaneous epinephrine is critical in many facial plastic surgical procedures where direct control of all bleeding vessels is not practical or possible. Avoidance of hypertension is equally critical in the control of blood loss and the prevention of hematoma formation. Hypertension results from both intrinsic and extrinsic factors. The pain and stress of surgery can cause hypertension in a normotensive patient. The use of local anesthetics, narcotics, and sedatives will usually control this response. Many facial plastic surgical patients are elderly and suffer from intrinsic hypertension. It is critical that the medical condition of the patient be optimized and his or her antihypertensive regimen be maintained throughout the surgery and into the postoperative period. Additional antihypertensive drugs may be required to maintain tight control of blood pressure.

Tachycardia is very stressful for patients with coronary artery disease. It increases myocardial oxygen demand while decreasing myocardial oxygen supply.[14] It is good practice to avoid increases in heart rate that can occur with epinephrine injection or with a painful stimulus. β-Blockers are very effective in treating tachycardia secondary to increased adrenergic stimulation. For this reason, they are the first-line drugs for treatment of hypertension, unless the patient is already bradycardic. The most common β-blocker in our use is labetalol. Intravenous doses of 5 to 20 mg in an average adult are usually effective.

There is a ceiling effect with β-blockers seen when increased drug causes no reduction in pulse rate or blood pressure. This typically occurs at doses of labetalol greater than 0.5 mg/kg. Vasodilators such as hydralazine or calcium channel blockers such as verapamil or diltiazem are effective second-line drugs. Hydralazine causes a reflex tachycardia when given alone but less so after administration of a β-blocker. The usual intravenous dose for hydralazine is 5 to 10 mg. The onset time of hydralazine is delayed and it is necessary to wait 15 minutes to assess the effect of an intravenous dose. The author uses verapamil as a third-line drug in cases of resistant hypertension. The dose is 2.5 to 5 mg for the average adult.

Some practitioners have advocated the use of clonidine to control perioperative blood pressure. Clonidine is not available for injection but must be given either orally or transcutaneously as a patch. The onset time for the antihypertensive effect is slow, and the final effect is unpredictable. Patients who are started on oral clonidine for primary hypertension must be cautioned regarding postural hypotension. In the dynamic situation of surgery, it makes no sense to rely on a drug with a delayed onset and unpredictable effect when highly titratable drugs with rapid onset and predictable effect are available.

Hemodynamic control to limit bleeding not only is important intraoperatively but must continue into the postoperative period to prevent hematoma and decrease swelling. It may be necessary to initiate a 2-day course of β-blocker therapy with or without a vasodilator. The author's preference is to use

atenolol 100 mg once or twice daily depending on previous response to intravenous β-blocker. In resistant cases, it may be necessary to add nifedipine (Procardia XL) 30 mg once daily.

The use of long-acting sedatives to control postoperative hypertension is not recommended. Only rarely will sedatives normalize the blood pressure in an otherwise hypertensive patient, and in situations where there may be bleeding into the airway they can be a recipe for disaster.

Where appropriate, the use of local anesthetics to reduce pain will often simplify postoperative management.

MONITORING

Intraoperative and postoperative standards for monitoring have been published by the ASA.[15] Following are the two published standards for intraoperative management.

Standard I

Qualified anesthesia personnel shall be present in the room throughout the conduct of all general anesthetics, regional anesthetics, and monitored anesthesia care.

The purpose of the first standard is to ensure the presence of competent personnel at all times during the administration of any deep sedation/analgesia or general anesthesia. This caregiver serves both to monitor the patient and to provide needed anesthesia care.

Standard II

During all anesthetics, the patient's oxygenation, ventilation, circulation and temperature shall be continually evaluated.

An important distinction is made between "continually evaluated" and "continuously evaluated." Continual is defined as "repeated regularly and frequently in steady rapid succession," whereas continuous means "prolonged without any interruption at any time." This standard applies to all anesthetics and in its broadest interpretation might even apply to a patient receiving only local anesthesia.

To assess oxygenation, use of a pulse oximeter is required unless prohibited by surgical or anatomic factors. The use of skin color to assure adequate oxygenation is vastly inferior as cyanosis does not become apparent until more than 5 g/dL of desaturated hemoglobin is present.

Ventilation can be assessed in the sedated patient by feeling for exhaled gases, observing chest expansion, and watching for signs of obstruction, such as retractions, "rocking boat" respirations, and snoring sounds. Some practitioners advocate the use of end-tidal carbon dioxide monitoring in sedated patients, but it is virtually impossible to obtain a quantitative sample.

Circulation is assessed by continuous electrocardiography and intermittent blood pressure monitoring. ASA standards call for blood pressure determinations at least every 5 minutes.

Temperature monitoring must be available for all patients and utilized whenever clinically significant changes in body temperature are intended, anticipated, or suspected. The use of convective warming blankets is the most effective way to maintain body temperature in a cold operating room. Warm fluids should be used whenever large volumes of intravenous, irrigation, or tumescent fluid are used.

Whenever general anesthesia is employed, additional monitors must be used.[15] Inspired oxygen concentration as well as ventilatory volume and pressure are standard on all modern anesthesia machines. End-tidal carbon dioxide monitoring is now the standard, and agent analysis is an evolving standard.

Bispectral Index (BIS) is a processed electroencephalographic monitor (Aspect Medical Systems, Newton, MA) that yields a number between 0 and 100 correlating with a patient's ability to recall events. An index of less than 60 virtually ensures total lack of recall, whereas an index greater than 70 puts the patient at progressively greater risk of recall. The monitor uses a proprietary electrode, which is applied to one side of the forehead just above the eyebrow. This position severely limits application of the BIS in facial plastic surgery. The company claims that BIS allows a reduction in anesthetic drug cost as well as a speedier discharge from recovery. The ultimate cost/benefit ratio has not been established.

The ASA standards for postoperative care can be summarized as follows. All patients who have received an anesthetic need to be monitored for an appropriate time in a postanesthesia care unit (PACU). Changeover from the caregiver in the operating room to the caregiver in the PACU is given at the time of transfer. Initial postanesthesia monitoring should include all of the same monitoring as was used in the operating room. Monitors can be withdrawn as the patient emerges from the effects of anesthesia. A physician is responsible for the discharge of the patient from the PACU.

ANESTHETIC COSTS

Working at a privately owned surgery center has influenced the author's appreciation of costs. Because facility fees paid by cosmetic patients fund anesthesia drugs and materials as well as nursing costs, any reduction in anesthesia materials cost or personnel costs will have a direct effect on the bottom line. When costs of differing drugs and anesthetic techniques are borne by third-party payers or facilities such as hospitals, the anesthetic of choice is simply whatever the surgeon and anesthesiologist prefer. When drug costs are taken out of the fee paid to a facility owned by the surgeon, cheaper may well be better. Anesthesia costs can make or break the profitability of facility fees in a highly competitive environment.

Figure 14–4 shows hourly propofol costs for differing dosages. The patient is assumed to weigh 70 kg. The dosage range displayed covers the usual range required for a deep-sedation anesthetic (Big MAC). Costs will vary depending on the weight of the patient. This analysis ignores the costs of adjuvant drugs, such as narcotics and oxygen, as well as equipment, such as airways.

For comparative purposes, Figure 14–5 shows the relationship between fresh gas flows and hourly anesthetic costs for desflurane, sevoflurane, and isoflurane. Again, this analysis ignores the cost of equipment and supplies as well as adjuvant drugs. You will note that there are no data for sevoflurane at fresh gas flow rates less than 2 L/min. This is in keeping with Food and Drug Administration recommendations of a minimum flow rate of at least 2 L/min to avoid patient exposure to toxic breakdown products of sevoflurane.

Higher fresh gas flow rates are used at the onset of administration of a general anesthetic to compensate for the substantial uptake of agent early on. As time passes, flow rates can easily be reduced to below 2 L/min for desflurane

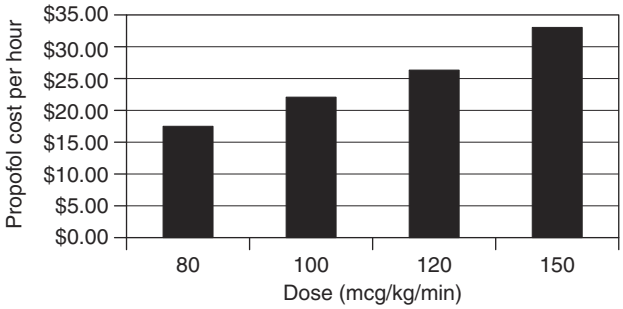

Figure 14–4 The hourly cost of propofol at typical clinical infusion rates. The analysis is based on a 70-kg patient. (Data from the Meridian Plastic Surgery Center, Indianapolis, IN. With permission.)

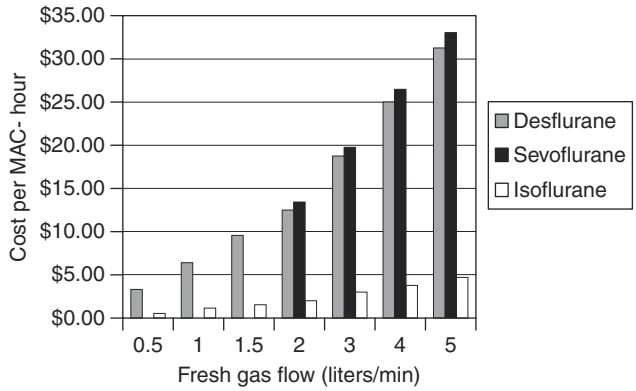

Figure 14–5 Cost per MAC-hour for the major inhaled agents at different fresh gas flow rates. Costs for sevoflurane are not quoted below 2 L/min flow (see text). (Data from the Meridian Plastic Surgery Center, Indianapolis, IN. With permission.)

and on long procedures can go as low as 500 mL/min. Profound cost savings can be realized with isoflurane at low flows if one is willing to accept a delay in emergence due to the higher blood gas solubility coefficient.

The obvious conclusion is that substantial cost savings can be realized over longer surgical procedures when general inhalation anesthesia is chosen over intravenous anesthesia with propofol. This is the same conclusion drawn by Alhashemi et al in their article on cost-effectiveness of inhalational, balanced, and total intravenous anesthesia.[16] On shorter procedures, the cost difference is not substantial and is therefore not a factor in choice of an anesthetic.

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Chapter 15

Rhytidectomy

Stephen Perkins and Steven Dayan

HISTORY

The majority of cosmetic surgical procedures have developed from procedures designed to give functional improvement. Therefore, written records, debates, and publications date back many years. In contrast, aging-face surgery—rhytidectomy, in particular—originated as various procedures intended to enhance a patient's self-image. Early on, aesthetic surgery was perceived negatively in the medical community. Many physicians and surgeons did not believe in the benefits of enhancing self-esteem through elective cosmetic surgery and forced this practice into shameful hiding. Others, recognizing the merit of self-improvement, felt that elective surgery with its inherent risks was an inappropriate method by which to achieve such improvement.

German and French surgeons are credited with pioneering facelift surgery. In 1906, Lexer is thought to have performed surgery to treat wrinkles, but it was Hollander in 1912 who was the first to report a case.[1] Other European physicians, including Joseph (1921) and Passot (1919), developed their own techniques for treatment of the aging face. Yet, for whatever reasons, these founding fathers were often guarded when it came to sharing their wisdom. Following The Great War, the practice of reconstructive plastic surgery blossomed. Along with the explosion of new ideas and techniques came the inevitable increased interest in cosmetic surgery. Although still shrouded in secrecy, even the most prominent physicians of the time recognized its existence. Many of these well-respected leaders were rumored to perform cosmetic surgery in their own private clinics or offices. Gilles in 1935 stated, "The operations for removal of eyelid wrinkles, cheek folds and fat in the neck are justifiable if the patients are chosen with honest discrimination."[1]

Following World War II, with the advent of newer medications and improved anesthesia methods, elective surgery became more of a reality. In addition, a progressive affluent society expressed interest in equating their appearance with a youthful outlook on life. However, the occult field of cosmetic surgery, surrounded by shameful secrecy, jealousy, and greed, had not allowed for the fostering of ideas and advancement that was common to the other surgical specialties of the time. Therefore, the results achieved by facelift surgery were marginal and not long lasting. Sam Fomon, a pioneer in facial cosmetic surgery and a founding father of what was to become the American Academy of Facial Plastic and Reconstructive Surgery (AAFPRS), was instrumental in teaching cosmetic surgery to all those interested. He recognized the limits of facelift surgery when he stated, "The average duration of the beneficial effects, even with the best technical skill, cannot be expected to exceed three or four years."[1] At the time, facelift surgery techniques consisted of a limited subcutaneous dissection and skin elevation resulting in a tightening of the preauricular skin and, often, an obvious "operated look." Unfortunately, these methods did not change significantly until the 1970s. The social renaissance of the 1960s and 1970s brought a new openness and acceptance regarding cosmetic surgery. This fueled scientific advances and dialogue, leading to better surgical techniques and results.

The first major contribution in a half century was provided by Skoog, who touted the benefits of dissecting in a subfascial plane.[2] This allowed for a significant improvement in the lower third of the face. The validity of this new fascial plane was solidified by Mitz and Peyronnie's landmark article in 1976, defining this fascia as the superficial musculoaponeurotic system (SMAS).[3] To achieve a more natural look, numerous modifications have since been made in the sub-SMAS rhytidectomy. Early sub-SMAS dissections mostly provided for an improved jaw line. However, today's surgeons, recognizing the importance of facial harmony, have concentrated efforts on improving the midface and nasolabial fold region. Hamra, the pioneer of the deep-plane and composite rhytidectomy, continues to present the beneficial effects that can be achieved in the middle third of the face.[4,5] Others have concurred with the improved results possible with deep plane rhytidectomy.[6,7] Still, there are those designing different methods to achieve facial balance, including venturing into a subperiosteal plane.[9–10] And there are even those who are revisiting the subcutaneous dissection, considering it the method of choice in select situations.

The variety of anatomically sound rhytidectomy techniques offers the surgeon options in challenging the effects of aging. However, in addition to recent advances in surgical techniques, there is a new emphasis on recognizing the importance of patient individuality. Each surgical technique has its place. The key for the prudent surgeon is to appropriately evaluate each patient, both physically and emotionally, and then utilize the correct treatment for the proper diagnosis.

CONSULTATION ANALYSIS AND PREOPERATIVE PREPARATION OF THE RHYTIDECTOMY PATIENT

In preparation for the initial consultation with the potential rhytidectomy patient it is imperative that your office present itself in an appropriate and appealing manner. The initial contact with any cosmetic surgical patient begins with the first phone call of inquiry. At this point, the potential patient may or may not have adequate information about you as a surgeon or your office to even make the decision to meet you in consultation. It is incumbent on the person who answers your phone to have a welcoming and pleasant voice and to be very informative. This person should be knowledgeable and willing to give appropriate information to the prospective consultation patient. However, he or she should not truly give a consultation over the phone, as this should be reserved for the doctor. Discussion of fees will most likely be necessary, but the conversation should not be an impediment to the patient scheduling the consultation appointment. Fees quoted should be within the comparative competitive range for your area.

Promptly on scheduling the appointment, the patient should receive a packet of well-written information outlining the procedures that will be followed, as well as an advance informational booklet or brochure about the procedures with which he or she is most concerned. Well-written informational brochures and consultation booklets are much appreciated by thoughtful and discriminating patients. This may include academy brochures regarding each procedure but also should include whatever personal information you would like to impart to the patient. This will truly shorten the time of the consultation with the patient and improve the overall communication effort. A well-informed surgical patient, starting from this stage of your encounter, will likely result in a happy patient postoperatively.

The day of the consultation may involve several points of interaction with your key employees. Although a preconsultation with the patient regarding office procedural issues and what to expect during that day's visit is helpful, the patient is looking forward to meeting the surgeon. It is critical that this be an unhurried, private, confidential meeting held as soon as possible after the patient's arrival. Focusing on the patient's importance to you in the office by being on time at this juncture may prove to be a pivotal issue with your prospective patient.

Just prior to your meeting the patient, it is appropriate for the photographer to capture the patient's image on the video imaging system. State-of-the-art consultations in facial surgery today involve a visual reaffirmation with the patient as to what you believe he or she can expect in terms of results after surgery. The discriminating patient in the marketplace today usually insists on this.

During the one-on-one initial consultation, it is very important for you to develop an immediate rapport with the patient. It is important for you to understand the motivating forces behind the patient's request for improvement in facial appearance. Is the patient's main concern truly correctable by standard facial rhytidectomy procedure? Often, the main concern may be true rhytids of the superficial surface of the face, which would be more appropriately treated by means other than a facelift procedure. If deep cheek–lip grooves are the primary problem and the patient is less concerned about jowling or submental skin and fat ptosis, a rhytidectomy (better described as a facelift) may not be the appropriate procedure.

It is the surgeon's responsibility to determine, with the patient's assistance, what the patient's true motivation for the surgery is. Being in the middle of a life-changing situation, such as divorce, is not in itself a contraindication for proceeding with facelift surgery. However, patients who expect the cosmetic surgical procedure or procedures to solve their situational dilemma may not be proper candidates for the procedure. Patients who truly believe they are doing this for their self-esteem and not for anyone else's benefit are more likely to have a successful psychological benefit. Patients must be realistic about what can and cannot be achieved by surgery, and it is incumbent on the surgeon to impart this information during the consultation.

It is important to evaluate the patient's family history to determine the likely speed at which the loss of elasticity of the tissues and the overall aging process is occurring. One must determine lifestyle and social habits, taking into account issues such as solar exposure and smoking, which accelerate aging.

One must have the patient complete a detailed history questionnaire. Identifying whether or not the patient has had previous cosmetic surgery or any other surgery is important, including what the experience was, as well as whether or not there were difficulties with particular medications or anesthetic techniques. This often weighs heavily on the patient's mind. Preparing the patient for an appropriate positive mental experience is crucial. If the patient is terrified of anesthesia or the idea of surgery, one must get past this to focus on the positive aspects of what can be achieved by surgery.

Certainly, it is important to take a complete medical history to ascertain which, if any, medical conditions exist that would preclude facelift surgery. Cardiovascular disease in itself is not a contraindication to surgery, but a complete clearance by their cardiologist is imperative prior to scheduling surgery. Certainly, an unstable cardiac history precludes any kind of anesthetic or surgical intervention. Liver and renal functions are important in determining the patient's sensitivity to anesthetics. Allergies to any medications that are required for the surgery should be taken into consideration.

There are a few diseases that would preclude facelift surgery. The history of advanced autoimmune diseases relating to the skin of the face may be a contraindication for facial surgery. Scleroderma and systemic lupus erythematosus are not contraindications to surgery unless the disease is manifesting in the face itself. Some of the other autoimmune diseases may be looked at with suspicion, particularly depending on the type of medication the patient is taking to suppress the autoimmune response. These medicines may suppress the patient's immune response or inhibit the healing process. Unstable cardiovascular disease is a contraindication to elective facial surgery. Diabetes mellitus in itself is not a contraindication to surgery, nor is taking chronic steroids, particularly in the lower dose ranges. Sjögren's syndrome may be a relative contraindication, depending on the involvement of the parotid glands and stasis of salivary tissues. The autoimmune diseases that relate to perivasculitis are of most concern.

A history of full-course radiation treatment to the preauricular regions or infra-auricular neck would preclude surgical intervention. The long-term chronic vascular compromise to the skin's microvasculature will make skin flap elevation too risky. Use of isotretinoin (Accutane), though unusual in the facelift age group population, is only a relative contraindication to surgical intervention. There is very little evidence of delayed healing of incisions specifically due to isotretinoin treatment. Medications that would preclude the surgeon from using epinephrine in a local anesthetic or true allergy to any of the local anesthetic classes of medication would contraindicate the performance of facelift surgery even with necessary, proper hemostasis.

Obesity in itself is not a contraindication to facelift surgery if you take into consideration that the results of the procedure may be less than satisfactory. Certainly, a patient who is overweight and plans dramatic weight loss in the ensuing 3 to 6 months should be counseled to lose the weight prior to having the facelift surgery. Generally, a loss or gain of 10 to 15 pounds postoperatively will not affect the overall results of the procedure. Conversely, any patient who is in the midst of dieting that may diminish their vitamin and otherwise nutritional intake should be advised against having any kind of surgery. Not only should one be healthy at the time of surgery, but a proper diet is imperative for proper healing as well as for electrolyte balance during the surgery. There are some significantly overweight patients who should be advised against facelift surgery due to the inherent limitations of the procedure, even if a large amount of suction-assisted lipectomy is included. The facelift itself is not a weight reduction procedure, and thinning the midfacial tissues is inappropriate and fraught with complications.

During the physical examination, the surgeon should be able to advise the patient as to what sort of outcome can be expected from the rhytidectomy. A physical examination is absolutely necessary before the surgeon can show the patient on the computer imaging system what his or her likely neck line and jaw line result will be. A good candidate for facelift surgery is a patient who has moderately thick skin and who has minimal sun damage, and who has retained some hereditary elasticity to the skin, particularly appropriate for the chronologic age. Those patients with premature loss of elasticity to their skin, despite it being smooth and non–photodamaged, may have a less than satisfactory duration of improvement.

Thick-skinned and overweight patients should not expect too much from the results of the rhytidectomy procedure. Not only is the initial result limited, but the length of time for which soft tissues remain firm and in an upward position may be shorter than average due to the increased weight of the tissues and gravity.

The visible presence of loss of elasticity in the jowl tissues, as well as laxity in the skin, platysma, and fat of the submental and submandibular regions, is a prima fasciae reason to entertain the idea of a facelift as an appropriate procedure for the patient. Certainly, benefits have to be of a significant degree to warrant the surgical intervention required, as well as the potential risks involved. Certainly there are patients with a very minor degree of ptosis of soft tissues or presence of signs that a facelift corrects who should be counseled either to consider other procedures or to return at a later date when the signs of aging have progressed and the procedure may be more indicated. Today's patient population may be slightly more anxious than they should be regarding when to begin the facelift process. It is incumbent on the surgeon not to be too eager to recommend, and on the patient not to be too eager to undergo, this procedure for marginal benefits.

Patients who are good candidates for facelift surgery may have a forward chin and strong bony structures, particularly prominent cheek bones. Patients with heavy cheeks and jowls and minimum malar prominences may be disappointed in the outcome of soft-tissue lifting alone. Malar augmentation may enhance the overall angulation of the face. In addition, midfacial hypoplasia or loss of midfacial subcutaneous soft tissue due to hereditary and aging processes often necessitates submalar augmentation to achieve an appropriate rejuvenative result with a standard facelift procedure. The alternatives to these two augmentation procedures may involve a different approach to facelifting, such as midfacial lift or composite facelift. Equally, patients with class II malocclusion, hypoplasia of the mentum, or microgenia may be poor candidates for an improved neck line result. Orthognathic consultation or, at the minimum, alloplastic augmentation of the mentum at the time of the facelift is indicated to truly achieve a satisfactory aesthetic result. This is one of the values of preoperative video imaging whereby the patient can observe the results of lifting allowed by his or her own soft tissues versus that with an enhanced bony architecture structure.

It is important for the surgeon to evaluate the cervical mental angle with respect to the underlying muscular tissues and position of the hyoid bone. Many patients are poor candidates for an improved neck angle due to a low-positioned hyoid, and this needs to be carefully shown to them, both through a mirror examination and on the video imaging machine. The surgeon must not overcorrect the neck angle on the video computer with respect to the true angle of the underlying tissues of the patient's neck so as not to convey a false or unrealistic impression as to what the facelift result will be. It is ethically mandatory to show the patient the true possible results of a facelift. This may determine whether or not the patient is satisfied postoperatively with the surgeon's work. Repositioning of the hyoid itself or sculpting of the digastric musculature has been described but is not recommended in the routine or standard neck portion of the rhytidectomy procedure. One must understand what can be accomplished with sculpting lipectomy and platysmaplasty, which can be remarkable at times but have inherent limitations.

Prior to leaving the consultation room, the surgeon must answer all the patient's questions and proceed to a discussion of the entire procedure, its alternatives, risks, and limitations. A fully informed patient is one who understands the risks and benefits of the procedure, as well as alternative forms of management that might be appropriate. The patient must understand the surgical procedure and the maneuvers involved, even if he or she does not understand or want to know the exact surgical steps. At the end of this chapter, the complications that may arise from rhytidectomy, or facelift surgery, will be covered. The patient must be at least adequately informed of the possibilities of these occurrences and their relative rates of incidence. The risks of anesthesia should be covered in terms of the choices and alternatives in a general sense. It is appropriate, however, that the risks of any particular anesthetic type be covered by the administering physician.

FURTHER OFFICE PROTOCOL FOLLOWING CONSULTATION

At the end of the initial consultation with the patient, adequate medical photodocumentation of the current condition of the patient's aging face, neck, and jowls must be performed. Adequate preoperative photographic documentation and analysis is state of the art and the standard of care in terms of preoperative chart documentation, as well as long-term evaluation of results. Professional self-evaluation and improvement can only be achieved with adequate pre- and postoperative photographic documentation.

Standard preoperative photographic views for facelift surgery include the full-face frontal view, as well as full-face left and right oblique views, and left and right lateral views. One may choose a close-up perioral photograph, as well as a close-up showing more detail of the submental neck tissues. A close-up view of each auricle, with hair pulled behind the ears, earrings removed, and all photographs taken in a Frankfort horizontal line, is imperative.

It is up to the surgeon whether or not to show patients, at their request, pre- and postoperative photographs of other facelift patients or merely use computer video imaging to show the expected results in the present case. Adequate disclaimers as to guaranteed final result must be understood by the patient. Video imaging consents are appropriate and signed by the patient prior to undergoing this portion of the evaluation. Any patient viewing preoperative and postoperative photos of other previous facelift patients must understand that those patients' confidentiality has been maintained and their permission for use in this setting was given. Furthermore, results from one patient to the next may not be comparable. When the full evaluation is undertaken by the physician and proper photographs have been taken, the patient must have an opportunity to be presented with the financial implications for his or her potential decision to undergo facelift surgery. Financial arrangements and requirements should be carefully and clearly outlined to the patient by the scheduling nurse or secretary. The patient's commitment and ability to financially pay for this cosmetic surgery procedure is as important as the decision to proceed with the surgery itself. Patients should not put themselves in any kind of financial stress to have this elective procedure. At this time, they need to be well informed as to whether this procedure will be performed in an ambulatory surgical suite or in a hospital environment. All facelift surgery today can be performed in an ambulatory setting, be it a hospital or a free-standing facility. Some patients may choose extended overnight stays for their own convenience, but this is not required. It is critical that appropriate arrangements be made for someone to drive a patient to the surgical suite and home again. Most patients remain sedated postoperatively for 12 to 24 hours and should not be responsible for themselves without assistance.

If a patient chooses to schedule surgery, a date should be selected and the appropriate informed consent form signed. The informed consent is a reiteration of what was covered in the consultation, with the patient's signed affirmation that the doctor conveyed the risks and benefits of the procedure, as well as its alternatives. Furthermore, it must state that all questions were appropriately answered. Consent for use of any kind of photography for purposes other than medical record documentation must be obtained from the patient prior to the doctor's using the photos. The patient is then asked to obtain appropriate preoperative laboratory and other physical assessment measures. These may or may not be the same or appropriate for all patients. Often electrocardiograms, liver functions, renal functions, and hematologic blood status are obtained as an appropriate assurance that the patient is able to undergo the anesthetic recommended. When appropriate, the physicians associated with the patient's normal health care should be contacted and made aware of the patient's decision for surgery. Certainly, any contraindications of surgery may be uncovered at that time if the patient has not been completely forthcoming. Any reservations about the patient's ability to undergo anesthesia may dictate further physical examination and consultation with the appropriate medical specialist.

Finally, at all times the entire confidentiality of the consultation and plans for surgery must be assured. The patient must give permission for any contact with outside laboratories, physicians, or insurance companies. Any reservations on the part of patients regarding whom to contact at their business must be documented in the chart and complied with.

ANATOMICAL CONSIDERATIONS AND TYPE OF FACELIFT PERFORMED

The fundamental decision as to what type of facelift will be required for an individual patient is primarily based on the preexisting condition of the patient as outlined and observed in the physical examination portion of the consultation. Not every patient requires the same degree of surgical intervention to achieve a satisfactory result. There are basically three types of facelift procedures, based on the general categories of surgical intervention required to achieve a satisfactory surgical result. Each procedure, whether it involves a minimal degree of skin undermining, plication or imbrication of the underlying superficial musculoaponeurotic system (SMAS), treatment of the platysma muscles or extensions into the deeper layers of the face, including the subperiosteal approach, will be covered. Most of the decisions are based on the preexisting condition of the patient, the underlying philosophy of the surgeon, and what one believes the long-term results of the surgical maneuvers performed may be (Tables 15–1 and 15–2).

TABLE 15–1 Ideal Candidates for Facelifting Exhibit

Good skin tone with minimal photoaging and few wrinkles
Strong facial bony structures
Strong foreward chin
Prominent cheek bones
Fuller midface
Shallow cheek–lip grooves
Sharp cervicomental sulcus
Nonsmoker

TABLE 15–2 Poor Candidates for Facelifting Exhibit

A low hyoid producing an obtuse cervicomental angle
Have receded or weak chins
Have low slung submandibular glands
Deep oral commissure cheek–chin grooves
Deep nasolabial grooves and prominent cheek mounds or folds

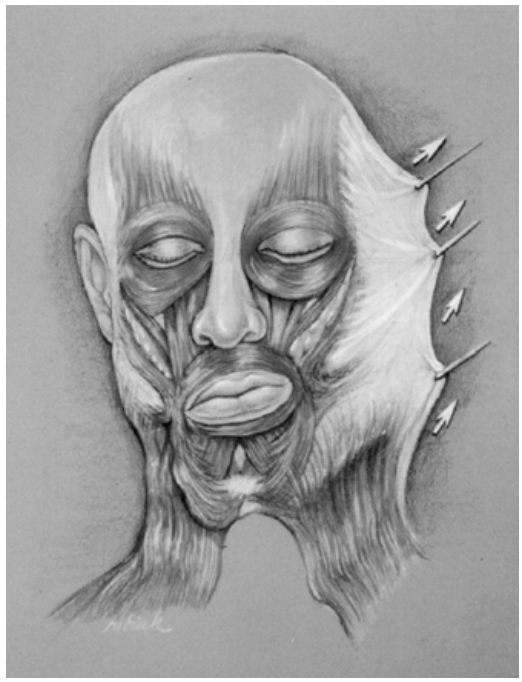

Figure 15–1 Superficial musculoaponeurotic system (SMAS) connected with platysma and facial musculature.

First of all, the fundamental concept of facelifting is based on certain anatomical relationships of the tissues. The elasticity and condition of the overlying skin, including its degree of photodamage and rhytid formation, is important. The relationship with the underlying subcutaneous adipose tissue, including the loss of position with gravity, true ptosis, or abnormal accumulation and distribution, must be noted. The underlying fascial arrangement of face, neck, and midface is such that the facial musculature is enveloped by continuous fascia that extends to the preparotid region. This fascia, which is contiguous with the platysma muscle of the neck, is the SMAS, first described as a dynamic contractile and fibromuscular web by Mitz and Peyronnie. The fascia deep to this is the superficial layer of the deep cervical fascia that envelopes and covers the sternocleidomastoid muscle, as well as the parotid tissues. It is superficial to the superficial layer of the temporalis muscular fascia as well as to the periosteum of the forehead. The SMAS is contiguous with the galea of the scalp. In the neck anteriorly, the platysma muscle may or may not be interdigitated forming a connected sling. Often, there is a laxity and dehiscence of the anterior borders of the platysma muscle, creating banding in the neck. It is the very nature and the existence of this SMAS layer that allows for a deeper plane of facelifting surgery than was performed in the original rhytidectomy procedure. Only skin was lifted, elevated, excised, and resutured in a more cephalic and posterior position. Skin, due to its inherent creep phenomenon and rebound stretch characteristics, often does not hold for any length of time. Therefore, the effects of the facelift surgery were brief when this was the only layer approached. Skin, particularly in the middle and more central portion of the face, is directly connected to the SMAS layer by firm dermal fibrous filaments. Often accompanying these dermal filaments is some penetrating vascularity from the deeper vascular systems to the superficial dermal plexus. It is easily demonstrable that lifting and pulling the SMAS layer with its integral attachment to the platysma muscle and midfacial muscles lifts and repositions the skin in the same fashion (Fig. 15–1). A superior and posterior vector of the pull of this fascia repositions the facial tissues in a more youthful position. The effect of gravity on these anatomical tissues is directly affected and improved by the facelifting procedures.

It is equally important to understand the anatomical relationships of the neurosensory and neuromotor branches of the face that supply sensation to the overlying skin as well as function to the mimetic muscles of the face. These relate directly to the expected sequelae of facelifting surgery for all patients, that is, loss of sensation and paresthesias, which usually are temporary but can be permanent. The fifth cranial nerve supplies sensation to the cutaneous surfaces of the face, head, and neck. The fact that performance of any type of facelifting surgery requires elevation and a certain amount of preauricular and postauricular skin necessitates interruption of the immediate innervation of this portion of the face. Typically, unless any major branch of the greater auricular nerve is interrupted, sensation returns to the skin in a relatively short time. The patient can expect return of sensation in the first 6 to 8 weeks, but occasionally 6 months to a year may be required for full return. In rare cases, the patient may report a decreased overall sensation to the skin than was there preoperatively, even beyond a year. Sympathetic and parasympathetic reinnnervation of the skin proceeds more rapidly in the postoperative period. Although the most common major nerve branch injured in facelifting surgery is the greater auricular nerve as it crosses over the sternocleidomastoid, even this rarely causes permanent loss of sensation of the auricle or the preauricular skin. As one is dissecting skin and its dermal attachments away from the superficial layer of the sternocleidomastoid muscular fascia, if one interrupts this fascia, direct injury to this very large and visible nerve branch may occur. When recognized at the time of surgery, direct suture reanastomosis is indicated and return of nerve function within a year or two is expected.

Motor branches to the facial mimetic musculature are potentially in danger during facelift surgery. Branches of the facial nerve become very superficial as they extend past the parotid masseteric fascia. The marginal mandibular branch is at some risk as it crosses the mandibular margin, deep both to the platysma muscle and to the superficial layer of the deep cervical fascia. Techniques requiring deep-plane elevation underneath the SMAS layer into the midface endanger branches to

the orbicularis, zygomatic, and buccinator muscles. Innervation to these muscles is still to the undersurface of the muscles, and deep-plane technique at this point would be superficial to those muscles. Direct visualization of the nerve is part of this procedure and will be discussed further in this chapter.

The branch of the facial nerve most commonly injured in facelift surgery, with or without temporal forehead lifting, is the frontal branch. This branch becomes very superficial at the level of the zygomatic arch and extends just beneath the subcutaneous tissues underlying the thin SMAS layer of the temporal region prior to its innervation of the deeper surface of the frontalis muscle. As it traverses this area, approximately 1.5 to 2 cm preauricular and halfway between the lateral orbital rim and the temporal tuft of hair is at greatest risk. It is imperative that the surgeon understand the anatomical relationships of the layers of the face and temporal region to prevent injury to the nerve. One can elevate the skin all the way to the lateral canthal region, the preauricular area overlying the zygomatic arch, up to the orbicularis muscle, as long as dissection is in the immediate subcutaneous layer. In addition, the surgeon can dissect freely under the frontalis fascia beneath the galeal layer superficial to the periosteum and the overlying superficial fascia of the temporalis muscle without injury to the frontal branch of the facial nerve, which is external to this avascular layer. However, at the level of the zygomatic arch, one needs to make the transition to beneath the periosteum or immediate transection of the facial nerve will occur as one follows the same plane overlying the zygomatic arch. Injury to the nerve in this area may or may not result in reinnervation of the frontalis muscle.

THE FACELIFT PROCEDURE

Incision planning and marking of the appropriate locations for the incisions for the facelift procedure is crucial to the long-term outcome. Changes in hairline or scars that are placed in visible locations may cause the patient to be totally dissatisfied with an otherwise good lift result. The natural look of the patient's hairline, the freedom with which hair styling can be done, and the invisibility of the scar lines separates the good facelifting surgeon from the one sought by patients as the best in the community. The facelift surgeon who pays attention to the details of incision placement and planning is often the one extolled and recommended by hairdressers and other cosmeticians who see the results from this aspect of the facelift.

There are three critical points that must be taken into consideration in planning the facelift incisions:

1. How to manage and maintain the preauricular tuft of hair, including the sideburn. Each patient is different in terms of the location of the lower portion of the sideburn and the width at which it extends anteriorly from the insertion of the helical curvature. If the preauricular sideburn hairline is 1 or 2 cm below the insertion of the superior portion of the helical insertion, it may be appropriate to design an incision that curves up into the temporal hair and allows some posterior superior lifting of the hairline. The curved hairline incision, rather than a straight vertical incision, is required to interrupt the forces of contracture, maintain a minimally wide scar, and avoid alopecia (Fig. 15–2). As long as the hairline is not lifted higher than the insertion of the superior helical insertion, the patient will have no cosmetic disturbance of this area. If the sideburn is at the helical insertion preoperatively, an inferior sideburn incision is required; this will usually be associated with a separate temporal incision if a lift is required in this region. At no time should the incision be carried anteriorly around the sideburn tuft and along the pretemporal hairline. All scars in this area will be visible and cannot be camouflaged by the fine, severely sloped hair as it exits the skin naturally in a posterior direction.
2. Preauricularly, the incision must at least follow the apparent curvatures of the auricle itself. There is a strong preference by the patient population for an incision hidden behind the posterior edge of the tragus so that the incision appears "inside the ear." No preauricular incision will be seen, as it otherwise follows the normal curvature of the helical insertion and goes behind the tragus about 1 to 2 mm, then exits at the junction of the earlobe with the face. As an alternative to this, for patients with hearing aids or very deep pretragal depressions and tall tragi, a curved incision extending into the incisura and then out around the curve in the helix may be acceptable. However, loss of pigmentation in the scar, no matter how thin, will leave a visible line forever and may necessitate a hairstyle modification in the future.
3. Postauricularly, the incision must be directed up onto the posterior aspect of the auricle above the sulcus so that when the ear settles posteriorly and the scar heals with some contracture of the skin, the scar falls into the postauricular sulcus and not on the postauricular skin. The incision should make a gentle curve across the junction of the auricle, with the postauricular skin not crossing the non–hair-bearing skin at the level of where the auricle meets the hairline. In most cases, the incision should be gently sloped back into the postauricular hair. When advancing the postauricular skin posteriorly and superiorly, the posterior hairline can then be approximated with no step-off or other deformity. However, when a patient has a significant amount of neck skin that must be reposi-

Figure 15–2 Typical facelift incision for patient with low sideburn tuft of hair.

tioned posteriorly, it is often imperative that the incision be designed to run along the postauricular hairline before being swung posteriorly into the hair. In that way a large amount of skin can be moved posteriorly and superiorly without stepping off the postauricular hairline. At no time should the incision be left visible at the base of the hairline toward the anterior neck.

In addition, a 1- to 3-cm incision is required in the submental area, just anterior to the preexisting deep submental crease, to facilitate the procedure that is required in the anterior neck. Prior to infiltration of anesthetic, a dotted line is often used to determine the area to be anesthetized and the area that will be subsequently undermined. Some surgeons prefer to mark the area of the zygomatic arch, McGregor's patch, and the angle of the mandible. Further outlining of the jowl and any platysma banding may be of benefit in highlighting areas that need correction during the operation.

One variation in the male facelift patient and the woman who has a fair amount of hirsute preauricular skin is an incision that is gently curved in the preauricular area in what is often a preexisting preauricular crease. This incision should not be entirely straight; rather, it should be a distance away from the incisura and in front of the tragus. One must leave a non–hair-bearing portion of skin when moving the bearded skin or hair-bearing skin posteriorly and superiorly (Fig. 15–3). (It is a very important part of the consultation for you to outline exactly where you plan to make the incisions and note this in the chart, graphically as well as in written form.)

Anesthesia for facelift surgery requires an appropriate amount of local infiltration anesthetic combined with epinephrine to control cutaneous bleeding with a comfortable, sedated patient. Although many surgeons prefer inhalation anesthetics for a complete general anesthetic, this is not usually required. What is required is a patient who is intravenously sedated and fully monitored for continuous cardiac blood pressure and oxygen saturation. A person is designated to monitor the patient, and this person can be an anesthesiologist, a certified nurse anesthetist, or a registered nurse under the direction of the operating surgeon. Having a patient who is well assured preoperatively is critical to the success of a conscious-sedation anesthesia. The patient who is comforted knowing that he or she will not experience pain, discomfort, or otherwise be mistreated during the operation will be mentally prepared for the appropriate effects of the sedation medicine administered. It is generally a good idea to provide the patient some oral medication for relaxation prior to administering intravenous sedation. Current medications confer a significant amount of amnestic effect, as well as proper sedation and analgesia. Any anesthetic administered should have some prolonged effect so that the patient remains comfortable for several hours in the immediate postoperative period. Infiltration of the incision lines is best accomplished with xylocaine 1% with 1:50,000 epinephrine. This provides not only good anesthesia but the maximum hemostasis for vasoconstriction that is possible. Infiltration of the areas to be undermined should be done with 0.5% xylocaine with 1:100,000 or 1:200,000 epinephrine. Some hemostasis is still required. Total volume of xylocaine must be carefully monitored. At no time should more than 500 mg of xylocaine with epinephrine be infiltrated at one time or within a 1- to 2-hour period. Overdosage of xylocaine with resultant toxicity can be a result of injudicious volume infiltration of this local anesthetic. It may be advisable to complete infiltration of one side of the face before proceeding to the other side. This sequential infiltration, as long as it is performed 10 to 15 minutes prior to the incision on that side, is safe and effective.

The patient must then be prepared for the surgical operation by having small bundles of hair twisted and secured away from the incision lines and operative field. This may require taping of these bundles prior to prepping. After the patient is prepped and draped with a head drape in the usual sterile manner, the operation may commence. No shaving of hair is required. Preoperative antibiotic prophylaxis is given to all patients, using a cephalosporin 1 day preoperatively and continuing for 4 days postoperatively.

Figure 15–3 Typical incision for a male with beard, preserving non–hair-bearing preauricular skin.

TREATMENT OF THE SUBMENTUM, JOWL, AND NECK

Initial treatment of the neck involves correction of the jowl, submandibular, and submental lipoptosis. In type I facelifts, there is generally little or no need for any intervention in the neck. Posterior tightening of the skin–SMAS–platysma is all that is required for that particular patient. However, in the majority of patients, some attention to the submandibular, submental, and jowl lipoptosis is required.

If only debulking and reduction of this lipoptosis is required, a 1-cm incision is made in the submental crease to admit a liposuction cannula. If one has determined by examination that no platysma redundancy is present and there is some elasticity to the remaining skin, liposuction is carried out as the only neck procedure. The initial 1-cm dissection is performed just beneath the skin in the middle of the fat layer or subcutaneous tissues. Small (1-cm) tunnels are started and then completed with a 2- or 3-mm liposuction cannula. No suction is applied initially, creating the tunnels all the way from the submental area across the mandibular margin into the jowl region, to the anterior border of the sternocleidomastoid and down and across the cervical mental angle to the area of the thyroid cartilage. This is done in a fanlike

Figure 15–4 A 3-mm three-opening liposuction cannula.

fashion from one jowl across the neck to the opposite jowl. A circular liposuction cannula with three openings on one side is then used to perform this liposuction maneuver (Fig. 15–4). Very careful and judicious liposuction in the jowl areas is performed so as to hold the tissues away from the mandibular margin and not create blunt trauma to the marginal mandibular nerve. Minimal liposuction is performed in an even fashion to prevent the creation of any furrows, tunnels, or dimpling. This can happen very easily in the jowl areas, so that care is taken to underdo this maneuver in this region. Depending on the amount of liposuction required in the submental and submandibular neck, a larger liposuction cannula may be required. A 4-mm or sometimes a 6-mm flat cannula with one opening on the inferior surface of the cannula is required to obtain adequate removal and contouring. Bimanual palpation is required to determine the symmetry and equality of the removal of the fat. Leaving a thin layer of subcutaneous fat is required to give supple skin contour. Caution should be excercised in terms of not being overly aggressive in performing liposuction across the cervical mental angle, as this has the potential for creating dermal injury and subdermal scarring, with late development of banding.

Often, this is all that is required in a type II facelift. However, in advanced type III facelifts involving a tremendous amount of fat and some platysma ptosis, as well as type III facelifts with significant collections of fat, laxity of skin, and platysma sagging, further work is required. This requires extension of the incision to at least 2.5 to 3 cm. Direct subcutaneous elevation is then performed after the liposuction to elevate the skin way from the platysma muscle. This is performed in a wide fashion, usually extending to the anterior border of the sternocleidomastoid and past the cervical mental angle. This then allows the surgeon to directly view the remaining lipoptosis beneath the platysma muscle and view the redundancy and laxity of the anterior platysma bands. Their dehiscence is highly visible.

The laxity and redundancy of these tissues is determined. Using a grasping forceps and a long curved Kelly clamp, the tissues are tightened in the midline. Their redundancy is progressively excised, with care taken to maintain adequate hemostasis. Suturing the anterior transected borders of the platysma together into a midline corset is done. The excess fat and muscle are removed all the way down past the cervical mental angle (Figs. 15–5 and 15–6). Several mattressing sutures using 3-0 Vicryl are placed. After a firm muscular corset is created and a sharper cervical mental angle achieved, the remainder of the facelift skin undermining will be accomplished from the posterior position. Redundancy of skin in the submental area will be determined at the end of the operation following tightening of the bilateral pre- and postauricular skin in a superior posterior direction.

SKIN ELEVATION AND UNDERMINING

The extent of undermining depends on the amount of redundancy of skin in the neck and to some degree on the facial tissues. With the use of SMAS lifting, the degree of undermining from older classic rhytidectomies is much less. A large degree of undermining increases the risk of vascular compromise as well as the development of small seromas, hematomas, and irregularities. However, when a large degree of skin and platysma redundancy is present in the neck, it is often unnecessary to separate the skin from the underlying

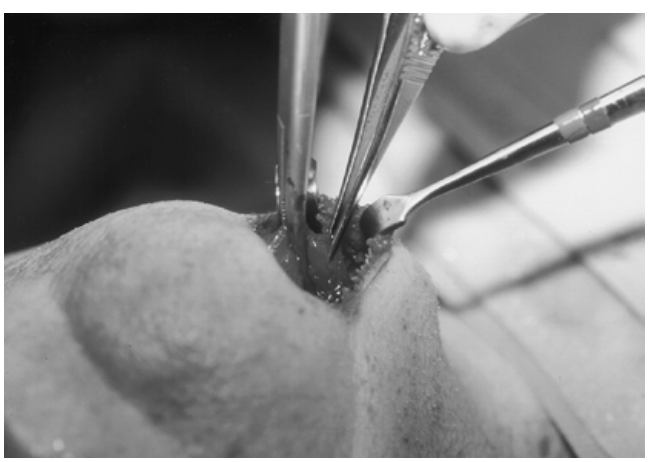

Figure 15–5 Use of Kelly clamp to tighten anterior platysma and anterior submental fat for incremental excision.

Figure 15–6 Sequential removal of redundant submental muscle and fat past cervicomental angle.

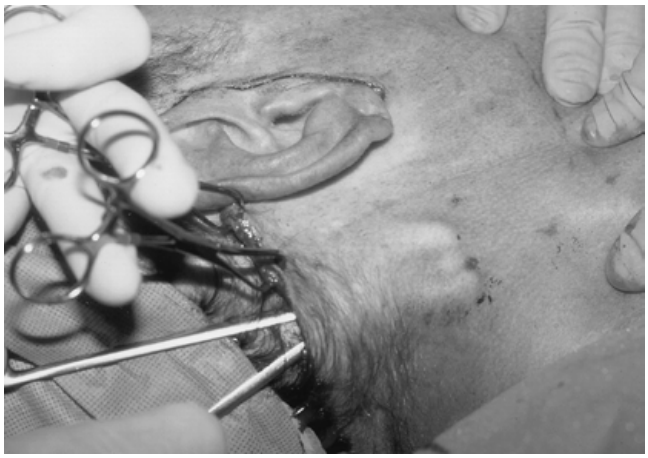

Figure 15–7 Undermining with beveled facelift scissors with advance-and-spread technique.

Figure 15–8 Postauricular and neck flap elevated within subcutaneous fat layer over the sternocleidomastoid muscle.

platysma muscle in order to redrape each in a sequential fashion and achieve maximal improvement. Generally, lifting the SMAS and the deep facial tissues is as effective and much safer than separating the skin all the way out to the melolabial crease. Although some surgeons still prefer this older technique, today this large amount of undermining has not been shown to be more effective than the SMAS techniques in improving the jowl or deep melolabial fold.

Undermining of the skin begins in the postauricular area and can be done with a beveled facelift scissors in an advance-spreading technique (Fig. 15–7). Direct knife elevation is an alternative. It is important to begin deep to the level of the hair follicles in this region so as to not injure the hair follicles and create permanent alopecia. However, when the dissection is continued anterior to the postauricular hairline, it should be quite superficial in the immediate subcutaneous layer. This subcutaneous layer is minimal in the postauricular region and the skin very closely adherent to the overlying fascia of the sternocleidomastoid muscle. Care must be taken to separate this layer carefully until the dissection is anterior to the sternocleidomastoid. Injury to the greater auricular nerve, as mentioned previously, is somewhat common due to the lack of a thicker subcutaneous layer and adherent dermal attachments in this region. Elevation is then continued to the subcutaneous plane superficial to the platysma muscle and anteriorly as far as the amount of neck surgery dictates (Fig. 15–8). Often the undermining is completed and meets the undermining that was done previously in the submental area. Although the undermining may extend slightly above the mandibular margin, it is generally confined to the neck region.

After the undermining of the neck has been achieved, undermining begins in the temporal area. Temporal lifting is required to achieve smoothing of the lateral canthal–temporal skin and lateral brow. Incisions are made down through the scalp tissues through the superficial galea and the superficial layer of the temporalis fascia is identified. Undermining can be performed in this layer all the way down to the lateral brow and the superior edge of the zygomatic arch. Elevation of the temporal unit is not required in all facelifts and is usually not required in type I facelifts. It is usually required when there is laxity of tissues in the lateral brow and lateral orbital region that must be redraped so as not to create bunching when the cheek tissues are brought up superiorly. The temporal lift may or may not be connected with other means of lifting the brow–forehead complex. Elevation is then begun in the preauricular area at the level of the temporal tuft in the immediate subcutaneous layer. This is a layer distinctly different than that for the temporal elevation, and a noninterrupted bridge of SMAS and neurovascular bundles should be left intact that extends superiorly toward the frontalis muscle. By maintaining this nonconnected bridge of tissue, one will not injure the frontal branch of the facial nerve (Fig. 15–9). Undermining can then proceed to the malar area, extending in the preauricular region anywhere from 4 to 6 cm depending on the elasticity of the skin. This undermining is continued in this intra-adipose layer, easily separating the subcutaneous dermal fat, leaving it with the skin flap, from the underlying fat overlying the SMAS. This preauricular space is connected to the same layer of elevation overlying the platysma muscle in the neck. Hemostasis is then assured under direct vision.

Depending on the nature of the facelift, one must determine the degree of intervention and manipulation of the SMAS layer. Even type I facelifts may require imbrication or

Figure 15–9 Maintain a noninterrupted bridge of tissue in the temporal region to avoid injury to the frontal branch of the facial nerve.

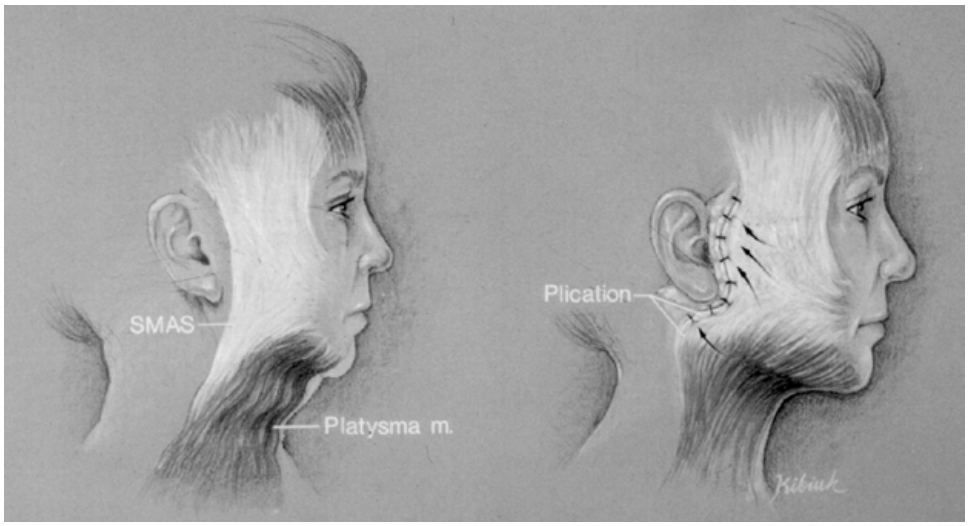

Figure 15–10 Plication of the SMAS and platysma with posterior suspension.

deep-plane maneuvers, depending on the need for elevation of the midfacial tissues. If only a small amount of jowl repositioning and posterior repositioning of the platysma muscle is required, plication of the SMAS may be the only maneuver (Fig. 15–10). However, one must remove the adipose tissue that is still on top of the SMAS in a semilunar fashion in the preauricular area so as to pull the SMAS over on itself while suturing. Otherwise, there will be no fibrous adherence of the SMAS and the lift may fail when the sutures give way. Some surgeons prefer a permanent suture for this plication or folding of the SMAS due to the fact that it needs to be maintained in this position over time.

Generally, facelifts do require some undermining of the SMAS layer and platysma so that it can advance superiorly and posteriorly (Fig. 15–11). The degree of this undermining will be dictated by the need for lifting of the jowl, platysma muscle, and midfacial tissues. This constitutes imbrication of the SMAS, whereby the SMAS is lifted, advanced, trimmed, and sutured end to end. This can be done with a long-term, but not permanent, suture.

For those patients requiring midfacial lift of the subcutaneous soft tissues, as a minimum, a modification of the deep-plane facelift is performed. This requires elevation of the SMAS layer at the level of the zygomatic arch over the malar eminence and superficial to the zygomatic muscle. Complete deep-plane facelift techniques necessitate undermining the SMAS layer all the way anterior to the anterior border of the masseteric muscle and connecting this to the elevation of the neck tissues superficial to the platysma muscle. Transition must be made, however, in the midcheek to the superficial layer overlying the zygomatic muscle or injury will occur to the nerve to this muscle, or the buccinator.

When the appropriate elevation of the midfacial tissues has been accomplished with the corresponding SMAS and platysma, this layer is advanced in an appropriate posterior superior direction (Fig. 15–12). Direct vision allows one to see the movement of the melolabial tissues, as well as the jowl, back and upward into a more youthful position. Often, a slip of this SMAS fascia is brought up to the firm preauricular tissues as a sling suspension. Similarly, the SMAS is divided at the level of the earlobe and an inferior slip of SMAS platysma is sutured with a 0-Vicryl suture as a supporting sling to the mastoid fascia and periosteum (Figs. 15–13 and 15–14). This provides crisp, sharp delineation of the cervical mental angle. Redundancies of

Figure 15–11 Metzenbaum scissors elevation of the preauricular SMAS.

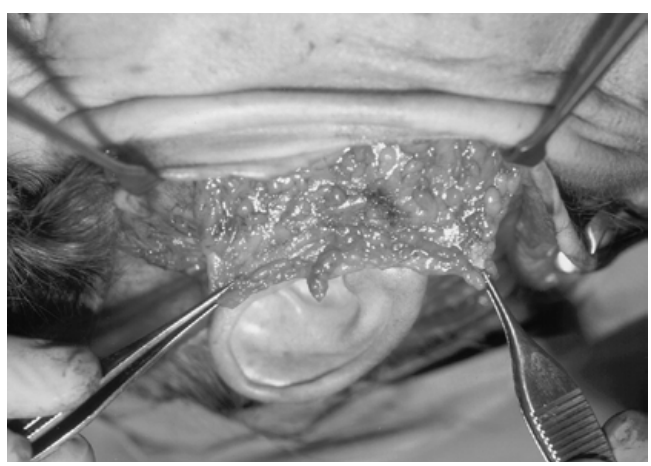

Figure 15–12 Advancement of the undermined SMAS prior to imbrication.

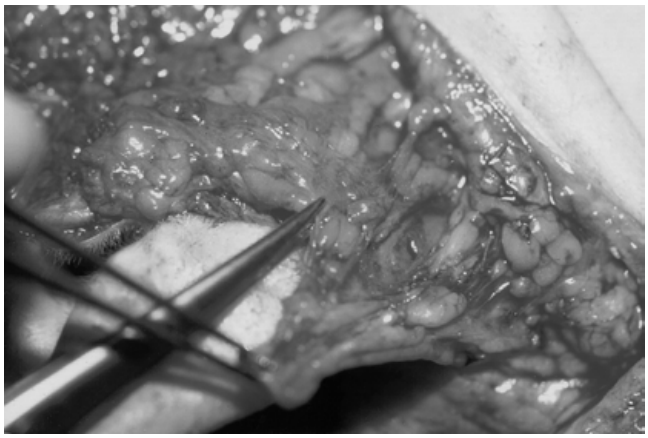

Figure 15–13 Splitting the SMAS–platysma flap at the ear lobe for suspension of sling of platysma.

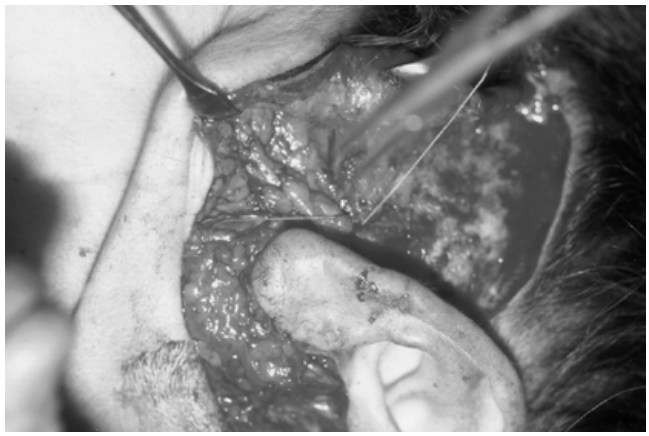

Figure 15–14 Suspension of posterior slip of platysma–SMAS with 0-Vicryl suture to the mastoid periosteum.

platysma and SMAS are trimmed and a few sutures placed to the posterior postauricular fascial tissues. Anteriorly, the SMAS is trimmed, the excess is discarded, and the SMAS is sutured end to end with a long-lasting, temporary monofilament suture, such as 3-0 PDS.

SKIN FLAP ADVANCEMENT

After adequate deep fascial lift has been completed for the long-term foundation of the facelift, the skin flap can be repositioned and modified as necessary. One can see, with minimum tension, the redundancy of skin that is draped over the ear in a posterior superior vector. The preauricular skin is moved mostly posteriorly and slightly superiorly, taking care not to let the sideburn tuft of hair be pulled too high. The neck skin is lifted in the postauricular area in a posterior but mostly superior fashion so as to not create a large step-off deformity of the postauricular hairline. When the skin has been secured in the high pre- and postauricular regions, an incremental cut is made and a staple placed (Fig. 15–15). The skin along the postauricular occipital hair is incised in a beveled fashion, and surgical staples are used to approximate these scalp tissues. The skin in the non–hair-bearing postauricular areas is sutured in a running interlocking fashion with a 5-0 plain gut-type suture. As there is no tension, no deep sutures are required. The earlobe is positioned with a deep 5-0 Vicryl suture and the skin trimmed so that the earlobe is tucked in a superior position. It is often important to exaggerate the upward lift to the earlobe so that when the tissues heal and drift inferiorly, the earlobe is not pulled down. An inferiorly distracted earlobe looks like a satyr's ear and is an obvious postoperative facelift deformity. The preauricular tissues are trimmed appropriately according to the planned preoperative incision. A tragal flap is left significantly redundant, so that when it is closed there is absolutely no tension in the earlobe and the tragal flap is bunched together in a pie-shaped fashion exaggerating the new tragus. When this heals, it will contract and look extremely close to a normal tragus and not be pulled anteriorly due to overly tightened scar contracture from injudicious trimming of the flap. The preauricular skin is closed with a running interlocking 5-0 plain gut suture. The temporal incision is closed, as was the occipital scalp, with interrupted surgical staples. Prior to complete closure, a flat, 4-mm, closed-suction drain is placed with an exit wound hidden in the postoccipital hair (Fig. 15–16). The drain is brought just to the level of the anterior angle of the mandible. The submental skin is then trimmed if there is

Figure 15–15 Posterior draping of the skin flap requires alignment of the occipital hairline.

Figure 15–16 A closed suction drain is used to prevent serohematomas.

excess, in a semilunar fashion with care taken not to create dog ears laterally or skin redundancies.

Prior to placement of the dressing in the operating room, the patient's hair twirls are removed, the hair is washed, and any blood is rinsed at this time. An antibiotic ointment is applied to a nonadherent dressing that is placed in the pre- and postauricular areas. A few 4 × 4s are placed over the undermined areas, and a cotton batting is applied loosely under the chin and over the top of the head. This is held in place with a minimally constrictive elastic-type chin strap. Care is taken not to cause pressure to the undermined skin flaps (Fig. 15–17).

The patient is discharged from the operating room to the recovery area. After adequate recovery has taken place, the patient is escorted to the car and driven home. The patient needs to be ambulatory with assistance before discharge and must have someone in attendance through the entire night. It is important to maintain phone contact with the patient that evening. The patient is required to stay within a 15- or 20-minute drive from the operative facility in the event that immediate postoperative care is required. The patient is requested to return the following morning, 12 to 18 hours postoperatively. At that time, the dressing is removed, the drains are generally removed, and a light chin strap is applied for an additional 24 hours. The patient is asked to shower once a day for a week and to keep the wounds clean and moist with peroxide and antibiotic ointment. One week postoperatively, the patient returns for staple and suture removal.

The patient is then asked to return at 10 to 14 days postoperatively at which time he or she is reexamined and given the opportunity to meet with a makeup artist. The patient is instructed regarding appropriate makeup coverage for any residual ecchymoses and is given a full skin-care lesson. The makeup artist introduces appropriate moisturizers, cosmetics, and sun screens, and informs the patient about future appropriate skin-care practices to maintain the facelift results. It is imperative to see the patient at 1 month, 3 months, 6 months, and 1 year postoperatively to follow the results (Figs. 15–18 to 15–25). In the second to fourth week, the patient often requires emotional support, as adjustment is still being made to the new appearance and reassimilating to work or social activities. Many of the postoperative sensations being experienced, as well as minor healing variabilities that the patient was told would occur, have been forgotten and reassurance is needed that everything is progressing as expected. Continuous reaffirmation of postoperative instructions and expectations is critical to the happiness of these cosmetic surgical patients. Your office should be a place they feel comfortable calling as well as returning to in this immediate postoperative time. Patients must feel that you are there for them, to answer questions and reassure them. This is critical to their long-term satisfaction. For longer term follow-up, it is important that you intervene if there is any tendency toward hypertrophic healing in the postauricular areas. Intralesional steroids may occasionally be required to settle down a slightly thickening postauricular scar. In addition, at the 4- to 6-week postoperative period, if the patient is going to experience some temporary surgical alopecia in the hair-bearing areas, he or she needs complete reassurance that these hair follicles will regenerate hair shafts and that within 4 to 6 months all of the hair will grow back. The patient further needs reassurance throughout the first 3 to 6 months that hypersensitivities and neuresthesias are completely normal and part of the healing process.

Figure 15–17 Postoperative facelift dressing for mild compression.

TUCK-UPS AND SECONDARY RHYTIDECTOMY

As you follow your patients in the 6-month to 1-year postoperative period, it is inevitable that they will experience a certain degree of rebound relaxation in the superficial tissues of the face and neck. This is despite excellent efforts on your part to give them a long-term tightened jaw line and neck line. This is very much a function of their inherent hereditary elasticity which, however, occasionally requires a small procedure to improve the overall results. Submental tuck-up procedures to take care of small residual submental bands or fullness may be required in 5 to 10% of patients, depending on their preoperative condition and skin elasticity. This should be offered to them as part of the overall facelift experience. It has nothing to do with your overall technique. More rarely, the jowl, due to its fullness and presurgical condition, will revert enough to require a cheek tuck-up. This is the area most likely to disappoint patients in terms of overall results. Patients must be informed ahead of time that the melolabial fold and groove is minimally helped with a standard facelift result. Nevertheless, when the jowl does settle somewhat due to this rebound relaxation, they can be quite disconcerted. For selected patients, a cheek-only portion and doing a SMAS plication may be helpful in achieving the long-term results they had expected.

Figure 15–18 Preoperative facelift, oblique view.

Figure 15–19 Six months postoperative facelift, oblique view.

Figure 15–20 Preoperative facelift, oblique view.

Figure 15–21 Two years postoperative facelift, oblique view.

Figure 15–22 Preoperative facelift, lateral view.

Figure 15–23 Eighteen months postoperative facelift, lateral view.

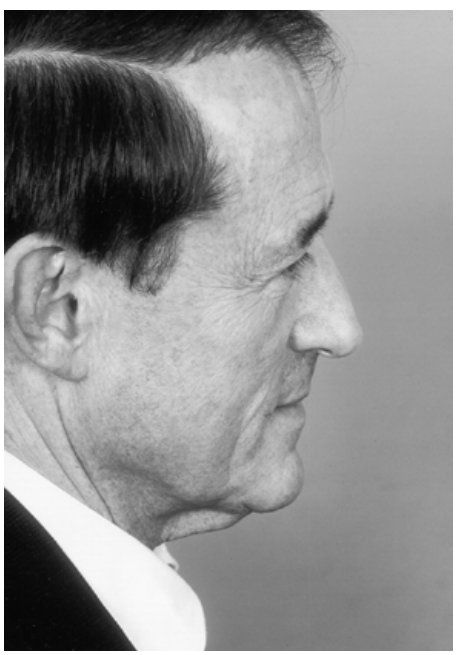

Figure 15–24 Preoperative male facelift, lateral view.

Figure 15–25 Ten months postoperative male facelift, lateral view.

However, despite all good efforts in the first year, there are patients whose facelift results do not last as long as they desire. This is often related to the age of the patient, the condition of the facial skin, and heredity. Patients must understand that a secondary facelift is never required; that they will continue to age and look normal, but will always look better than if they had never had the facelift. They will always look younger than their chronologic age. A repeat facelift can indeed be done in the future but is not usually necessary for 5 to 8 years postoperatively. Techniques similar to those used in the original facelift may be required, depending on the advancement of the aging process in all layers of tissue involved.

RHYTIDECTOMY COMPLICATIONS

Hematoma

The most common complication following rhytidectomy is hematoma formation, occurring in 2 to 15% of patients.[11–13] Major hematoma requiring reoperation and exploration usually presents within the first 12 hours postoperatively (Figs. 15–26 and 15–27). Hematoma formation is heralded by pain and increasing facial edema. Interestingly, there is no correlation between the volume of intraoperative blood loss and hematoma occurrence. Conversely, hypertension predisposes to hematoma formation, increasing its incidence 2.6 times.[14] The importance of blood pressure control cannot be overstated; it must be closely monitored both intraoperatively and throughout the preoperative period. Particular attention should be paid to assuring a smooth emergence from anesthesia and avoidance of postoperative nausea, vomiting, and anxiety. Other predisposing factors associated with hematoma formation include ingestion of aspirin-containing products, nonsteroidal anti-inflammatory drugs, high doses of vitamin E, and the dominantly inherited Ehlers–Danlos syndrome.[15] A detailed list of aspirin-containing medications should be distributed because many of these products are not obvious. All of these products should be stopped at least 2 weeks preoperatively and remain so for at least 1 week postoperatively.

Certainly, management of patients taking anticoagulants needs to be carried out in conjunction with the prescribing physician. We routinely screen all patients for prothrombin time, partial thromboplastin time, and platelet counts, referring those for further workup if abnormal values are noted twice. Special precautions should be afforded to male patients as consensus among most facial plastic surgeons is that they are more susceptible to hematoma occurrence. Although not proven, it is felt to be secondary to an increased blood supply to the skin and beard follicles.

Delay in treatment may lead to skin flap necrosis, especially in those with a malignant rapidly expanding hematoma. In addition, the fluid accumulation may become an ideal culture medium, increasing the chances of infection. Often at the time of evacuation it is difficult to identify a single vessel at fault; rather, the norm is a diffuse oozing. Treatment should consist of clot evacuation, irrigation, exploration, and cautery of suspicious bleeding vessels. Suction drains and pressure dressing should be reapplied.

Minor hematomas are commonly encountered and probably account for the large range of hematoma percentages reported. Minor hematomas are usually identified in the first week postoperatively and consist of small pockets of fluid, usually in the postauricular area. Once liquified, these fluid collections can be evacuated by 18-gauge needle aspiration under sterile conditions. If not yet liquified a small opening in the incision line may be necessary to remove the clot. These patients are refitted with a pressure dressing, and an extended course of antibiotics is prescribed. Undetected hematomas lead to fibrosis, skin puckering, and discoloration,

Figure 15–26 Acute hematoma, 1-hour post facelift.

Figure 15–27 Acute expanding hematoma, 3 hours post facelift.

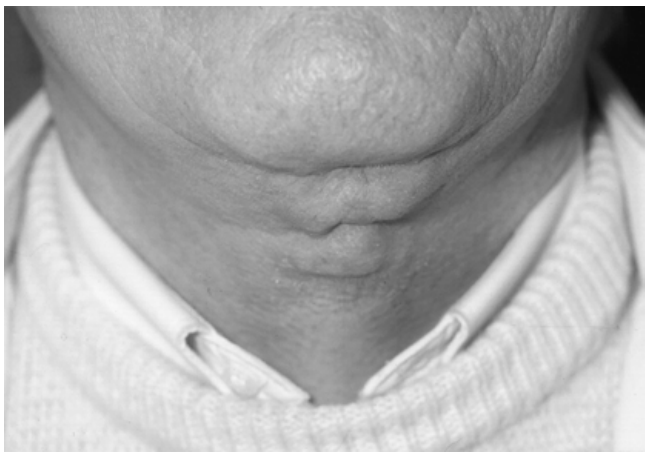

Figure 15–28 Fibrosis and skin irregularities 2 months postop hematoma and seroma in submental neck.

which can take months to resolve (Fig. 15–28). If such a course is encountered, serial steroid injection of triamcinolone acetonide (Kenalog) 10 mg/mL or 40 mg/mL may be helpful.

Flap Necrosis

Skin flap necrosis occurs when blood supply to the distal ends of the random skin flap is compromised. Predisposing conditions include poor flap design, extended subcutaneous flap elevation, injury to the subdermal plexus, extensive closing tension, certain systemic medical conditions, and smoking. The postauricular area followed by the preauricular area are at greatest risk to necrosis. Deep-plane and SMAS rhytidectomy benefit from decreased necrosis by allowing for a more robust vascular flap and reduced closing tensions. The toxic effects of nicotine and smoking have long been identified as the most preventable cause jeopardizing blood supply in random skin flaps. The risk for flap necrosis is increased 12.6 times in smokers.[16] It is imperative that patients abstain from smoking for at least 2 weeks before and after surgery. Systemic diseases, such as diabetes mellitus, peripheral vascular disease, and multiple connective tissue disorders, may predispose patients to vascular compromise and warrant strong consideration preoperatively (Fig. 15–29).

Flap necrosis is preceded by venous congestion and flap discoloration. Frequent massaging of the area and an extended antibiotic course is instituted. Necrosis is usually accompanied by eschar formation. The compromised area should be treated conservatively with daily peroxide cleaning, limited debridement, and topical antibiotic ointment placement. Fortunately, most affected areas will heal nicely by secondary intention, but frequent postoperative visits and patient reassurance are necessary.

Nerve Damage

A cervical sensory branch, the great auricular nerve, is the most commonly injured nerve in facelift surgery, occurring in 1 to 7% of patients.[13,17] This nerve can be found at the anterior border of the sternocleidomastoid muscle. The skin flap tends to get thinner approaching the postauricular and mastoid area. Care must be taken not to violate muscle and nerve during this dissection. Increased bleeding is often an eminent sign of muscle injury. Great auricular nerve injury is often

Figure 15–29 Partial facelift flap necrosis in a patient taking immunosuppressive drug for severe arthritis.

noted at the time of surgery, in which case the ends should be anastomosed with epineural repair using 9-0 nylon suture. Failure to repair the injury will lead to regional hypoesthesias and possibly painful neuroma formation.

Motor branch injury fortunately is much less common, occurring in 0.53 to 2.6% of facelift patients.[11,18] The two most commonly injured nerves are the temporal branch and the marginal mandibular branch of the facial nerve. The more commonly injured of the two branches depends on the method of surgery performed and the report cited. However, both of these injuries can lead to devastating outcomes for the patient and the physician. Mastery of facial nerve anatomy is mandatory for all those planning to perform facelift surgery. The temporal branch of the facial nerve assumes a superficial course at the level of the zygomatic arch. Dissection in this area must be immediately subcutaneous or subperiosteal to avoid injury. Rather than the single branch that is often depicted in textbooks, the temporal branch of the facial nerve consists of multiple rami. Anatomical studies have identified the rami crossing the middle portion of the inferior arch. Dissection in the immediate preauricular 10 mm of the arch and the distal 19 mm of the arch is safe. Unfortunately, injury to the facial nerve is usually not recognized at the time of surgery, but if it is, an attempt should be made for direct anastomosis. Microscopic assistance may be helpful. If immediate postoperative facial paralysis or paresis occurs, do not panic. Initially, allow at least a 4- to 8-hour time period for the effects of local anesthesia to dissipate. In the unfortunate event that a motor branch injury has occurred, surgical exploration and an attempt at anastomosis of these small distal branches is not practical. However, be reassured; clinical evidence has shown that a majority of these injuries (85%) will resolve with time.[6] The high incidence of recovery may be because injury was due to a temporary neuropraxia from local insult. Others theorize that, in the case of temporal nerve, multiple branches may allow for reinnervation

even in the case of neurotemesis.[19] However, if recovery is not evident by at least 1 year, reconstructive options must be considered, including browlift, contralateral frontal branch neurolysis, and eyelid reanimation procedures.

Subplatysmal dissection places the marginal mandibular branch of the facial nerve at risk. Staying in the immediate subplatysmal plane and dissecting using a blunt scissors with the tynes in a vertical motion will protect the nerve from injury. The nerve, which initially runs posterior and inferior to the mandible, enters a superficial plane over the mandible 2 cm lateral to the modiolus.[18] Dissection in the subcutaneous plane in this area is without benefit and fraught with disaster. Zygomaticus and buccal branch nerves surface at the anterior end of the parotid gland and are rarely identified in standard facelift techniques. However, in deep-plane dissections, the branches are often encountered. Injury in this area may be obscured by the multiple branches and anastomosis.

Bell's palsy recurrence has been reported following facelift surgery, and patients with a history of Bell's should be counseled to the possibility.[20] Total facial paralysis should be referred to the appropriate colleague for consultation. Electrical nerve testing may be of prognostic benefit in these patients, as well as in those with isolated motor branch injuries.

Hypertrophic Scarring

Hypertrophic scarring can occur if excessive tension is placed on flap closure and is most commonly associated with the isolated subcutaneous flap dissection (Fig. 15–30). Hypertrophic scarring can appear as early as 2 weeks postoperatively and usually occurs within the first 12 weeks. Interval intralesional injections with steroids can be helpful. Excision and primary closure of the hypertrophic scarring should be delayed for at least 6 months.

Incision Line Irregularities

Poor planning of incision lines may lead to loss of temporal tufts of hair, alopecia, excessive dog-ear formation, and hairline stair-stepping pattern. The temporal tuft of hair can be recreated with micrograft placement or through creative local flap designs. Hair loss is usually secondary to follicular shock (telogen effluvim), and reassurance can be given. However, if follicles were transected or tension on closure is excessive, hair loss may be permanent (Fig. 15–31). After a waiting period of 3 to 6 months, if there has been no hair recovery, alopecia areas may be excised and closed primarily. Micrografting can also help to camouflage the area.

Failure to advance and rotate the postauricular flap can lead to a stair stepping of the hairline. Fortunately, for most patients this area is easily hidden. However, if it is a problem for those interested in wearing their hair back, flap revision may be necessary.

Infection

Infection is rare in rhytidectomy patients. Mild cases of cellulitis will respond well to an extended antibiotic course covering the common variants of *Staphylococcus* and *Streptococcus*. These patients generally heal without sequelae. In the rare event of abscess formation, incision, drainage, and wound culturing are necessary (Fig. 15–32). Intravenous antibiotic administration should be considered.

Earlobe Deformity

Satyr's ear (devil's ear) can occur if the earlobe is not tucked up properly. During the healing period, the earlobe is drawn inferiorly (Fig. 15–33). Poor placement of the earlobe can lead to the tell-tale signs of facelift surgery. Repair of the unnatural earlobe can be deceptively difficult. The best method to create the inferior lobe sulcus is by V-Y plasty; however, this should be delayed for at least 6 months after surgery.

Parotid Injury

Parotid parenchyma injury leading to sialocele or fistula formation is exceedingly rare. Intraoperative injury should be oversewn with available SMAS. Postoperative fluid accumulation may be treated with needle aspiration and pressure dressing. Persistent fluid accumulation may require a drainage procedure.

Sequelae of telangiectasias, hypertrichosis, and temporary hypoesthesias over the elevated flap tend to improve with time. However, persistent vascular lesions and problematical excessive hair can be effectively ameliorated with appropriate laser treatments.

Figure 15–30 Postauricular hypertrophic scar with widening due to excess tension on closure.

Figure 15–31 Temporal alopecia secondary to excess tension and damage to hair follicles.

Figure 15–32 Postop abscess and infection 1 week post facelift.

Figure 15–33 Satyr's ear (devil's ear) with poor scar placement.

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Chapter 16

Rejuvenation of the Brow and Midface

Vito C. Quatela, H. Devon Graham III, and Paul Sabini

Rarely does an individual's face age in an asymmetrical manner, yet for a long time surgery of the aging face was synonymous with a rhytidectomy and blepharoplasties. Often, the upper and midface were inadequately addressed. Eventually, surgeons began to focus attention on the contribution of brow position and often included a browlift as part of their treatment. The final piece of the puzzle emerged with the advent of endoscopic facial plastic surgery, first introduced in 1992 by Core et al[1] and by Liang and Narayanan.[2] The endoscope and its accompanying surgical instruments provide us with access to both the brow and the midface. It is now possible to treat an aging face without neglecting any component. In this chapter we will focus on the use of the endoscope in forehead and midfacial surgery. For clarification, an "endoscopic forehead lift" describes a procedure in which the dissection and suspension do not extend below the zygoma. When the dissection is carried below the zygomatic arch to the pyriform aperture and to the upper alveolar ridge, we refer to the suspension as a "midface lift."

Smaller incisions, decreased risk of alopecia, and equivalent results to traditional browlifts are among the benefits of endoscopic forehead lifting. Dissection of the midface is an extension of this procedure and provides us with a means of repositioning the malar fat pad. Another advantage is the lack of hair-bearing skin excision, which serves to maintain the existing hairline. A relative disadvantage is the need for specialized equipment and an initial learning curve.

FOREHEAD AND MIDFACIAL ANATOMY

Surgeons often contrast "surgical anatomy" with anatomy to distinguish the unique perspective of the operative field from the gross anatomy lab. "Endoscopic anatomy" is an additional perspective that the facial plastic surgeon must master. Through the endoscope, familiar structures are viewed in an unfamiliar manner; therefore, a thorough grasp of the anatomy and the fascial planes is indispensable.

Scalp and Forehead Musculature

The scalp consists of the skin, subcutaneous tissue, aponeurosis or galea, loose areolar tissue, and periosteum. The galea is a tendinous inelastic sheet that connects the frontalis muscle to the occipitalis muscle. The galea merges laterally with the temporoparietal fascia, which is continuous with the superficial musculoaponeurotic system (SMAS) in the lower face. The frontalis muscle originates from the galea and inserts in the forehead skin. This muscle is the primary elevator of the brow, and its nerve supply is the frontal branch of the facial nerve. During the subperiosteal endoscopic forehead lift, the frontalis muscle is not visualized unless there is inadvertent tearing in the perisoteum. The depressor muscles of the brow include the paired corrugator supercilii, the orbicularis oculi, and the procerus muscle. The corrugator supercilii muscles are responsible for the vertical rhytides of the glabella. The procerus muscle, originating from the nasal bones, produces the transverse rhytides in the glabella.

Fascia

During an endoscopic forehead/midface lift, the dissection crosses several fascial planes. Endoscopic forehead lift occurs in both a supraperiosteal (laterally over the temporalis muscle) and a subperiosteal plane (in the forehead). Although midface lift has been described in a supraperiosteal plane,[3] we prefer a subperiosteal dissection. To safely approach the brow and the midface, it is necessary to have a thorough understanding of these different fascial planes.

The fascial planes are described in the order in which they are encountered during the procedure. The superficial temporal fascia, also known as the temporoparietal fascia (TPF), is located immediately beneath the skin and subcutaneous fat of the temporal area. The temporal artery and vein course superiorly within this fascial layer. Medially, over the forehead, the TPF merges with the galea. The TPF is continuous with the SMAS in the lower face. Beneath the TPF is the deep temporal fascia or true temporalis fascia. Dissection in the temporal region occurs on top of this fascia and therefore below the TPF. The deep temporal fascia splits at the level of the supraorbital ridge to become the intermediate temporal fascia and the deep temporal fascia with the intermediate fat pad in between (Fig. 16–1). The intermediate temporal fascia attaches to the superior edge of the zygomatic arch laterally and the deep temporal fascia attaches medially. Deep to the deep temporal fascia is the deep temporal fat pad. Violation of the fascial covering of the deep temporal fat pad can result in atrophy of the fat and the appearance of temporal wasting.

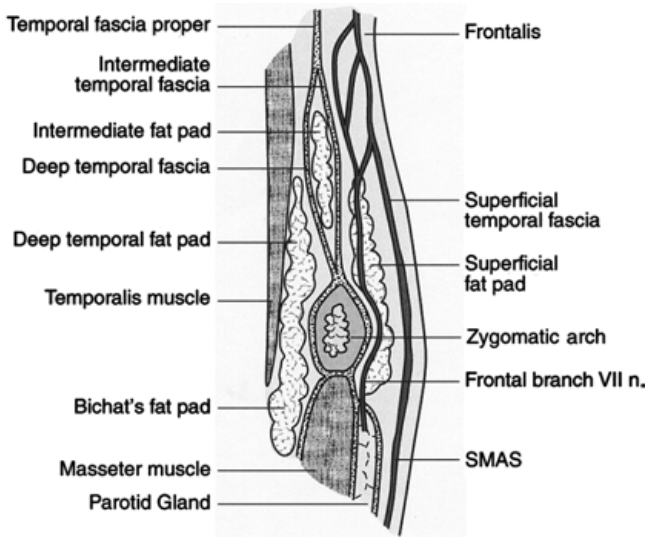

Figure 16–1 A coronal slice at the level of the mid-zygomatic arch reveals the relationship of the fascial planes, facial nerve, and intermediate and deep temporal fat pads.

Sensory and Motor Nerves in the Forehead

The facial nerve supplies all of the muscles of facial expression, including the corrugator and procerus. Sensation is provided by the trigeminal nerve. The supratrochlear and supraorbital branches emerge from the skull deep to the eyebrow. They are visualized and should be preserved when corrugator resection is performed. These nerves typically exit from the supraorbital notch or foramen; however, in up to 10% of cases one or both of these nerves may arise from a true foramen 1 to 2 cm superior to the orbital rim. In the latter situation, the nerves are at risk for transection if a blind non-endoscopic-assisted dissection is performed.[3]

The temporal branch of the facial nerve crosses the zygomatic arch halfway between the lateral canthus and the root of the auricular helix within the TPF. Sabini et al uncovered a more accurate means of identifying the precise location of the frontal branch of the facial nerve during endoscopic forehead surgery. A series of bridging vessels, including one larger sentinel vein, are encountered between the deep temporal fascia and the TPF during the dissection in the temporal region. These bridging vessels were shown to point to the frontal branch of the nerve as it coursed through the TPF[4] (Fig. 16–2).

Midfacial Anatomy

The malar prominence descends inferomedially with aging to deepen the nasolabial crease and expose the lateral orbital rim. It is composed of a subcutaneous malar fat pad with underlying orbicularis oculi muscle. Deep to this is the suborbicularis orbital fat (SOOF), which is intimately associated with the periosteum of the infraorbital rim and maxilla and the insertions of the zygomaticus major and minor muscles. Motor nerve supply to the muscles of the midface comes from the zygomatic and buccal branches of the facial nerve traveling along the deep surface of the muscles. Sensory innervation of the midface comes from the second division of the trigeminal nerve, the infraorbital nerve, which exits the infraorbital foramen, and the zygomaticotemporal branch of the trigeminal nerve that exits through the body of the zygoma.[5] The zygomaticotemporal nerve supplies the lateral temple region of the scalp and is encountered in a midfacial dissection, although it is rarely visualized. Transection of this branch, while not desirable, does not seem to adversely affect recovery of sensation in the lateral brow.

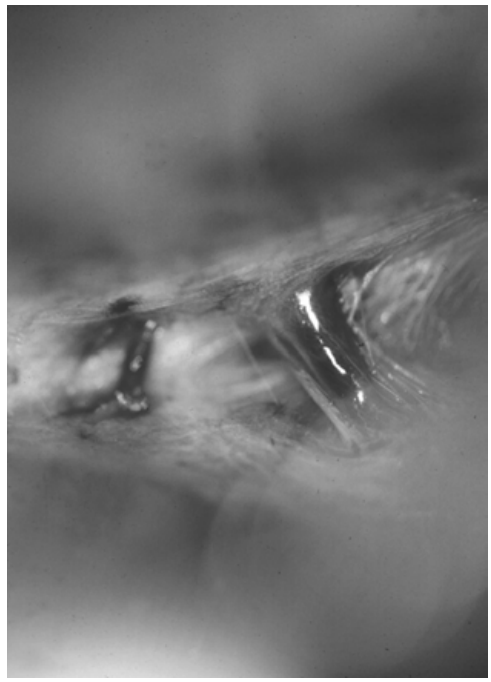

Figure 16–2 During the temporal dissection, multiple vessels are encountered "bridging" the space between the temporoparietal fascia above and the deep temporalis fascia below. Often a substantially larger vessel (sentinel, vein on the right) is encountered adjacent to the superior edge of the lateral orbital rim. These veins indicate the precise location of a frontal branch of the facial nerve in the temporoparietal fascia above.

AESTHETICS OF THE ORBITAL COMPLEX

The surgeon should evaluate the orbital complex with consideration to all structures of the upper face. Consideration should be given to the brow position, glabella infrowning, amount of periorbital fat shifting that has occurred, and displacement of periorbital structures such as brow fat, lateral canthus, SOOF, and malar eminence.

The "classic" brow has its medial origin along a vertical line drawn through the nasal alar–facial junction. The lateral extent is along a line drawn from the nasal alar–facial junction through the lateral canthus. Both the medial and lateral brow should be at the same horizontal position. Generally, in women, the brow should arc delicately above the orbital rim, whereas in men it should be more horizontal. The male brow should rest on the superior orbital rim and the female

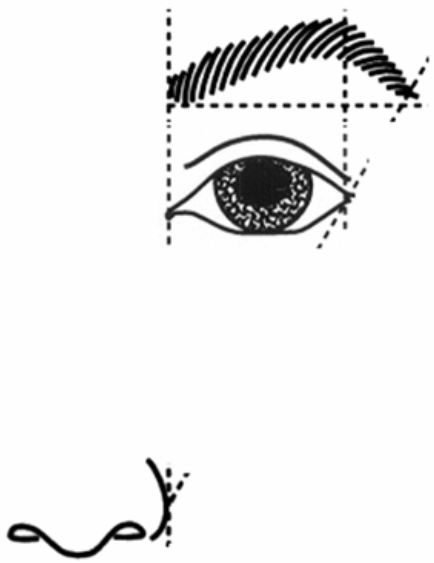

Figure 16–3 Ideal brow position with the apex of the brow above the lateral limbus.

brow extends well above this, with its highest point not at the lateral limbus, as often described, but at the lateral canthus (Fig. 16–3).[6] The more medial elevation tends to create an unnatural, surprised look. The glabella should not reveal infrowning at rest. The infraorbital fat should be slightly superficial to a plane tangential to the orbital rim. The inferior and lateral orbital rim should be padded with malar fat and SOOF. When the midfacial structures are ptotic and the orbital rim is exposed, the juxtaposition of prolapsed orbital fat and the fallen SOOF creates a double contour (Fig. 16–4A). Attempts to erase this double contour with lower-lid blepharoplasty and excessive fat removal result in a sunken, hollowed appearance. Other treatment options, including suborbicularis implantation and redistribution of orbital fat, camouflage the double contour; however, unlike the midface lift, they do not have the advantage of restoring the fallen SOOF to its earlier youthful position (Fig. 16–4B).

ENDOSCOPIC BROW AND MIDFACE LIFT

Preoperative Assessment

As with any facial plastic surgery procedure, patient selection is critical. Patient evaluation should begin with a thorough and complete history and physical examination. In the history, we typically elicit complaints about droopy eyelids and the appearance of weariness. The angry countenance of glabellar infrowning is also a frequent concern of the patient. Botulinum toxin injections are very effective for this; however, the endoscopic approach with partial resection of the corrugator supercilii and procerus muscles yields a more lasting result. Physical examination of the periorbital area may reveal brow ptosis, a ptotic SOOF, a ptotic malar fat pad, and scleral show. The latter is often seen in a patient who has had an overaggressive lower lid blepharoplasty with subsequent scleral show. The midface suspension reduces the downward pull on the lower lid and effectively raises the lower lid position and reduces scleral show (Fig. 16–5). A midface suspension can also improve mandibular jowling. If this were the patient's isolated complaint, we would not propose a midface lift in lieu of a rhytidectomy; nevertheless, we have observed dramatic improvement in mandibular jowling following the procedure (Fig. 16–6).

The ideal candidate is in good mental and physical health without systemic disease existing in an uncontrolled state. Preoperative screening for diseases and conditions that

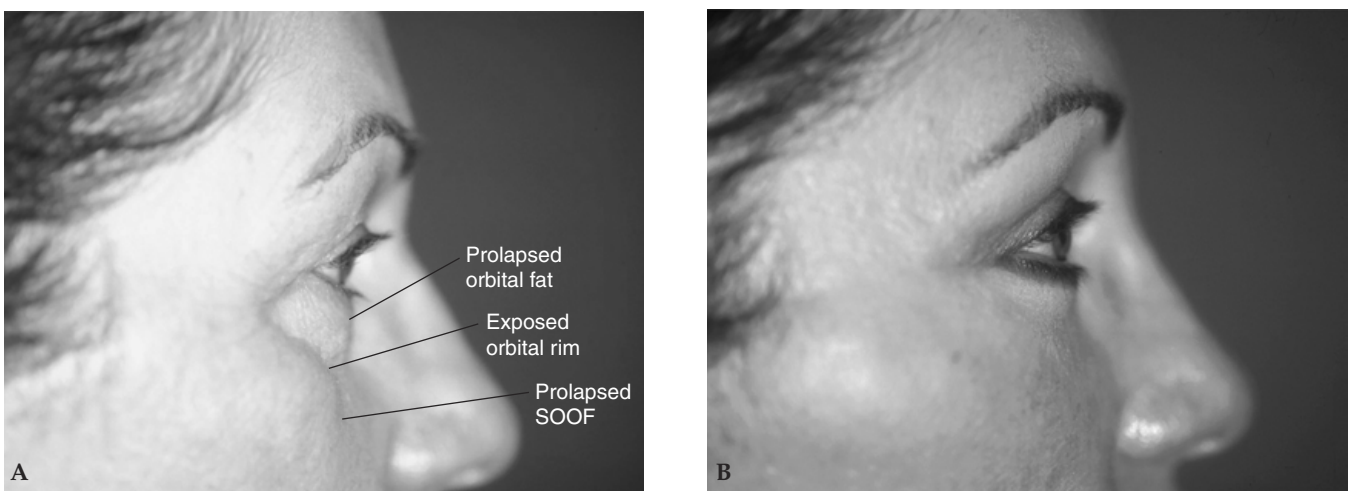

Figure 16–4 **(A)** Juxtaposition of prolapsed orbital fat against the orbital rim creates a double contour. The lower half of the double contour is created with proplapse of the suborbicularis orbital fat, thereby exposing the orbital rim. **(B)** Postoperative midface lift shows correction of the double-contour deformity.

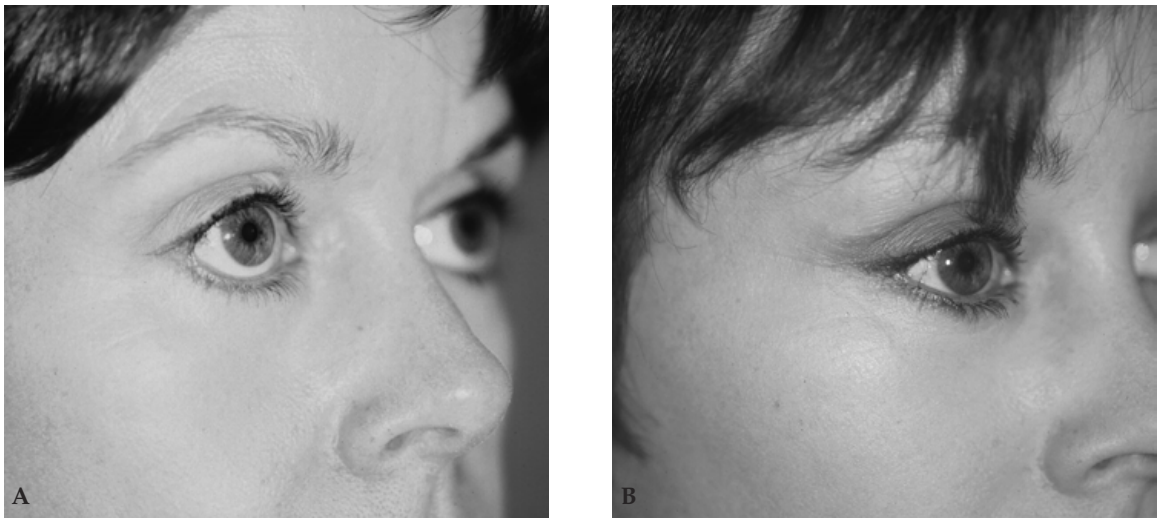

Figure 16–5 Improvement of scleral show following a midface lift. **(A)** Preoperative. **(B)** Postoperative.

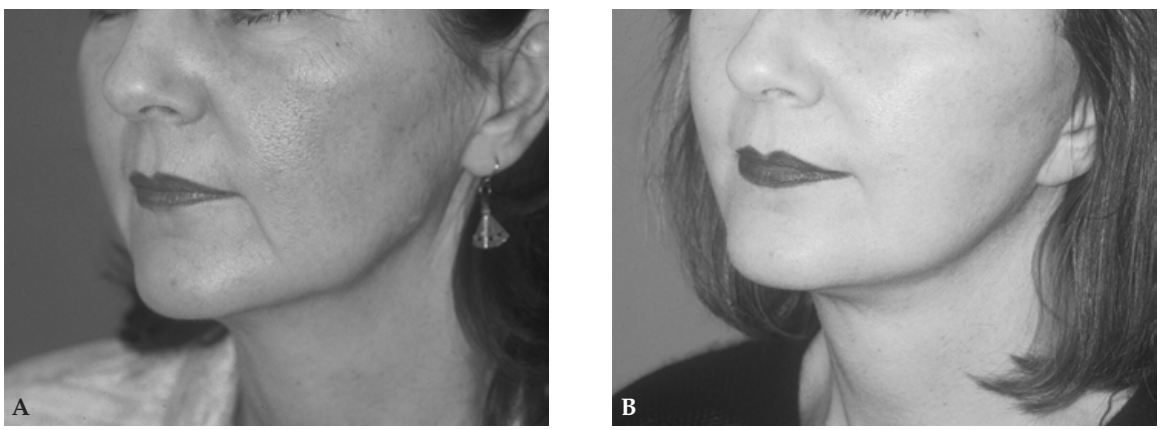

Figure 16–6 Moderate improvement in the mandibular jowl is a consequence of the midface lift. **(A)** Preoperative. **(B)** Postoperative.

could adversely affect the patient's surgical experience is standard. Patient education is a powerful and effective tool for reducing anxiety and establishing realistic postoperative goals and should begin at the initial consultation. A patient who is a candidate for a midface lift deserves special mention. This procedure induces a more protracted period of postoperative edema (4 to 6 weeks) secondary to the subperiosteal dissection. These patients will require more intensive pre- and postoperative counseling to guide them through the normal healing of this deeper dissection.

Evaluation of the Brow

When examining a patient for aging upper face, the patient should be in front of a mirror. When evaluating the forehead and eyes, the patient should face forward with the head level, utilizing the Frankfort horizontal plane. The patient closes his or her eyes and relaxes the forehead for a full 15 to 20 seconds. Next, the patient opens the eyes just enough to look straightforward without raising the brows. In this manner, the level of the brows can be evaluated in repose without the effects of exaggerated muscle contraction. The shape and position of the brows as they relate to the underlying orbit is then evaluated and compared with the classic brow. Usually in cases involving the aging upper face, the brow fat pad, which is designed to lay on and cushion the orbital rim, is ptotic, lying to various degrees on the upper eyelid. This is seen in the majority of these patients while in true repose and indicates the need for brow repositioning. A mistake that is often made is to overlook the brow position and simply address this as upper lid dermatochalasis. By performing an upper lid blepharoplasty without repositioning and fixating the brows, the natural spaces between the lateral canthus and lid crease as well as the lid crease and brow are shortened, sometimes markedly, leaving an abnormal appearance. It is important to diagnose brow ptosis if present because blepharoplasty performed without initial repositioning and stabilizing of the brow can

exacerbate the problem and result in additional lowering of the brow. A helpful guideline is to maintain a distance of approximately 1.5 cm between the eyebrow and the upper eyelid skin crease.[7]

Evaluation of the Midface

In the mid- to late thirties the aging process results in a descent of the midface. The malar prominence shifts inferomedially, resulting in exposure of the lateral orbital rim and a deepening of the nasolabial and alar groove. The SOOF descends revealing the inferior orbital rim and orbital fat, causing a double contour (Fig. 16–4). The endoscopic midface suspension effectively repositions these tissues and counters this aging process. This procedure reduces jowling and partially effaces the nasolabial groove. However, there is no benefit to the neck contour.

Surgical Technique (Forehead and Brow)

Upon selection of an appropriate candidate for endoscopic brow and forehead lifting, a useful adjunct is injection of botulinum toxin A to the central brow and glabella depressor muscles 2 weeks before the surgical procedure. This allows not only an excellent aesthetic improvement but also redraping and reattachment of the elevated periosteum unencumbered by depressor muscle action pulling the brows downward. Alternatively, the corrugator supercilli muscles can be partially resected during the procedure.

The procedure begins in the holding area prior to administration of anesthetic. The patient is examined in the sitting position and the brow position is assessed. The amount of medial brow elevation desired is measured. Despite its name, an endoscopic browlift does not always result in brow elevation. The procedure may be useful in a patient for whom glabellar infrowning is treated and brow position is kept neutral. Elevation of the medial endoscopic incision of approximately 8 mm is required to retain the preoperative medial brow height. Therefore, if medial brow elevation of 2 or 4 mm is desired, the medial incision will require superior advancement of approximately 10 or 12 mm, respectively. The planned vectors of pull are determined and marked on the patient's forehead and temporal area. In women the vectors are typically more superior and lateral, whereas in men the emphasis is on a slightly more lateral than superior vector (Fig. 16–7). These markings are performed with the patient in the upright position, allowing gravity its full effect. If concomitant blepharoplasty is to be performed, the lower limb of the blepharoplasty incision corresponding to the existing lid crease is marked at this time. Additional preoperative marking includes the supraorbital notch bilaterally, glabellar infrowning lines, and the frontal branch of the facial nerve (Fig. 16–8).

The patient is then brought to the operating suite where the equipment is arranged for proper visualization and function (Fig. 16–9). Intravenous analgesics are administered, followed by infiltrative local anesthesia using nerve and field blocks. After 15 or 20 minutes has been allowed for localization and vasoconstriction, two or three 1 to 1.5-cm incisions are made in a vertical fashion approximately 1.5 cm posterior to the anterior hairline in the midline and in the paramedian areas corresponding to the desired vectors of pull

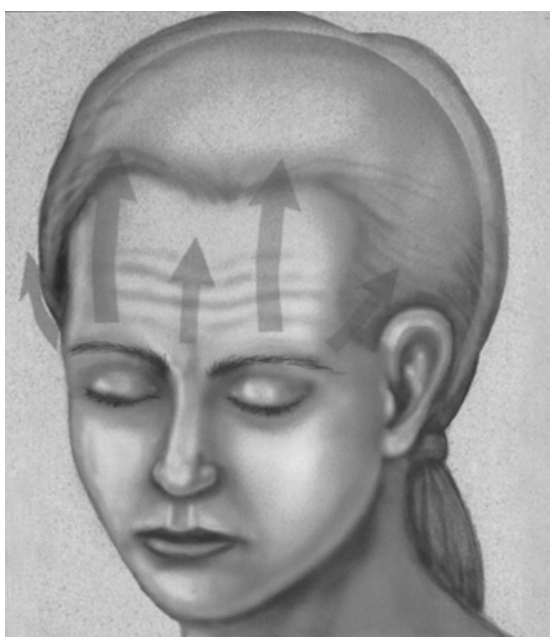

Figure 16–7 Planned vectors of pull.

Figure 16–8 Preoperative markings highlight the topographic course of the frontal branch of the facial nerve, the incisions, the location of the supraorbital notch, and the surface rhytides secondary to the action of the corrugator supercilii.

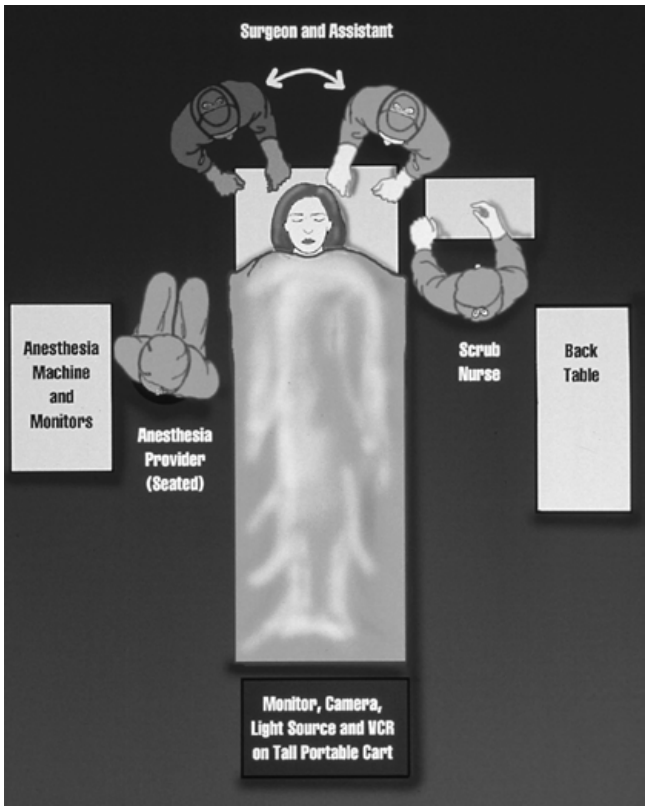

Figure 16–9 Arrangement of OR equipment and personnel during endoscopic brow and face lifting.

(Fig. 16–10). The vectors of pull and the need for central fixation determine whether two or three incisions are used in this area. The incisions are made with a no. 15 blade through all layers down to the skull. The periosteum is then elevated carefully in the region of the incision utilizing a caudal elevator, with care taken not to fray or damage the periosteum. Complete continuity of the periosteum around this incision is necessary, as this will be vitally important when the time comes to place the suspension sutures. Elevation then proceeds blindly utilizing endoscopic dissectors in the subperiosteal plane to a level approximately 1.5 cm above the orbital rims inferiorly, to the temporal lines laterally, and to approximately the coronal suture line posteriorly. At this point the 30-degree endoscope with sheath is introduced and the dissection proceeds inferiorly under direct vision. The visualized optic cavity should be almost bloodless, with excellent contrast between the underlying bone and overlying periosteum (Fig. 16–11).

Attention is directed to the area of the supraorbital neurovascular bundles. Care must be taken when dissecting toward this area as 10% of patients will have their neurovascular bundle exit through a true foramen as opposed to a supraorbital notch (Fig. 16–12). If corrugator and procerus resections are performed, the neurovascular bundle can be delineated with blunt dissection parallel to the fibers using a small pick. A temporary transcutaneous stitch is placed in the medial brow and lifted by an assistant to help

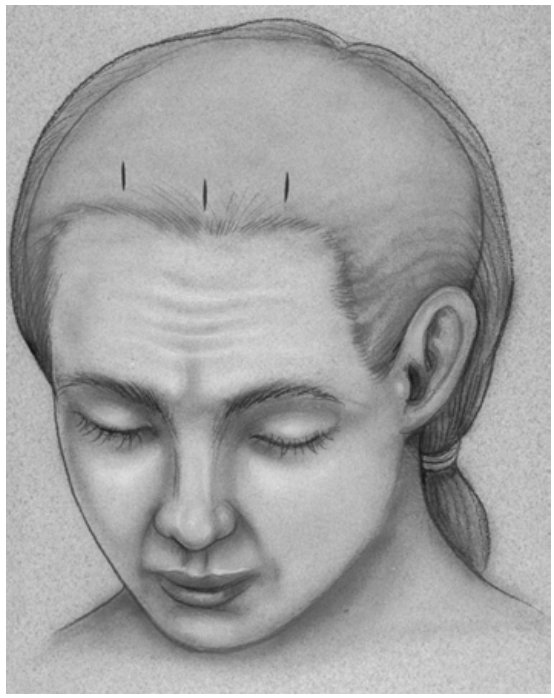

Figure 16–10 Central pocket incisions.

open the pocket of dissection. If called for, the corrugator supercilii and procerus muscles are resected and cauterized to maintain hemostasis. Orbicularis oculi myotomies are then performed by making multiple radial incisions in the muscle deep to the brow with a Colorado tip cautery, with caution to avoid the frontal branch of the facial nerve. We have performed unilateral orbicularis myotomies on the depressed brow to allow for increased single-brow elevation in patients with asymmetrical brows. Once the neurovascular bundles have been located, dissection is continued medially and laterally to these continuing inferiorly

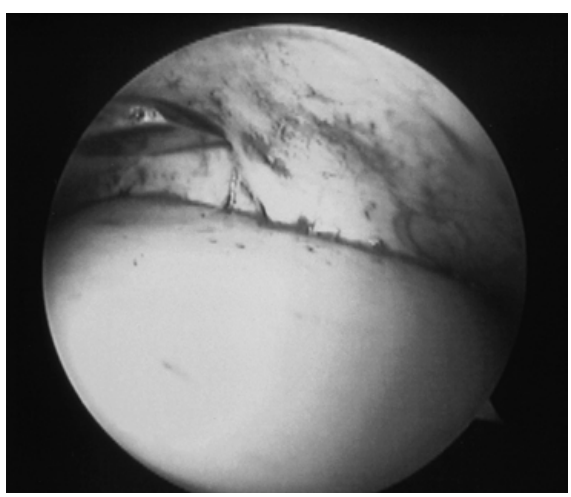

Figure 16–11 Central optic cavity.

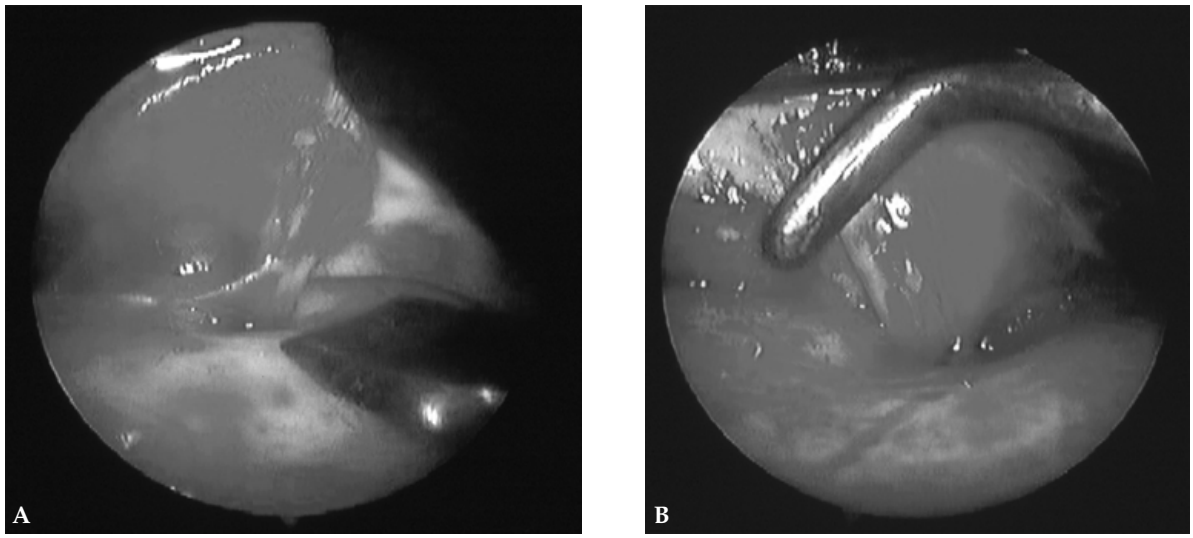

Figure 16–12 **(A)** Supraorbital neurovascular bundle exiting skull through a true foramen. **(B)** Supraorbital neurovascular bundle exiting skull through the supraorbital notch.

over the orbital rim releasing the periosteum at the arcus marginalis (Fig. 16–13). A gentle prying maneuver causes the periosteum to separate, revealing the overlying brow fat pad or ROOF (Fig. 16–14). It is critical that this periosteal separation be performed at the arcus marginalis, which lies below the level of the eyebrows. Only by a complete release at this level can the periosteum be elevated and resuspended as a bipedicled flap (Fig. 16–14B). In patients with very heavy brows and thick corrugator musculature, the muscle may be divided and a portion removed if warranted. After work is completed in the central pocket, attention is turned to elevation of the temporal pockets bilaterally. These will then be connected to the central optic cavity for completion of the elevation. The temporal pocket lies over the temporalis muscle and is bordered by the cephalic edge of the zygomatic arch inferiorly, the orbital rim anteriorly, and the temporal line superiorly.

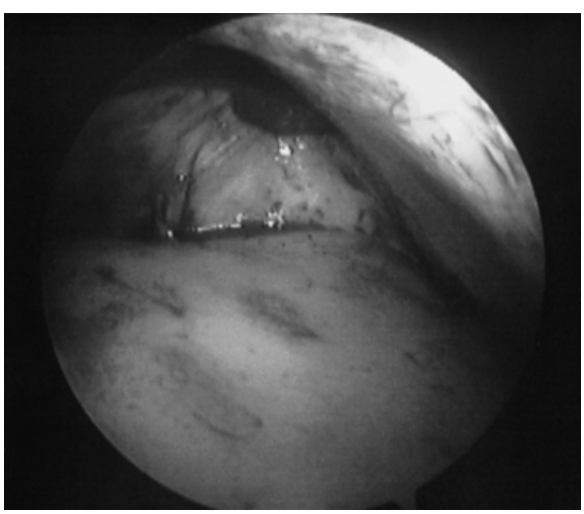

Figure 16–13 The periosteum is released at the arcus marginalis.

Temporal pocket access is obtained through a 1.5- to 2-cm incision within the hairline of the temporal tuft corresponding to the superior and lateral vector of pull desired for the brow. If a midface lift is planned in addition, this incision is extended to approximately 3 to 4 cm. The incision is made through the skin, subcutaneous tissues, and TPF. The incisions should be beveled according to the direction of hair growth to preserve the follicular units and minimize alopecia (Fig. 16–15). The dissection proceeds inferiorly in the plane deep to the TPF and above the deep temporal fascia covering the temporalis muscle. This dissection is performed carefully using a blunt endoscopic dissector under direct visualization using the 0-degree endoscope.

In a standard brow and forehead lift, the inferior dissection is complete at a level just superior to the zygoma approximating a horizontal line from the lateral canthus. The temporal pocket is then joined to the central pocket under direct visualization by sharp and blunt dissection of the temporal line attachments consisting of periosteum, galea, and temporal fascias (Fig. 16–16). The dissection to join the temporal and central pockets should proceed in a lateral to medial direction to maintain the proper plane. Once the two pockets have been joined under direct visualization superiorly, the dissection proceeds inferiorly using the beveled edge of the endoscopic elevator to elevate the temporal attachments. This is carried inferiorly to the area of the lateral orbital rim where dense connected tissue attachments to the bone are encountered. This conjoined tendon is sharply

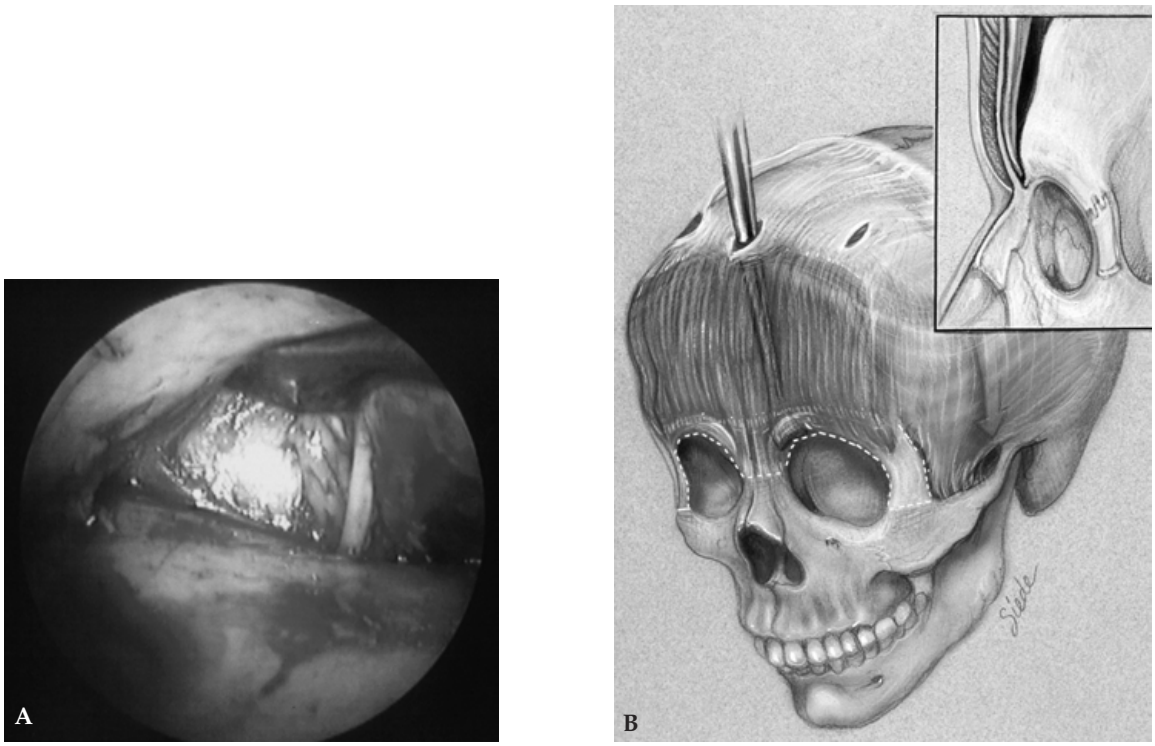

Figure 16–14 **(A)** Release at the arcus marginalis reveals the retro-orbicularis oculus fat (ROOF). **(B)** Complete release of the periosteum at the arcus marginalis bilaterally is essential.

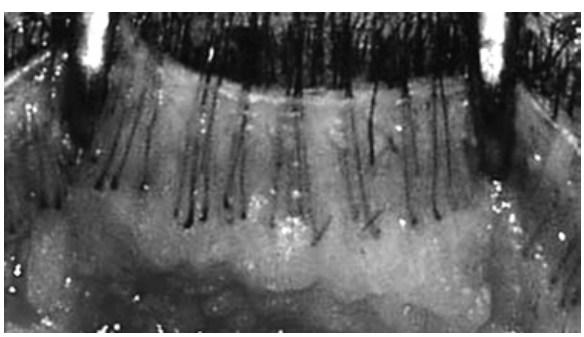

Figure 16–15 A cut beveled in the direction of hair growth preserves the maximal number of follicular units and prevents traumatic alopecia.

elevated in the subperiosteal plane using an endoscopic dissector, scissors, or endoscopic knife (Fig. 16–17). Once this dissection has been completed, the contralateral side is performed in the same manner. With this completed, the entire forehead–brow complex will be quite mobile and can be slid superiorly and inferiorly over the underlying bone.

After the entire elevation has been completed, the TPF is suspended through the temporal incision to the deep temporal fascia utilizing a heavy absorbable suture. Maximal support in this area should be obtained, as this region cannot be overcorrected. After this has been completed bilaterally, suspension in the central region is begun. There are multiple approaches to fixation of the forehead, including permanent microscrews left under the scalp, cortical tunnels to fix the galeal pericranium with prolene suture, and external tied over foam dressing.[5] The method of fixation reflects the surgeon's preference and should be based on patient comfort, surgical ease, and cost. Complete surgical release of the entire forehead–brow complex is more significant than the method of suspension. However recent laboratory studies indicate that the elevated periosteum is completely reattached within a week, indicating that long-term suspension may not be necessary.[8] In any event, final adjustments to brow height are made and suspension sutures are secured after the patient is brought to an upright sitting position, again allowing gravity its full effect. Incisions are then closed with skin staples. Computer analyses of long-term results have been gratifying and indicate that this technique will stand the test of time.

OPERATIVE TECHNIQUE FOR THE ENDOSCOPIC MIDFACE LIFT

The endoscopic forehead approach with midface suspension can be performed with or without elevation of the brows. In the majority of patients, the lower eyelid must be addressed

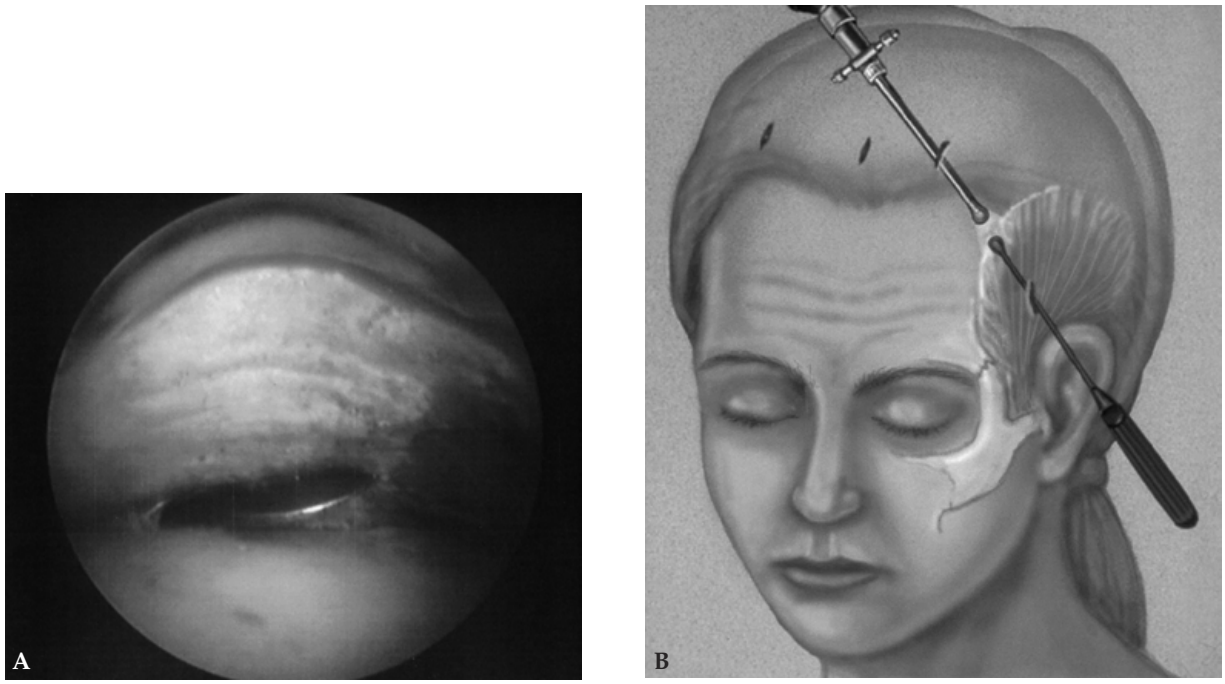

Figure 16–16 Temporal pocket is joined to the central pocket from lateral to medial under direct visualization.

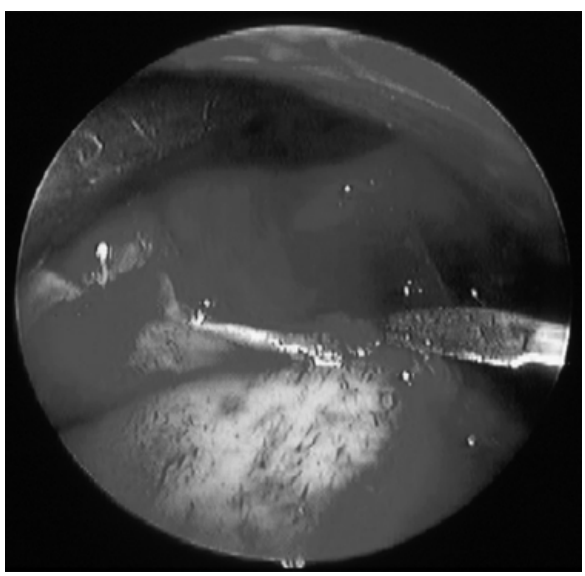

Figure 16–17 The conjoined tendon often must be sharply dissected.

during performance of an endoscopic forehead–midface lift, either with a lower lid skin pinch or periorbital laser resurfacing. This is because suspension of the midface elevates the cheek, frequently resulting in a bunching of skin under the eye. If lower lid fat removal is required, this is performed through a transconjunctival approach prior to placing the midface suspension stitches; otherwise the lower lid will be too tightly approximated to the globe to allow access.

Attention is first directed to the lateral incision. This incision is made with care to bevel the incision so as to not transect the hair follicles. The incision is carried down to a level just superficial to the temporalis fascia proper. A set of endoscopic instruments is necessary for this dissection. A double hook is used to elevate the skin, whereas a no. 4 Ramirez or flat dissector is used to create a plane of dissection just superficial to the temporalis fascia proper. This plane can be elevated blindly to the superior aspect of the ear and posteriorly where it will become a subperiosteal dissection after leaving the temporalis muscle. A lighted Aufricht retractor provides better optical visualization. The dissection then continues

inferiorly along the temporal line to the superior orbital rim as this subperiosteal plane is safe from the frontal branch of the facial nerve. The same dissector is then used to continue the plane of elevation over the temporalis fascia proper anteriorly using a gentle sweeping motion, keeping the temporal line as a landmark. Care must be taken here not to go too deep into the infratemporal fat, which can cause trauma and temporal wasting. Superficial dissection can traumatize the frontal nerve.

Multiple penetrating vessels will be encountered during the dissection (Fig. 16–2). They indicate the location of the frontal branch of the facial nerve. Dissect completely around the vessels and then, with traction, bipolar the deep aspect of the vessel so as to not cause thermal conduction trauma to the nerve that is superficial. This dissection is continued down to the superior orbital rim, and the periosteum is elevated off of the lateral aspect of the superior orbital rim. A bimanual elevation with one hand over the upper lid is performed to release the arcus marginalis. Attention is then directed to dissection to the zygomatic arch. The temporalis fascia proper splits at approximately the level of the supraorbital ridge to form an intermediate fascia and a deep temporal fascia with the intermediate temporal fat pad in between. Some surgeons prefer to continue the dissection in the middle of the intermediate fat pad, but our preference is to stay just superficial to the deep temporal fascia and elevate the intermediate temporal fat pad (Fig. 16–18). This plane can be more easily defined approaching the posterior one third of the zygomatic arch with moderate downward pressure on the flat dissector as the temporal fascia is thicker and stronger posteriorly. This plane of dissection is continued down to the superior edge of the zygomatic arch along its entirety. A lateral cuff of tissue of approximately 1 cm is preserved at the lateral canthus, depending on the amount of mobility desired in this region. The periosteum is incised at the superior aspect of the zygomatic arch with the dissector or a scalpel. A downcurved dissector is used to elevate the periosteum over the arch and release some of the masseteric aponeurosis attachments to the inferior aspect of the zygomatic arch. The dissection is then continued subperiosteally over the maxilla in blind fashion. A finger is kept on the infraorbital foramen to protect the nerve as subperiosteal elevation is performed inferior to the nerve. An additional finger is placed over the inferior globe as dissection is performed along the infraorbital rim just superior to the infraorbital nerve (Fig. 16–19). Dissection is carried all the way to the nasal bones and piriform aperture. Bimanual elevation of the cheek with the retractor further helps to release the periosteum, which is then tethered on the infraorbital nerve. A gauze is then placed in this cavity for hemostasis, and the identical procedure is performed on the other side.

The midface/SOOF is suspended with a large absorbable stitch placed through the periosteum just lateral to the zygomaticotemporal foramen and back to the temporalis fascia proper. Care is taken not to overcorrect with this suture. A second stitch is then placed proximal to the frontal nerve and back to the deep temporalis fascia. The excess skin in the temporal region is then smoothed out by placing three stitches in the superficial temporal fascia of the anterior skin edge and tacking it to the temporalis fascia proper posterosuperiorly. The skin is then closed with vertical mattress sutures to

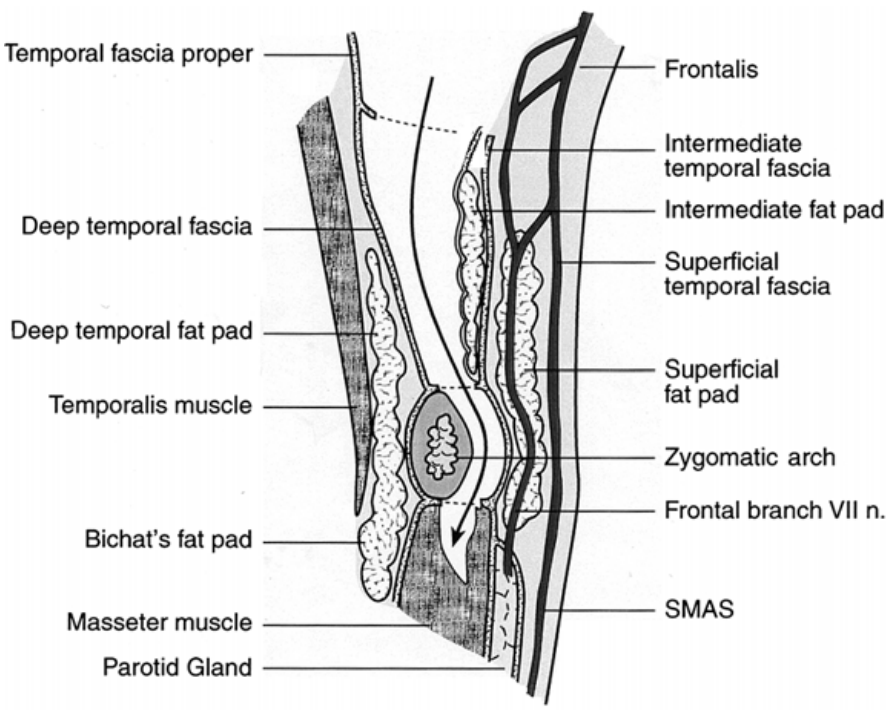

Figure 16–18 The approach to the midface hugs the deep temporal fascia and elevates the intermediate temporal fat pad. This provides maximal protection to the frontal branch of the facial nerve. Violation of the intermediate fat pad impedes visualization; however, it does not seem to contribute to temporal wasting.

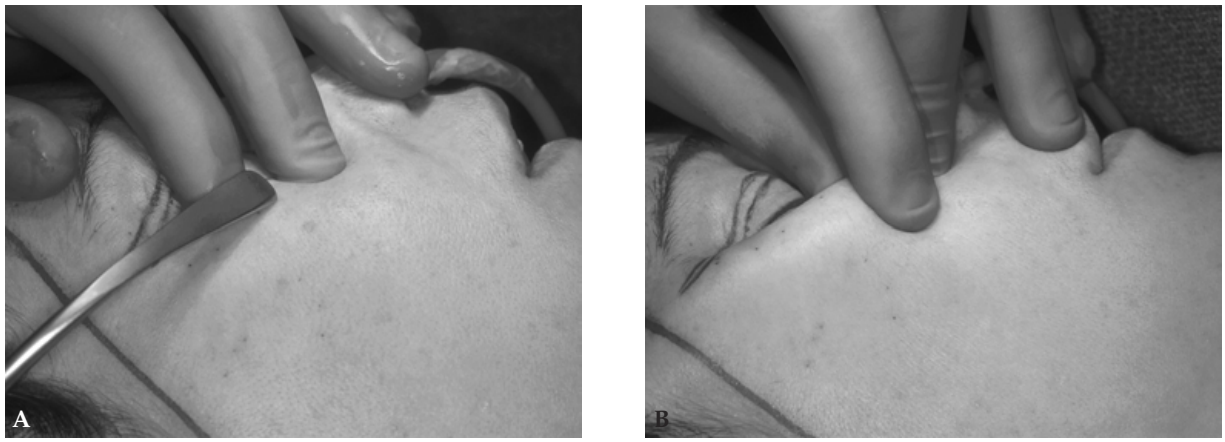

Figure 16–19 The path of the midface dissection hugs the infraorbital rim. Placing a finger at the superior edge of the rim protects the globe.

prevent a step-off deformity. Initially the skin will be puckered at this incision, but this will flatten relatively quickly and no skin excision is required.

A single small suction drain is placed at the level of the brows and exits laterally in the scalp. This is removed on postoperative day 1. Paper tape is placed on the forehead to minimize edema followed by a facelift pressure dressing, which is removed on postoperative day 1. Subperiosteal midface dissection induces more facial edema, and patients have to be prepared for this as well as a mild temporary distortion in the lateral canthal area. Patients are told that they will be presentable with makeup in 2 to 3 weeks but that edema and distortion do not completely resolve for 6 weeks.

COMPLICATIONS

Some numbness is invariably present following a forehead lift but typically resolves within 2 to 6 months in the forehead and 9 to 12 months at the crown. During recovery of sensation, paresthesias and itching are very common. There can be alopecia along the incisions if tension is placed during suspension, but hair growth generally returns in about 3 months (Fig. 16–20). Transient frontal nerve palsy has occurred and is felt to be a function of either thermal trauma secondary to electrocautery or overzealous temporal pocket elevation. An abnormal brow position may occur, which is initially treated with massage. If this does not achieve the desired result, releasing of the tissue may be necessary. Hematomas in the forehead or scalp may occur; however, the use of a closed-suction drain and/or compression dressings will minimize this.

The midface lift has a longer recovery and more potential pitfalls than a forehead lift. An expectation (as opposed to a complication) is masticatory tenderness. The release of the masseter combined with the suturing in the temporalis muscle can trigger muscle spasm and simulate temporomandibular joint syndrome. This typically resolves within the first week. The patients are usually presentable at 3 weeks, but it is usually about 6 to 8 weeks before edema has resolved. Periorbital edema and chemosis may linger beyond 6 weeks postoperatively. Photosensitivity as well as dry-eye syndrome may occur in this context. As the edema resolves, orbicularis function returns to normal and the lower lid resumes its apposition to the globe. Asymmetry of eye shape is always present initially but usually resolves as patient massage coupled with the strong circular action of the orbicularis oculi muscle brings the lids back toward their baseline. Revision prior to 6 months is not recommended.

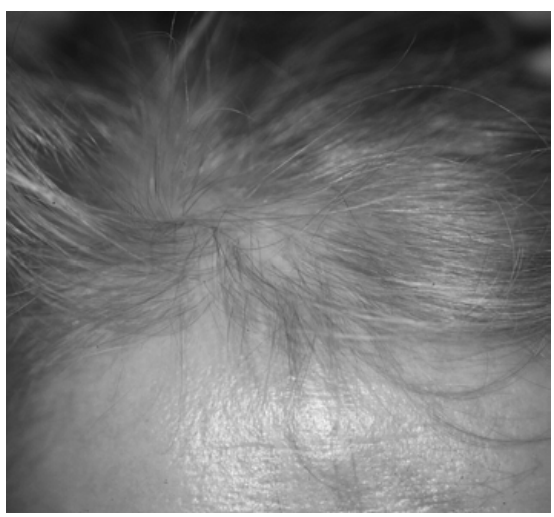

Figure 16–20 Incisional alopecia can result in a generalized thinning. Typically this improves in 3 to 6 months.

CONCLUSION

The endoscope and its accompanying equipment have provided facial plastic surgeons the opportunity to treat the aging brow and midface with smaller incisions and decreased risk of alopecia. The results are as reliable and impressive as those of more traditional techniques (Figs. 16–21 and 16–22). The more prolonged edema associated with the midfacial dissection does make the recovery longer, however, correction of the infraorbital complex at this time seems to justify the intervention.

Figure 16–21 **(A, B)** Pre- and postoperative view of a patient following endoforehead/midfacelift. **(C, D)** Pre- and 1-year postoperative view of a patient following endoforehead lift along with facelift.

Figure 16–22 Pre- and 1-year postoperative views of a patient following a forehead/midface lift. Close-up lateral views **(D)** highlight the double contour and its correction. The patient also underwent a rhytidectomy and rhinoplasty. The rhytidectomy and midface lift complement one another in their ability to improve the nasolabial and melolabial folds **(A–C)**. *(Continued on next page)*

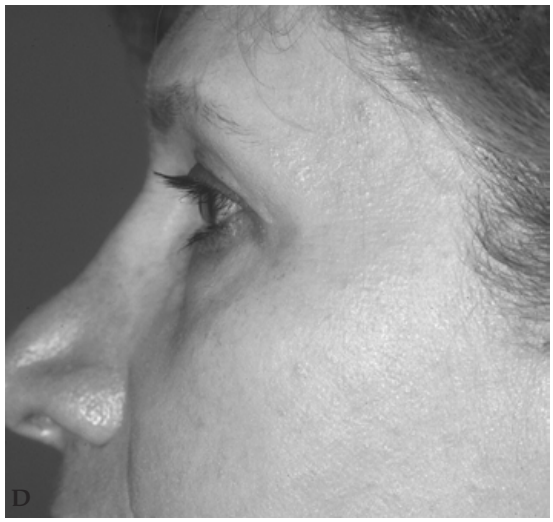

Figure 16–22 *(continued)*

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Chapter 17

Upper Lid Blepharoplasty

Norman J. Pastorek

Successful upper lid blepharoplasty begins with the surgeon's artistic understanding of the relationship of the upper lid, eyebrow, forehead, and bony orbital rim and a general appreciation of the current concept of the beautiful American face. The latter can be seen on the cover of many magazines. Today's beautiful face is determined by the beauty editors who choose them, the photographers who record them, the advertising executives who hire them, and the product clients who endorse them. The beautiful eyelid is a fairly static concept. Although it is fashionable, it is not a rapidly changing fashion. Today's look is the result of a process that has been slowly evolving over the past 30 years. Today's female eyelid–brow appearance includes a relatively full brow positioned at the orbital rim, centrally or just slightly above the orbital rim, and laterally above the orbital rim. The upper lid crease is usually less than 10 mm above the lid margin. The sulcus below the orbital rim should not actually define the bony margin. The lateral lid is free of hooding or skin draping over the lateral orbital rim. The overall appearance of the eyelid is one of a healthy, assertive youth. Absent is the high, thin, arched brow placed entirely above the bony orbital rim; the high, dramatic lid crease; and the deeply sculpted lid sulcus. The gaunt, fragile, aloof appearance became a liability in the late 1980s and will continue to be so in the 2000s. New York's mannequin manufacturers have redesigned the standard beautiful American female image to incorporate the slightly heavier, healthier, fuller, and more assertive look. Some latitude is allowed for individual faces and individual tastes. For example, the young face with particularly heavy, ruddy skin, relatively low brows, and a weak chin–neck complex often looks much better with elevation of the brow–forehead unit to a relatively high level. Evaluation of the prospective blepharoplasty patient involves obtaining motivational and medical history, evaluation of the lid–brow complex, discussion of the proposed surgery, discussion of the preoperative and postoperative course and possible associated complications, and photographic documentation.

MOTIVATIONAL HISTORY

The ideal candidate for upper lid blepharoplasty has had a relatively long-term desire for reversal of the progressive deterioration of the lid appearance. The patient is in an employment or social situation that warrants facial attractiveness and is realistic about the possible outcome. There should be no expectations of external-world changes as a result of the surgery (e.g., regaining a lost romance or obtaining an elusive job). The patient's questions, answers, forethought, and general dress and manner should appear correct and "feel right" to the interviewing facial plastic surgeon. Interestingly, almost all patients coming for blepharoplasty are good candidates. The psychological and motivational problems seen in rhinoplasty and facelift patients are much less common in blepharoplasty patients.

MEDICAL HISTORY

Obviously, any general medical problem that contraindicates elective surgery also contraindicates upper lid blepharoplasty. Particular attention must be given to any condition that may be aggravated by the use of local anesthetic with epinephrine. Many of the newer psychological agents interact with the sympathomimetic amines and must be discontinued before surgery. Homeopathic medications are becoming a common part of many Americans' daily nutritional supplements. Many of these herbal preparations interact with medications used at surgery. St. John's wort, yohimbe, and licorice root can have a monoamine oxidase inhibitory effect. Gingko biloba, used for short-term memory loss, is a powerful anticoagulant. It is best to have a patient report all medications, including alternative medications.

Any condition that produces fluid retention, including the myxedema of hypothyroidism, must be considered in-depth before surgery. Allergic dermatitis conditions, especially of the face and lid skin, should be controlled before blepharoplasty to avoid poor scarring or delayed wound healing.

Ophthalmic medical history is critically important. Use of eyeglasses, contact lenses, or eye medications must be documented. Any indication of dry-eye syndrome (e.g., burning, tearing, use of artificial tears, waking at night with stinging pain in the eye, or sensitivity to windy conditions) merits a complete evaluation. Personally, I will not perform upper lid blepharoplasty on any patient who presents with any degree of dry-eye syndrome. Even minimal upper lid blepharoplasty can result in upper lid closure failure, exposing the corneal tissues and aggravating the dry-eye syndrome with potentially severe complications. Judicious lower lid blepharoplasty can be performed in the presence of dry-eye syndrome with much less worry about serious consequences. Unmasking or worsening the dry-eye syndrome in an upper lid blepharoplasty patient creates one of the unrelenting postoperative problems in facial plastic surgery. It totally overwhelms even a perfect aesthetic surgical outcome.

A vision history should always be obtained. A near-vision (reading) acuity examination can easily be incorporated into the questionnaire the patient is given to fill out in the waiting area before consultation.

The history of previous upper lid blepharoplasty, even if done many years ago, is important. The possibility of lagophthalmos is always present in these patients, and the indication for conservative secondary surgery is imperative. These patients can present with an impressive amount of apparent upper lid skin redundancy. However, when the eyes are closed the amount of upper lid skin redundancy that can be removed without causing lagophthalmos is usually minimal.

EVALUATION OF THE BROW–LID COMPLEX

Brow Evaluation

The assessment begins with simple observation while the patient is talking and listening. Eyebrow position during animation and during repose is noted. The patient with low-position eyebrows often elevates them when speaking, producing deep, horizontal forehead creases. In the female patient the lateral and central brow should ideally be above the superior orbital rim. If the lateral and central brow is at or below the orbital rim, a browlift procedure should be considered. An upper lid blepharoplasty performed on a patient with brows below the orbital will invariably pull the brows into a lower position. Of particular interest is a patient with unilateral brow ptosis. This patient invariably sees the problem as a unilateral excess upper lid skin and sees the surgery required as removal of more skin from one eyelid than from the other. This is understandable because patients with unilateral brow ptosis in repose observe this as their natural appearance in a mirror and in a lifetime of family photographs. These patients are quick to see that the problem is not the eyelid but the ptotic eyebrow and are amenable to a concomitant unilateral browlift. The patient with unilateral brow elevation present only with facial animation is also common. No attempt should be made to elevate the lower nonanimation eyebrow in these patients because this will only create an asymmetry in facial repose. After observation, the position of the eyebrow in relationship to the orbital rim is determined by palpation.

Lid Evaluation

The upper eyelid is examined. It should be kept in mind that in the simplest terms the aesthetic goals of upper lid blepharoplasty can be achieved by excision of redundant skin, removal of some part of the musculus orbicularis oculi when necessary, and resection of the pseudoherniated fat. The relative presence of medial fat and central fat is noted. The presence of a palpable lacrimal gland and lateral upper lid gland is also noted. The position of the eyelid crease at the superior tarsal margin is determined. The skin type is especially important in upper lid blepharoplasty. The patient with thin skin is usually an older individual requiring conservative resection of fat in the central compartment to avoid a retracted, hollow look postoperatively. Conservative muscle resection will also be required. In these patients, the eyelid appearance should be returned to one that was present at least a decade earlier. This can be demonstrated by using the wooden portion of a cotton-tipped applicator to roll the redundant skin toward the orbital rim while the patient is observing in the mirror. The patient with very heavy lateral orbital rims may be a candidate for removal of fat from beneath the orbitalis muscle in the region of the lateral brow. This procedure can be done in conjunction with upper lid blepharoplasty.

Special Considerations

The patient with heavy skin, and especially the younger patient with thick skin, has usually never had a discernible upper eyelid crease. Surgical creation of a sculpted eyelid requires excision of considerable fat and the musculus orbicularis oculi and possibly a lateral extension of the lid skin excision. It is particularly important to show these patients how they will look postoperatively, because they have never seen themselves with an eyelid sulcus. These patients often will say, "I've never had eyelids, not even when I was very young." The patient with thick heavy skin, especially in the outer third of the lid, may have some tendency toward scarring for several weeks after surgery. This should also be discussed with the patient. Also, when an upper lid blepharoplasty incision must cross the lateral orbital rim onto the facial skin (i.e., when there is considerable lateral hooding), the facial skin portion of the scar will take longer to mature.

The symmetry of the palpebral fissures is noted. The upper lid should cross the limbus just above the pupil in a bilateral symmetric position. A 2- to 3-mm noncorrectable, unilateral ptosis of the upper eyelid will often not be noted by the patient before surgery. Understandably, it is overlooked among the redundant skin and fat herniation. When blepharoplasty has eliminated all of the lid problems, the palpebral fissures asymmetry will be unmasked. If the surgeon fails to identify this condition and carefully show it to the patient before surgery, it will become a point of contention between the doctor and the patient after surgery. It will be the first thing that friends notice. Any postoperative explanation, even with pictorial evidence, becomes an excuse. If this palpebral fissure asymmetry is noted before surgery, the patient will think of the surgeon as a careful and astute observer.

Notation is made of any associated skin lesion (e.g., xanthoma, syringoma, trichoepithelioma, hypertrophic sebaceous glands, skin pigmentation, enlarged veins, and telangiectasias). Whether these lesions will be removed at the time of surgery, at a later secondary procedure, or not at all must be discussed.

PREPARATION FOR SURGERY

Decision to perform upper lid blepharoplasty is based on favorable results of psychological, general medical, and ophthalmologic examinations. It is vital that the patient's expectations are in balance with what is possible surgically. The patient should be prepared for the procedure with an in-depth discussion of preoperative recommendations, the surgical procedure itself, the usual postoperative course, and the possible complications.

Preoperative recommendations include asking the patient to avoid aspirin, vitamin E, ibuprofen, and other nonsteroidal anti-inflammatory medications for 2 weeks before surgery. All of these medications are known anticoagulants. Use of any of these medications before surgery carries a possibility of intraoperative bleeding and almost certain postoperative moderate to severe ecchymosis. Alcohol ingestion in the immediate preoperative period can cause swelling, and the anticoagulative benefit of daily wine consumption is a detriment before surgery.

The patient should be aware of any physical activities, exercise programs, or travel plans that would adversely affect the immediate postoperative result. It is best to assume that the patient is totally ignorant of these matters at the time of the initial consultation.

Financial arrangements should be clearly understood by the patient so there is no confusion before the operation.

Photographs of the patient are obtained either in the office or by a photographer. The standard views include full-face frontal, close-up frontal (eyes open, eyes up, and eyes closed), close-up oblique, and close-up lateral.

THE SURGICAL PROCEDURE

Most frequently upper lid blepharoplasty can be done as an outpatient procedure under local anesthesia with minimal preoperative and intraoperative medication of choice.

Planning Incisions

The procedure begins with marking of the lids. To minimize "bleeding" of the skin marking and maximize the permanence of a fine-line drawing on the lid skin, the lids must be totally clean of natural skin oil. All makeup is removed the night before by the patient. The lids are degreased with alcohol or acetone before marking.

The initial lid marking is at the natural lid crease, which can almost always be seen clearly with a bright light and adequate magnification. This lid crease is at the upper margin of the underlying superior tarsal plate. If the natural lid crease is at 8 mm or more above the lid margin, it is always best to use this natural landmark. The lid crease is usually at the same level bilaterally. If there is a 1-mm discrepancy between lids, then adjustments in the lid crease marking are made so that both are 8 to 10 mm above the lid margin. The medial end of the incision is carried far enough nasally to include all of the fine creped skin but never beyond the nasal orbital depression to the nasal skin. Carrying the incision too far nasally causes almost irreversible webbing. Laterally the lid crease line is carried in the natural crease of the sulcus between the orbital rim and the eyelid. At this point, the line breaks laterally or slightly upward (Fig. 17–1).

Figure 17–1 The natural lid crease is used as the guide for the lower lid marking. It is marked on both eyes so that symmetry is achieved. The mark should naturally lie at 8 to 10 mm above the lid margin. If the mark is lower or higher than these limits the scar may become obvious. In this patient the line has been extended laterally to encompass the lateral hooding. The dotted line shows the orbital rim.

With the patient in a supine position, the real amount of the upper lid skin redundancy can only be determined after the brow is physically pushed downward. In the supine position the mobility and weight of the scalp and forehead pull the brow above the orbital rim. This is not the true, natural position of the brow. The upper lid skin redundancy is transiently lessened. To plan the upper lid blepharoplasty correctly the brow must be gently pushed down toward the orbital rim into a position noted when the patient was seated or standing (Fig. 17–2A, B). The upper lid skin is then

Figure 17–2 **(A)** With the patient in the supine position, the brow position becomes elevated by the weight of the scalp. This elevates the lid skin and diminishes the amount of upper lid skin redundancy. The brow must be repositioned for lid marking. **(B)** With gentle pressure, the brow relocated downward. This is the position the brow would naturally assume if the patient were upright.

Figure 17–3 The skin is grasped with a forceps so that all excess skin is incorporated. The lower blade of the forceps is on the mark indicating the natural lid crease. The lid should not open with this maneuver. Removal of enough skin to allow opening of the lid could cause lagophthalmos.

Figure 17–4 With the patient's eyes closed, the amount of skin to be removed can be seen as a gentle sinuous shape extending beyond the lateral orbital margin.

gently grasped with forceps. One blade of the forceps is at the previously marked lid crease. The other blade grasps just enough redundant skin to smooth the lid but not to move the lid margin upward. In other words, if the skin between the forceps blades were to be removed, surgical elevation of the lid margin and lagophthalmos should not occur (Fig. 17–3). This marking technique is used at several points across the lid. As these points are connected a line is created that parallels the lid crease line. Medially and laterally the lines join at a 30-degree angle. The medial skin redundancy should always be slightly underestimated in patients with a large amount of medial fat. The defect created by the excision of a large amount of fat medially may cause a dead space to occur subcutaneously. If slightly less skin is excised medially the repaired medial end of the lid falls inward rather than tenting over the area of removed fat. If tenting of the medial lid skin occurs, dense scarring is almost a certainty in this region.

The lateral extent of the planned skin excision is determined by the amount of lateral hooding. If no hooding is present in a younger patient, the lateral excision ends just beyond the lateral canthus. If the lateral hooding is extensive, the excision may be carried 1 cm or more beyond the orbital rim laterally. The direction of the resultant scar should always lie between the lateral canthus and the lateral eyebrow (Fig. 17–4). In this position the incision can be camouflaged by eyeshadow makeup in the female patient (Fig.17–5). The area demarcated by the surgical pen marking should be a gentle sinuous shape (Fig. 17–6).

Anesthesia

Once the marking is complete, local anesthesia can be infiltrated. Xylocaine 2% with 1:100,000 epinephrine buffered with sodium bicarbonate 8.4% is recommended. The ratio is 10 mL xylocaine to 1 mL bicarbonate. Approximately 1 mL is infiltrated into the upper lid subcutaneous space with a $1\frac{1}{2}$ in. or 25- to 27-gauge needle. To gain the maximal effect from the epinephrine, at least 10 minutes must elapse before an excision is made.

Initial Incision and Muscle Excision

The initial incision is made by stretching the lid skin marking into a straight line and incising the lid crease marking with a

Figure 17–5 With the patient's eyes open, the considerable amount of skin lateral to the palpebral fissure can be seen. The lateral excision will eliminate the lateral hooding.

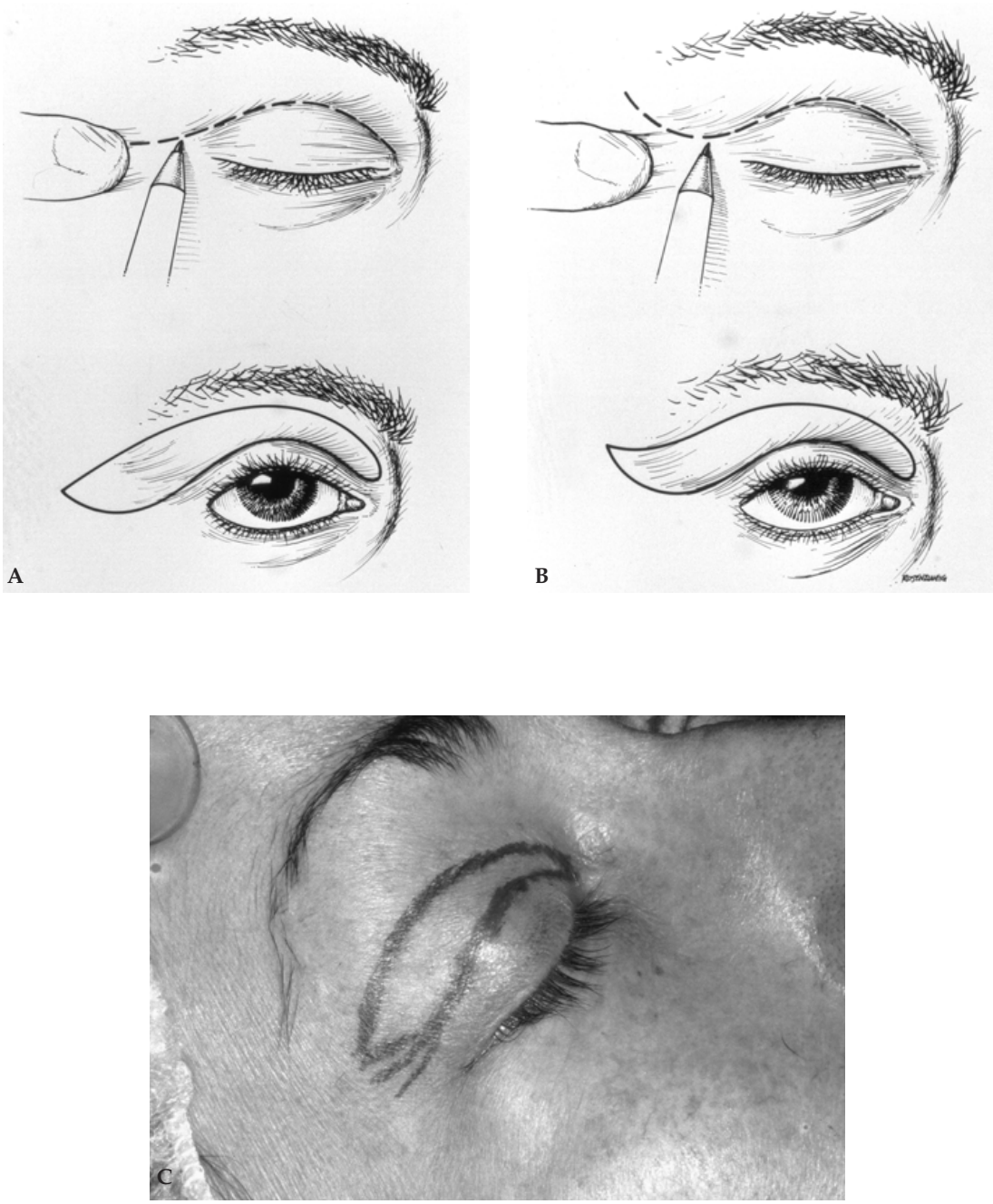

Figure 17–6 **(A)** The classic skin excision follows the general line of the natural lid crease. The lateral extent of the incision tends to fall below the lateral hooding just beyond the orbital rim. The cleanness of the upper lid following excision of redundant skin may exaggerate the lateral hooding. **(B)** There are several advantages to moving the lateral extent of the incision upward at the lateral orbital rim. The resulting scar lies between the lateral brow and the lateral canthus. In this position the healing wound can be camouflaged by eyeshadow makeup in the first few days following blepharoplasty. Moving the lateral extent upward also avoids a permanent scar directly in a lateral crow's foot. The most significant advantage, however, is that the superior limb of the wound is stabilized by the firm subcutaneous tethering in this area. The idea for this modification came about when it was noted that the temporal skin cannot be drawn downward to close a defect in this area. **(C)** The surgical pen marking in this patient shows the various choices possible for skin incision in the lateral aspect of upper lid blepharoplasty. The most inferior position is the classic one placing the incision in a lateral rhytid. The midlevel mark would be used in a patient with minimal hooding. The superior mark (to be used in this patient) shows the best position for eliminating lateral hooding.

blade of choice (Fig. 17–7). A no. 67 Beaver blade is preferred because it is sharp and small. The upper limb of the incision is made, and the skin is removed with a forceps and curved Stevens scissors. At this point a decision is made about the underlying musculus orbicularis oculi. Some muscle is removed in almost all cases. Usually thin-skinned, older patients require less muscle excision, whereas younger and especially heavy-skinned patients require more muscle excision to gain a good aesthetic effect.

The muscle excision is made along the path of the skin excision. The width of the skin excision is as wide or as narrow as necessary. The depth of the excision is to the orbital septum (Fig. 17–8).

Fat Removal

If there is an abundance of fat, it is probably wise to remove the central compartment before removal of the medial fat compartment. The central compartment can be opened by incising the orbital septum in one place or by opening along its entire length. A small fat pseudoherniation can be removed with one clamping. Larger amounts may require dividing the central compartment into two or more sections. The medial

Figure 17–7 The skin is stretched tightly in preparation for skin incision. The surgical mark should be made with the finest line possible. Natural skin oil on the lid surface may cause the surgical pen mark to widen. A thick mark can lead to excessive skin excision. It is always best to remove skin oil prior to marking.

Figure 17–8 **(A)** In this patient with thin skin there was no redundancy of orbicularis muscle. Once the skin is removed the underlying orbital septum is exposed. **(B)** In this patient with moderately thick skin there is a corresponding moderate increase in the thickness of the underlying orbicularis muscle. In this case, it is important to remove a central trough of muscle to produce a proper upper lid cleft in the postoperative eyelid. **(C)** This patient with major orbicularis muscle hypertrophy required a significant excision of muscle to allow definition of the upper lid cleft. If the muscle is not removed the lid will continue to appear full.

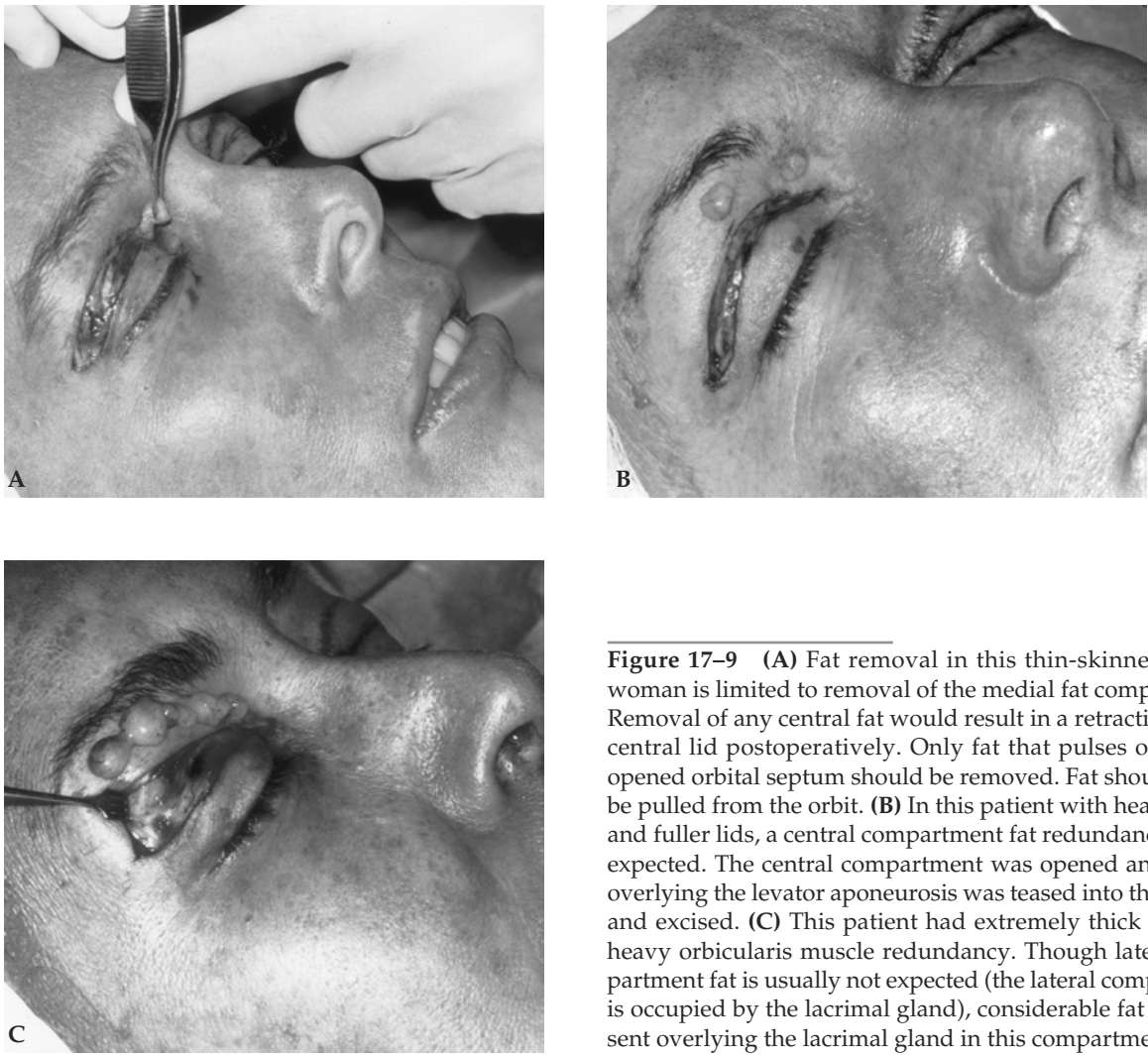

Figure 17–9 **(A)** Fat removal in this thin-skinned young woman is limited to removal of the medial fat compartment. Removal of any central fat would result in a retraction of the central lid postoperatively. Only fat that pulses out of the opened orbital septum should be removed. Fat should never be pulled from the orbit. **(B)** In this patient with heavier skin and fuller lids, a central compartment fat redundancy can be expected. The central compartment was opened and the fat overlying the levator aponeurosis was teased into the wound and excised. **(C)** This patient had extremely thick skin and heavy orbicularis muscle redundancy. Though lateral compartment fat is usually not expected (the lateral compartment is occupied by the lacrimal gland), considerable fat was present overlying the lacrimal gland in this compartment.

fat compartment is teased into the wound and excised. Although classically there is no lateral fat compartment in the upper lid, fat can be present external to the lacrimal gland in an apparent lateral compartment (Fig. 17–9). All fat is injected with a small amount of local anesthesia before clamping. The subcutaneously injected local anesthesia will not ordinarily penetrate the orbital septum. If additional anesthetic agent is not used, the patient will feel pain from the fat clamping. The fat is clamped with a small, narrow hemostat. It is then excised, leaving a small cuff of tissue available for cauterization. It is important not to actively pull fat from the orbit into the wound for removal. Only fat that comes into the wound easily should be removed. This is especially important in the area of the medial aspect of the central compartment. Removal of too much fat here can lead to a retraction of the lid and a pronounced overhang of the orbital rim. The resulting appearance can be that of aging and must be avoided.

The medial fat compartment may be elusive. It is important to analyze its significance preoperatively so that it is removed at surgery. At times, because of the patient's position, the medial fat falls back into a seemingly insignificant position. If it was seen to be a problem before surgery, then the medial fat pocket must be sought and removed. To underestimate the amount of redundant medial fat is the most common aesthetic error in upper lid blepharoplasty. The fat medially is whiter than yellow and also denser than the central compartment fat. Medial fat position is somewhat variable compared with all of the fat compartments in the upper and lower lids. The central and medial fat compartments are separated by the musculus obliquus superior oculi. In contrast with the musculus obliquus inferior oculi, this muscle in the lower lid is rarely observed. Still its presence should always be sought before applying a hemostat to the fat.

If during the preoperative evaluation a lateral orbital rim fat pad has been noted to be a part of the aesthetic problem, it can be removed at this time. The upper outer limb of the incision is retracted. Blunt dissection beneath the orbicularis muscle exposes the lateral orbital rim fat pad. Scissors sculpting removes the fat. There are several small vessels in the fat. Hemostasis must be absolute and complete.

It is possible to remove fat from the medial compartment via a transconjunctival approach. The upper lid is everted with a lid retractor. Digital pressure is placed on the medial fat compartment. The fat will be seen as a bulge beneath the conjunctiva. The levator aponeurosis does not lie between the conjunctiva and the subseptal fat as it does in the central compartment. The conjunctiva is injected just as it is in the lower lid transconjunctival approach. The conjunctiva is opened sharply

and the fat is extracted, clamped, and excised. No suturing is necessary. This approach may be worth considering when the only problem is medial fat psuedoherniation. It may also be considered when medial fat is found to persist following upper lid blepharoplasty. Care is taken to avoid the superior oblique muscle.

Cauterization

A hot-tipped cautery is preferred; however, bipolar cautery may also be used. Unipolar electrocautery applied directly to the hemostat can cause the patient pain, especially under local anesthesia with light premedication. Apparently there is transfer of electrical impulses deep into the orbit. The patient will report pain "in the back of the eye." Animal studies at the University of Oregon have demonstrated transmission of heat up to a distance of 1 cm internal to the application of unipolar cautery to clamped fat. Thermal transmission was negligible to minimal with hot-tipped and bipolar cautery.

Hemostasis must be meticulous before wound closure. It is important not to be too aggressive with the cautery in the subcutaneous tissue at the incision margin because thermal injury here can interfere with the fine postoperative scar.

Wound Closure

The use of Prolene 6-0 for wound closure of the eyelids is preferred. This suture almost never leaves suture marks even if for some unpredictable reason the sutures remain in place beyond the usual 3- to 4-day ideal time. Also, the occurrence of suture tunnels or suture milia is rare. The lateral aspect of the wound where tension is the greatest is closed first (Fig. 17–10A). This area is repaired with several individual simple sutures. After the lateral one fourth of the wound is closed, the remainder of the wound is repaired with a running subcuticular 6-0 Prolene suture beginning medially. It is unnecessary to knot the Prolene at the entrance and exit of the skin (Fig. 17–10B). The ends of the subcuticular suture are taped to the forehead. When any suspicion of wound tension exists, the entire wound can be taped with $\frac{1}{8}$ in. surgical strips.

At the end of the procedure attention is directed to the medial aspect of the lid. Any remaining skin crepe can be excised as small triangles above and below the medial incision. These excisions can be opposite one another or staggered. The base of the triangle lies at the incision. Care is taken not to cut the subcutaneous suture during skin excision. These triangular defects can be taped closed with $\frac{1}{8}$ in. surgical squares. Occasionally, a single 6-0 Prolene suture can be used to close the triangular defect. Most times the skin edges lie in approximation without any need to secure the wound. This final maneuver flattens the medial aspect of the lid. If any wound separation is noted at the conclusion of the surgery, an additional simple suture can be used at that area of tension.

UPPER LID BLEPHAROPLASTY IN MEN

Upper lid blepharoplasty surgery in women differs substantially from the procedure in men. In male patients, the surgeon must be extremely conservative. Extension of the lateral excision beyond the lateral canthal boundary, in general, should not be done in males. If the incision is carried beyond the lateral orbital rim, the immediate scar produced cannot be covered with makeup. The surgeon should always assume that the male patient would not wear cosmetics of any kind. The long-term scar, though very slight, may remain objectionable for years.

The surgical goal for the lid sulcus differs markedly in women and men. A deep superior lid sulcus is contraindicated in the male. It is not only feminizing but also radically changes the masculine appearance. It is not the usual male look. A man in today's society usually looks best with some upper lid skin redundancy, some skin crepe, and a lid crease just a few millimeters above the lid margin.

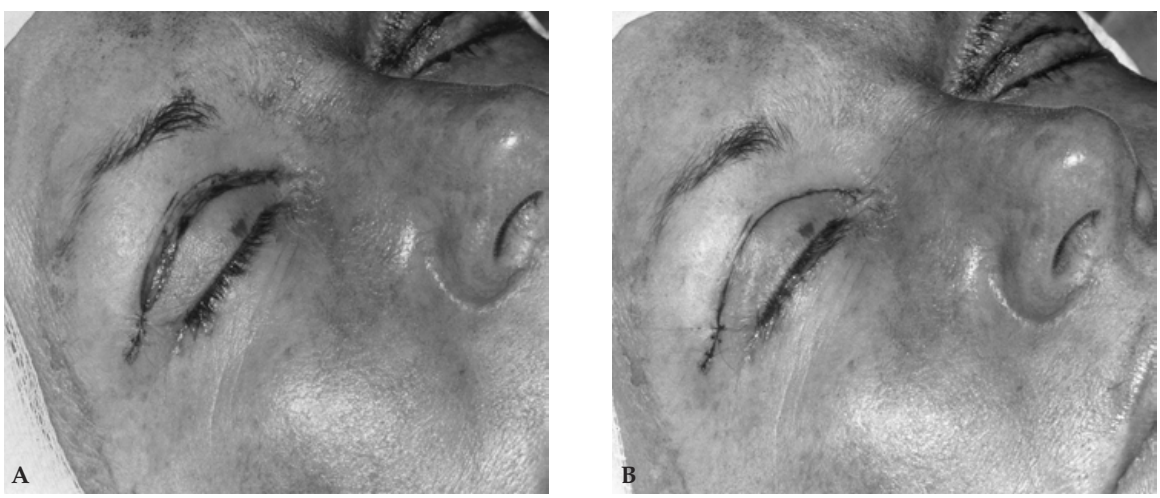

Figure 17–10 **(A)** The lateral wound angle is closed first with individual 6-0 polypropylene sutures. The most tension is present in this area of transition between the eyelid skin and facial skin. It is most important that the angle be closed without any irregularity. **(B)** Following repair of the lateral aspect of the wound, the remainder of the wound is closed with a subcuticular running 6-0 polypropylene suture beginning at the medial angle of the wound. The suture repair can be supplemented with $\frac{1}{8}$ in. surgical tape over the wound and/or surgical glue to give further support.

POSTOPERATIVE CARE

The patient is asked to remain quiet for the remainder of the day of surgery, preferably in a two-pillow supine position. Ice cold compresses are used continuously during the waking hours and an ophthalmic ointment is used over the incision line several times a day. Pain is minimal and is relieved with acetaminophen or acetaminophen with codeine. The patient should not watch television or read for the next 24 hours. Individuals who are accustomed to a regular physical workout also must avoid physical exercise. Men especially must be counseled regarding what is expected in the postoperative behavior. The surgeon or staff must be available and approachable concerning any questions the patient or the patient's family or caretaker might have.

When Prolene is used to close the wound, the sutures are removed on the fourth postoperative day. The use of the other suture materials requires different schedules for suture removal. Silk sutures used in the eyelid should be removed within 24 hours to avoid suture tunnels or track marks. Nylon also can leave marks if left in beyond 3 days. It is rare to find any suture reaction with Prolene. At the time of suture removal, the lateral wound must be closely observed for any minute wound-edge overlap or wound separation. Either condition warrants a "roughing up" of the wound edges and replacement of the sutures for 24 to 48 hours. The lateral eyelid wound, because it continues in many cases onto the facial skin beyond the limit of the orbital rim, has a tendency to become obvious. This is because of the difference in thickness of the eyelid skin and the facial skin beyond the orbital rim. The lateral wound will not show if great attention is given to it postoperatively. In any case, even if the wound looks perfect at the 4-day suture removal, $\frac{1}{8}$ in. surgical tape strips or surgical glue should be used to support this area for an additional 24 to 48 hours. The patient may apply cosmetics to the upper eyelid incision on the sixth postoperative day. Mild physical activity may begin at 10 days, progressing to full physical activity at 4 weeks. The patient should avoid direct, unprotected sun exposure for 6 weeks (Figs. 17–11 to 17–14).

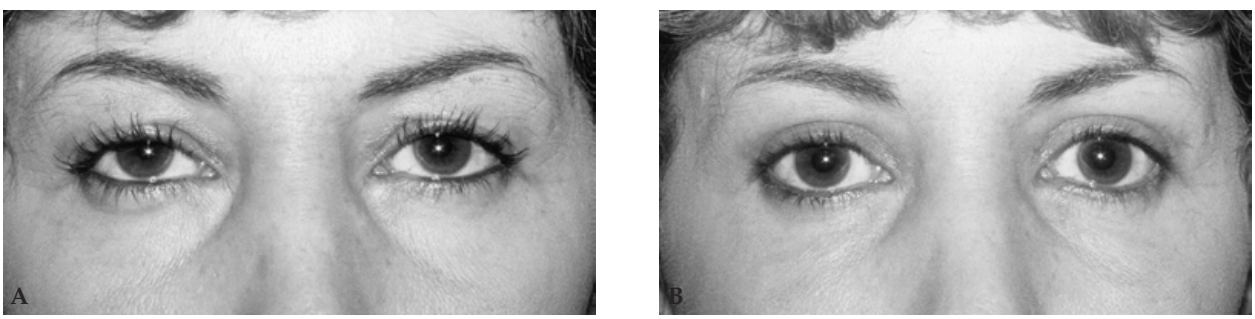

Figure 17–11 **(A)** Preoperative frontal view of a 38-year-old woman with moderate upper lid blepharochalasis. **(B)** Postoperative view at 6 months.

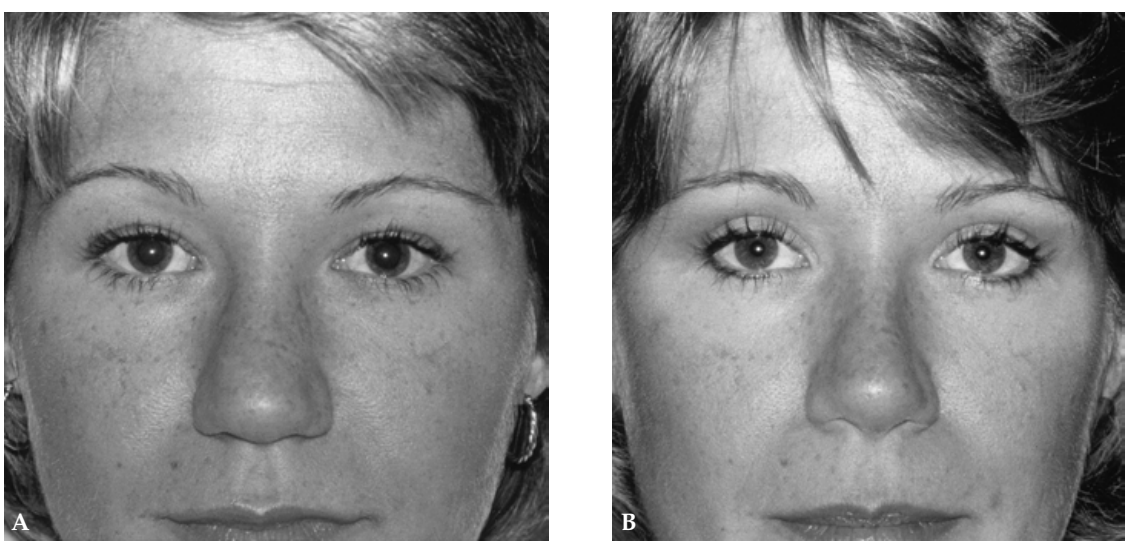

Figure 17–12 **(A)** Preoperative view of a 32-year-old woman with long-term blepharochalasis. The fleshy appearance of the lids has been present since childhood. It is not unusual for these patients to also have a fleshy nasal appearance. Often the combination of rhinoplasty and blepharoplasty is synergistic. **(B)** Postoperative appearance 6 months following upper lid blepharoplasty and rhinoplasty.

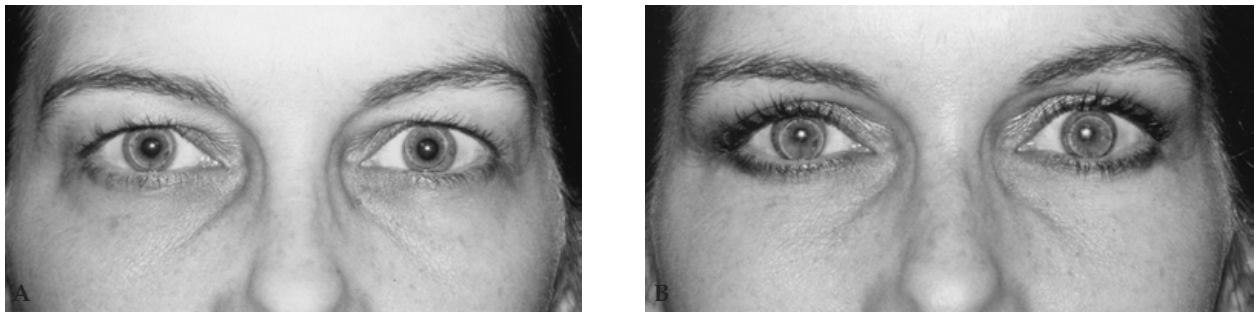

Figure 17–13 **(A)** Preoperative frontal appearance of a 32-year-old woman with upper lid blepharochalasis. There is a slight asymmetry of the brows, which is common. This degree of asymmetry usually does not have to be addressed. Most patients are unaware of the condition. **(B)** Postoperative frontal view of the patient at 6 months following upper lid blepharoplasty.

Figure 17–14 **(A)** Preoperative frontal view of a 33-year-old woman with moderate upper and lower lid blepharochalasis. She has distinct medial fat compartments. **(B)** Postoperative frontal view of the patient 1 year after four-lid blepharoplasty. **(C)** Preoperative oblique view of the patient. **(D)** Postoperative oblique view of the patient at 1 year.

COMPLICATIONS

Erythema along the incision, a sensation of tightness or minor tearing, numbness and edema of the lids, and obviousness of the lateral half of the surgical wound are all natural and transient events following upper lid blepharoplasty.

Hematoma

Hematoma is rare after upper lid blepharoplasty. The occurrence of unilateral swelling and discoloration immediately postoperatively should raise the suspicion of hematoma. The wound must be reopened. The bleeding vessel is cauterized and the wound is resutured.

Subconjunctival Ecchymosis

Subconjunctival ecchymosis is an unusual problem. Its cause is rarely obvious. Although it is usually frightening to the patient, it is only a cosmetic problem. The patient should be assured that within time the whiteness of the eye will return. The red discoloration persists for 3 weeks or more.

Chemosis

Chemosis (edema of the conjunctiva) is unusual in upper lid blepharoplasty. It can persist for 6 weeks after the procedure. Blephamide ophthalmic drops will shorten its course in most cases.

Lagophthalmos

Lagophthalmos is present for a short period postoperatively in many cases. It is most likely the cause of transient tearing and burning reported by some patients. The use of ophthalmic ointment initially and then daily use of synthetic tear drops and ointment quells the symptoms during the healing period. Persistent lagophthalmos can lead to dry-eye syndrome. Surgical interference with the upper lid visor function of corneal protection mechanism is a serious problem that is most likely to occur when upper lid blepharoplasty is performed simultaneously with a forehead lift or during secondary upper lid blepharoplasty. It is difficult to estimate the amount of redundant upper lid at the time of forehead lift. It is never a mistake to postpone upper lid blepharoplasty until a few months following the forehead lift. Most of the acute problems resolve with time, but constant use of artificial tears, night taping of the lids, and ophthalmic consultation are often necessary.

Poor Scars

Obvious scars in the lateral upper lid wound may occur when wound separation at suture removal is not recognized or when sun exposure occurs to pigment the wound. In either case, a later secondary excision and repair procedure may be necessary. Poor medial scars are always due to excessive skin excision or unanticipated removal of large amounts of fat that leads to a wound closure tented over a dead space. These scars are best treated with minute injections of triamcinolone (Kenalog 10 mg/mL).

Loss of Vision

Most reported cases of vision loss follow hematoma formation after lower lid or upper and lower lid blepharoplasty. Hypertension, old age, anticoagulant mediation, and metabolic diseases are also usually present. Vision loss secondary to bleeding in the upper lid blepharoplasty is distinctly rare. In all cases of hematoma, rapid decompression of the progressing retrobulbar hematoma is essential.

SUGGESTED READINGS

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Chapter 18

Lower Eyelid Blepharoplasty

Brett S. Rankin, Richard L. Arden, and Roger L. Crumley

ANATOMIC CONSIDERATIONS

In no other area of facial aesthetic surgery is such a fragile balance struck between form and function as that in eyelid modification. Owing to the delicate nature of eyelid structural composition and the vital role the eyelids serve in protecting the visual system, iatrogenic alterations in eyelid anatomy must be made with care, precision, and thoughtful consideration of existing soft tissue structures. A brief anatomic review is necessary to highlight some of these salient points.

With the eyes in primary position, the lower lid should be well apposed to the globe, with its lid margin roughly tangent to the inferior limbus and the orientation of its respective palpebral fissure slanted slightly obliquely upward from medial to lateral (occidental norm). An inferior palpebral sulcus (lower eyelid crease) is usually identified approximately 5 to 6 mm from the ciliary margin and roughly delineates the inferior edge of the tarsal plate and the transition zone from pretarsal to preseptal orbicularis oculi[1] (Fig. 18–1).

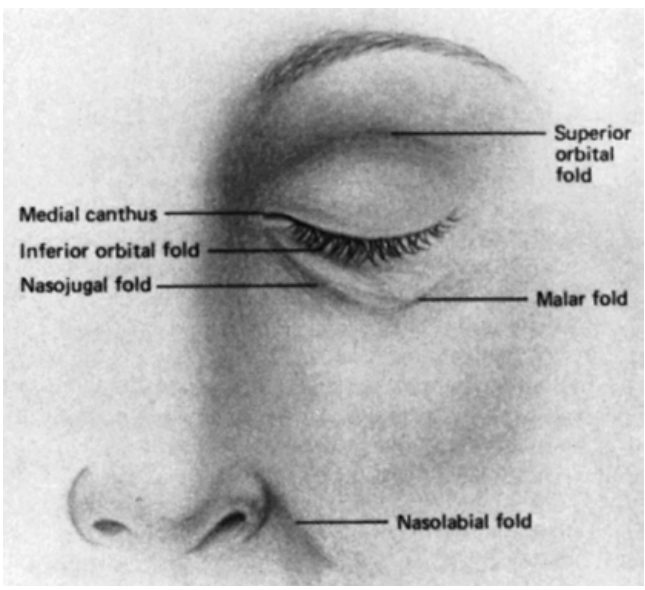

Figure 18–1 Topographic anatomy of the eyelid, demonstrating natural folds. (From Kohn R. *Textbook of ophthalmic plastic and reconstructive surgery.* Philadelphia: Lea & Febiger, 1988. With permission.)

Lamellae

The eyelids have been considered as being composed of two lamellae: (1) an outer lamella, composed of skin and the orbicularis oculi muscle and (2) an inner lamella, which includes tarsus and conjunctiva. The skin of the lower eyelid, which measures less than 1 mm in thickness,[2] retains a smooth delicate texture until it extends beyond the lateral orbital rim, where it gradually becomes thicker and coarser. The eyelid skin, which is essentially devoid of a subcutaneous fat layer, is interconnected to the underlying musculus orbicularis oculi by fine connective tissue attachments in the skin's pretarsal and preseptal zones.

Musculature

The orbicularis oculi muscle can be divided into a darker and thicker orbital portion (voluntary) and a thinner and lighter palpebral portion (voluntary and involuntary). The palpebral portion can be further subdivided into preseptal and pretarsal components (Fig. 18–2). The larger superficial heads of

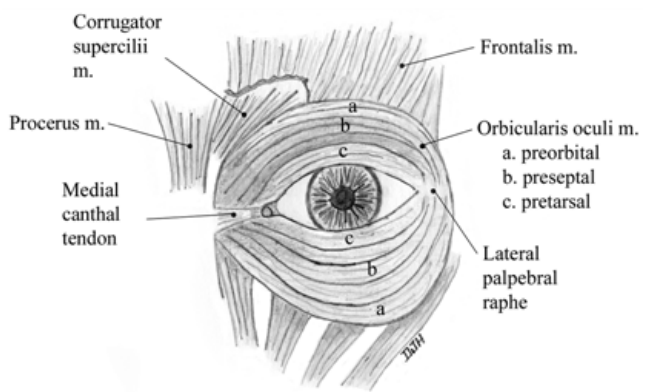

Figure 18–2 Major divisions of the m. orbicularis oculi into pretarsal, preseptal, and orbital components.

the pretarsal orbicularis unite to form the medial canthal tendon, which inserts onto the anterior lacrimal crest, whereas the deep heads unite to insert at the posterior lacrimal crest. Laterally, the fibers condense and become firmly attached at the orbital tubercle of Whitnall, becoming the lateral canthal tendon.[3] Although the preseptal orbicularis has fixed attachments with the medial and lateral canthal tendons, the orbital portion does not and instead inserts subcutaneously in the lateral orbital region (contributing to crow's feet), overlies some of the elevator muscles of the upper lip and ala, and possesses attachments to the infraorbital bony margin.

Immediately beneath the submuscular fascia, extending along the posterior surface of the preseptal orbicularis, lies the orbital septum. Delineating the boundary between anterior eyelid (outer lamella) and intraorbital contents, it originates at the arcus marginalis along the orbital rim (continuous with orbital periosteum), and after fusing with the capsulopalpebral fascia posteriorly about 5 mm below the lower tarsal edge, it forms a single fascial layer that inserts near the tarsal base.

The capsulopalpebral head of the inferior rectus is a dense, fibrous, connective tissue expansion, which by virtue of its ultimate attachments to the tarsal plate allows for lower lid retraction during downward gaze. During its forward extension, it encompasses the musculus obliquus inferior, and after reuniting anteriorly, it contributes to the formation of Lockwood's suspensory ligament (inferior transverse ligament, at which point it is termed the capsulopalpebral fascia, CPF.[4] Although the majority of its fibers terminate near the inferior tarsal border, some extend through orbital fat contributing to compartmentalization, some penetrate the preseptal orbicularis to insert subcutaneously about the lower eyelid crease, and others extend from the inferior fornix superiorly to contribute to Tenon's capsule (Fig. 18–3)

Orbital Fat

Contained behind the orbital septum and within the orbital cavity, the orbital fat has been classically segmented into discrete pockets (lateral, central, and medial), although interconnections truly exist.[5] The lateral fat pad is smaller and more superiorly situated, and the larger nasal pad is divided by the inferior oblique muscle into a larger central fat compartment and an intermediate medial compartment. (During surgery, care must be taken to avoid injury to the inferior oblique.) The medial pad has characteristic differences from its other counterparts, including a lighter color, a more fibrous and compact lobular pattern, and a frequent association with a sizable blood vessel near its medial aspect. The orbital fat can be considered an adynamic structure because its volume is not related to body habitus, and once removed it is not thought to regenerate.

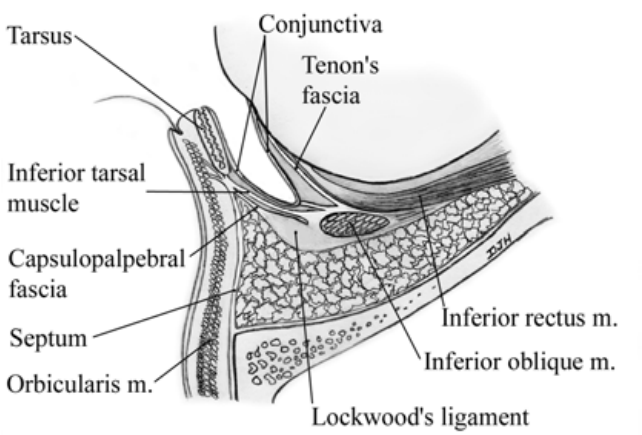

Figure 18–3 Cross-sectional diagram of the lower eyelid demonstrating connective tissue expansion of inferior rectus into its terminal insertions.

Innervation

Sensory innervation to the lower lid derives mainly from the infraorbital nerve (V_2) with minor contributions from the infratrochlear (V_1) and zygomaticofacial nerve (V_2) branches. The blood supply is obtained from the angular, infraorbital, and transverse facial arteries. Situated 2 mm below the ciliary margin, between the orbicularis oculi and the tarsus, is the marginal arcade, which should be avoided if a subciliary incision is used.

TERMINOLOGY

A number of descriptive terms are used pervasively in the literature of eyelid analysis and should be understood by those involved in surgical management of this area.

Blepharochalasis is a commonly misused term. It is an uncommon disorder of the upper eyelids, of unknown cause, which affects mainly young and middle-aged females. Blepharochalasis is characterized by recurrent attacks of painless unilateral or bilateral lid edema, causing a loss of skin elasticity and atrophic changes.

Dermatochalasis is an acquired condition of increased, abnormal laxity of the eyelid skin interrelated with genetic predisposition, natural aging phenomenon, and environmental influences. It is frequently associated with prolapsed orbital fat.

Steatoblepharon is a condition of true herniation or pseudoherniation of orbital fat behind a weakened orbital septum, causing areas of discrete or diffuse fullness in the eyelids. This condition and dermatochalasis are the two most common reasons why a patient presents to discuss eyelid surgery.

Festoons are single or multiple folds of orbicularis oculi in the lower lid that drape over onto themselves, creating an external, hammock-like bag. Depending on location, this bag may be preseptal, orbital, or jugal (cheek). It may contain fat.

Malar bags are areas of soft-tissue fullness on the lateral edge of the infraorbital ridge and zygomatic prominence just superior to the palpebromalar sulcus. They are believed to be a result of recurrent dependent tissue edema and secondary fibrosis.

PREOPERATIVE EVALUATION

A systematic and thorough preoperative assessment of blepharoplasty candidates is essential to minimize potential postoperative complications. Thus, patient analysis is directed to determining how much eyelid skin, orbicularis

oculi, and orbital fat needs to be resected to optimize functional and aesthetic results, and whether the ocular and adnexal structures will tolerate such a surgical manipulation without undesirable sequelae.

Risk Factors for Postoperative Dry-Eye Syndrome

Realizing that the protective physiologic functions of blinking and eyelid closure are temporarily impaired following blepharoplasty, an appropriate ocular history should elicit information that might put the patient at greater risk for postoperative dry-eye syndrome. Excessive tearing, a burning or gritty sensation, ocular discomfort, foreign bodies, mucus production, eyelid crusting, and a frequent need to blink are all symptoms suggestive of borderline or inadequate tear production. A possible atopic cause has to be ruled out.

Certain systemic diseases, particularly the collagen vascular diseases (i.e., systemic lupus erythematosus, scleroderma, periarteritis nodosa), Sjögren's syndrome, Wegener's granulomatosis, ocular pemphigoid, and Stevens–Johnson syndrome, can interfere with the glandular lubricating function and should be identified.[6,7] The infiltrative ophthalmopathy of Graves' disease can result in vertical eyelid retraction and inadequate corneal protection after surgery and should be managed with medical treatment preoperatively and surgical conservatism during surgery. Thyroid hypofunction associated with a myxedematous state may mimic the baggy eyelids of dermatochalasis and should be ruled out. Incomplete recovery of a previous facial nerve insult may interfere with eyelid closure and predispose a patient to dry-eye syndrome.

Risk Factors for Postoperative Blindness

Postoperative blindness, the most catastrophic complication of blepharoplasty, is associated with retrobulbar hemorrhage.[8,9] Factors that influence bleeding tendencies should therefore be identified and controlled before surgery.[10] Ingestion of aspirin, nonsteroidal anti-inflammatory drugs (NSAIDS), antiarthritics, cortisone preparations, and vitamin E should be withheld for at least 14 days before surgery because of qualitative effects on platelet function. Over-the counter medications should be discontinued as well because gingko biloba, for example, has been implicated in excessive bleeding. Similarly, St. John's wort is known to have hypertensive effects through a monoamine oxidase inhibitor mechanism. Warfarin compounds, if medically feasible, should be withheld to normalize the prothrombin time and may be reinstituted 48 to 72 hours after surgery.

Any history of abnormal or easy bruising, prolonged clotting time, or family members with bleeding dyscrasia should be noted with appropriate coagulation profiles. Hypertensive patients should be medically stabilized at least 2 weeks before surgery to ensure a nonfluctuating normotensive state. Women have a greater bleeding tendency during their menstrual period than at other cycle times, and this should be considered in planning surgery. Other important factors include drinking and smoking history, as the former (in large amounts) may influence platelet function, and the latter has been associated with delayed wound healing and diminished flap viability. Finally, any patient with a documented or suspected history of glaucoma must be evaluated and managed by an ophthalmologist to normalize intraocular pressures and guard against a potential acute closed-angle attack prior to any eyelid surgery. Some facial plastic surgeons recommend a routine ophthalmologic exam for all of their patients preoperatively.

Ocular Assessment

Examination of the eyes should begin with an overall inspection. The eyelid should be assessed for symmetry (by noting palpebral fissure height and length), position of the lower eyelid margin with respect to the inferior limbus, scleral show, and the presence of ectropion/entropion or exophthalmos/enophthalmos. Scars or skin lesions should be noted because it may be possible to include these in the resection. Areas of skin discoloration or abnormal pigmentation should also be noted.

Other baseline features of the periorbital area should be pointed out to the patient, particularly in lieu of the inability of blepharoplasty to correct them.[11] The fine wrinkling and "crepe paper" appearance of the eyelid skin is not amenable to correction by blepharoplasty alone. Areas of abnormal pigmentation or discoloration (e.g., from venous stasis) will not be changed if outside the area of surgery and in fact may be more noticeable after surgery (because of light-refractile changes associated with conversion of a convex surface to a concave or flattened one). One of the greatest sources of dissatisfaction after lower blepharoplasty is the persistence of malar bags. The patient should realize that the upward tension necessary to attenuate such a soft-tissue prominence would not be tolerated by the supporting structures of the lower lid and could lead to ectropion. Finally, lateral smile lines (crow's feet), despite the amount of lateral extension and undermining, are also not amenable to correction by standard blepharoplasty technique. All of these factors need to be discussed with the patient.

As a minimum, baseline ocular assessment should document visual acuity (i.e., best corrected vision if glasses or contact lenses are worn), extraocular movements, gross visual fields by confrontation, corneal reflexes, the presence of Bell's phenomenon and lagophthalmos. If there is any question of dry-eye syndrome, the patient should be evaluated with Schirmer testing (to quantitate tear output) and tear film break-up times (to assess stability of precorneal tear film).[12] Patients who demonstrate abnormalities in either or both of these tests or who have past or anatomic evidence that would predispose them to dry-eye complications should be thoroughly evaluated by an ophthalmologist preoperatively. Also, a conservative skin–muscle excision (if not staged resection of upper and lower lids) would seem prudent.

Assessment of Fat Pockets

Evaluation of the adnexal structures should include assessment of the fat pockets. Palpation of the infraorbital rim is an essential component of this examination. A surgeon must recognize that a prominent rim limits the amount of orbital fat that can be removed without creating disparities in confluence between the lower eyelid and the anterior cheek. What appears to be an appropriate fat resection may contribute to a sunken-eye appearance if the patient has a very prominent rim. Assessment of the fat pockets may be facilitated by directing the patient's gaze in certain directions; a superior gaze accentuates the medial and central pockets, whereas looking upward and to the contralateral side accentuates the lateral pocket. Further confirmation of fatty prominence may be obtained by gentle

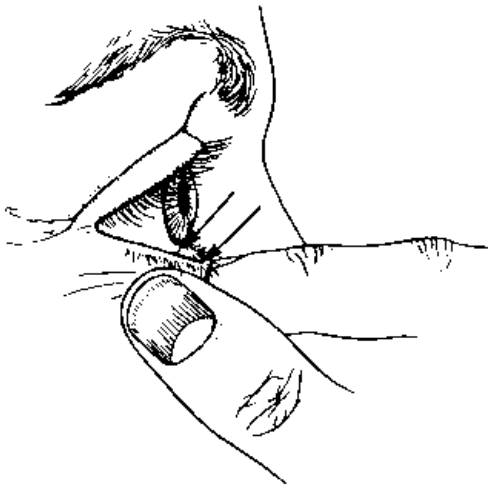

Figure 18–4 Lid distraction test used to assess laxity of tarsoligamentous sling. (From Tenzel RR. Complications of blepharoplasty: orbital hematoma, ectropion, and scleral show. *Clin Plast Surg* 1981;8:799.)

retropulsion of the globe with the eyelid closed and observation of the outward movements of the respective fat pads.

Assessment of Lid-Supporting Structures

Because the most common cause of lower lid ectropion after blepharoplasty is failure to recognize a lax lower lid before surgery, it is essential to properly assess the lid-supporting structures. Two simple clinical tests aid in this evaluation. A lid distraction test (snap test)[13] is performed by gently grasping the midportion of the lower eyelid between the thumb and index fingers and outwardly displacing the eyelid from the globe (Fig. 18–4). Movement of the lid margin greater than 10 mm indicates an abnormally lax supporting lid structure and suggests the need for a lid-shortening procedure. The lid retraction test[11] is used to assess lid tone as well as medial and lateral canthal tendon stability (Fig. 18–5). By using the index finger to inferiorly displace the lower lid toward the orbital rim, observations are made in terms of punctal or lateral canthal malposition (movement of puncta greater than 3 mm from the medial canthus indicates an abnormally lax canthal tendon and suggests the need for tendoplication). Releasing the eyelid, the pattern and rate of return of the lid to resting position should be observed. A slow return, or one that requires multiple blinks, indicates poor lid tone and eyelid support. Again, a conservative skin–muscle resection and lower lid–shortening procedure would be warranted.

OPERATIVE PROCEDURE

Three basic surgical approaches have been described in lower lid blepharoplasty: (1) transconjunctival, (2) skin–muscle flap, and (3) skin flap.

Transconjunctival Approach

The transconjunctival approach to lower eyelid blepharoplasty was first described in 1924 by Bourquet.[14] Although it is not a new procedure, over the last 10 years there has been a surge of interest and a growth of proponents for this approach. The transconjunctival lower lid blepharoplasty

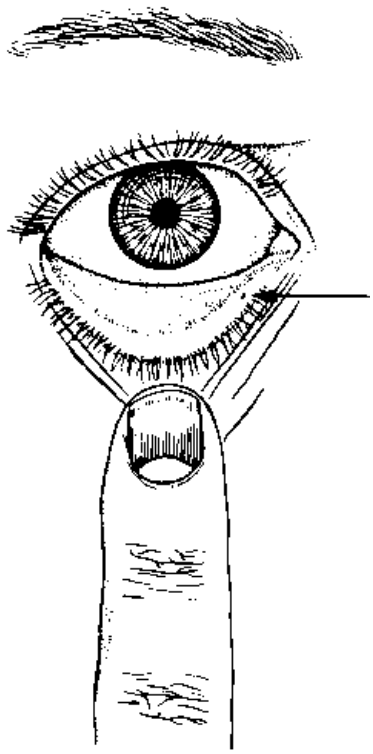

Figure 18–5 Lid retraction test used to assess lower eyelid tone and stability of medial and lateral canthal tendon attachments. (From Tenzel RR. Complications of blepharoplasty: orbital hematoma, ectropion, and scleral show. *Clin Plast Surg* 1981;8:800.)

respects the integrity of the orbicularis oculi, an active support structure of the lower eyelid. This minimizes the incidence of ectropion. Also, an external scar can be avoided.

Proper patient selection for the transconjunctival approach is required. Ideal candidates include older patients with pseudoherniation of orbital fat and a limited amount of skin excess, young patients with familial hereditary pseudoherniation of orbital fat and no excess skin, all revision blepharoplasty patients, patients who do not want an external scar, patients with a history of keloids, and dark-skinned individuals who have a small possibility of hypopigmentation of the external scar.[15,16] Because several authors have reported a significant reduction in short- and long-term complications with the transconjunctival approach to lower eyelid blepharoplasty compared with the skin–muscle method, the indications for the technique have been gradually expanding.[15,17] The presence of excess lower lid skin does not preclude use of the transconjunctival approach. In the senior author's practice, the most commonly performed lower lid procedure consists of transconjunctival fat excision, pinch excision of skin, and 35% trichloroacetic acid (TCA) peeling (described later).[15,18–20] The skin excision is needed to recontour the lower eyelid once the fat has been removed. There frequently is less excess than one initially estimates before the fat excision is performed.[17,21]

Preparation

While sitting upright, the patient is asked to look upward. This helps to refresh the surgeon's memory as to which fat pads are the most prominent, and these are marked. The patient is then placed supine. Two drops of ophthalmic tetracaine

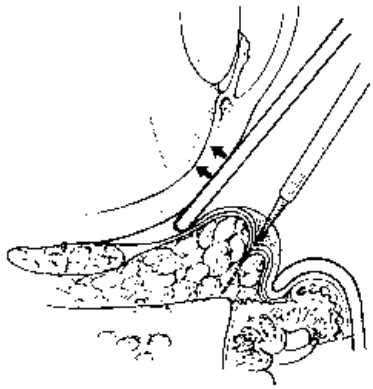

Figure 18–6 Transconjunctival approach to lower eyelid fat pockets. Simultaneous eversion of the lower eyelid and ballottement of the globe produces a bulge of orbital fat that helps to guide the dissection. (From Baylis HI, Long JA, Groth MJ. Transconjunctival lower eyelid blepharoplasty: technique and complications. *Ophthalmology* 1989;96:1027.)

hydrochloride 0.5% are then instilled into each inferior fornix. Prior to the local injections, our patients typically receive some intravenous sedation composed of midazolam (Versed) and meperidine hydrochloride (Demerol). Ten milligrams of intravenous dexamethasone (Decadron) is also given to help minimize postoperative edema. A local anesthetic mixture, consisting of equal parts of 0.25% bupivacaine (Marcaine) and 1% lidocaine (Xylocaine) with 1:100,000 epinephrine to which is added a 1:10 dilution of sodium bicarbonate, is then injected into the lower lid conjunctiva using a 30-gauge needle. Experience has demonstrated that this mixture affords prolonged analgesic effect while minimizing the sting of initial infiltration through alkalinization of the local agent. The needle is advanced through the conjunctiva until the bony orbital rim is palpated. The local is slowly injected as the needle is withdrawn. This is performed medially, centrally, and laterally. Several surgeons also like to inject V_2 transcutaneously, although we have found that this is usually not necessary and may lead to unnecessary bruising.

Incision

After waiting a full 10 minutes for vasoconstriction to occur, the lower lid is gently retracted by an assistant using two small, double-pronged skin hooks (Figs. 18–6 and 18–7). The upper lid is placed over the globe to protect it. Either a guarded needle-tip bovie on a low setting or a 15-blade is used (others prefer a laser) to make the transconjunctival incision 2 mm below the inferior edge of the inferior tarsal plate. This inferior tarsal edge appears gray through the conjunctiva. The medial aspect of the incision is in line with the inferior punctum. The incision is carried just 4 to 5 mm shy of the lateral canthus.

Immediately after the transconjunctival incision is made, a single 5-0 nylon suture is placed in the conjunctiva closest to the fornix and used to retract the posterior lamella over the entire cornea (Fig. 18–8). Mosquitos snapped onto the patient's head wrap are used to hold the sutures under tension. The conjunctiva acts as a natural corneal protector and the superior retraction allows for easier plane dissection. The two skin hooks are then carefully removed and a Desmarres retractor is now used to evert the free edge of the lower lid (Fig. 18–9).

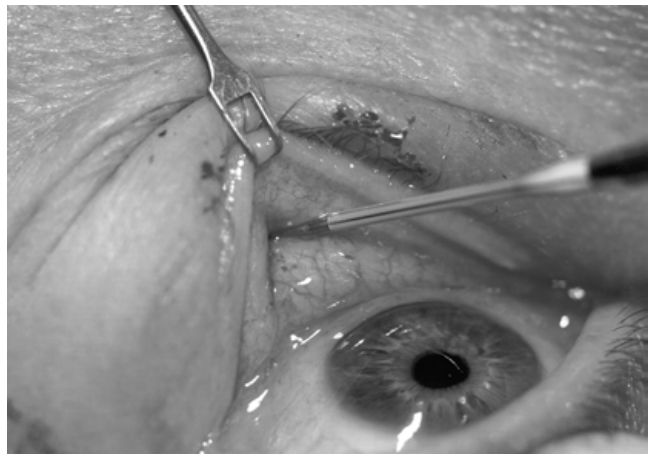

Figure 18–7 The needle-tip bovie is poised to initiate the incision. (A corneal protector, or upper lid skin is used for protection when the actual incision is made.)

The distance of the transconjunctival incision from the inferior edge of the inferior tarsal plate determines whether one will approach the orbital fat preseptally or postseptally.[16] We usually utilize the preseptal approach; therefore, our incisions are always approximately 2 mm below the tarsus. The preseptal plane is an avascular plane between the orbicularis oculi and the orbital septum.[22] Because the orbital septum is still intact while the preseptal plane is being developed, orbital fat does not bulge into one's view. The visualization obtained is closely similar to the orientation one is used to having when performing a skin–muscle flap blepharoplasty. The orbital septum will still have to be opened to access the orbital fat below (Fig. 18–10).

Others prefer the postseptal approach to the orbital fat.[19] To directly access the fat pads the conjunctiva is incised

Figure 18–8 Retraction suture in place; cotton-tipped applicator spreads incision site.

Figure 18–9 Desmarres retractor exposes orbital septum.

approximately 4 mm below the inferior border of the inferior tarsal plate and directly toward the anterior edge of the inferior orbital rim. The big advantage of this method is that the orbital septum is kept completely intact. Proponents for this technique state that the intact orbital septum adds to the support of the lower eyelid. One disadvantage is that the orbital fat immediately bulges into one's view. Care must be taken not to incise close to the conjunctival cul-de-sac to avoid the risk of synechiae.[16] Also, the view from the direct approach is one to which most facial plastic surgeons are less accustomed.

After the 5-0 suture retraction and Desmarres retractor are in place, the preseptal plane is developed with a combination of blunt dissection with a cotton swab and sharp dissection with scissors. It is mandatory to maintain a dry surgical field. Therefore, a bipolar cautery, "hot loop," or monopolar cautery is used to cauterize any bleeders.

The medial, central, and lateral fat pads are each individually identified through the septum with the help of some gentle digital pressure on the conjunctiva covering the globe. The orbital septum is then opened with scissors. Using forceps and a cotton-tipped applicator, the excess fat is carefully teased above the orbital rim and septum. Care must be taken to remove only the excessive and herniated fat because the eyes may take on a hollowed-out appearance following excessive fat excision. The ultimate goal is to achieve a lower eyelid contour that forms a smooth, gentle concave transition between it and cheek skin.

A 30-gauge needle is then used to inject a small amount of local anesthetic into the excess fat (Fig. 18–11). The bipolar cautery is used to cauterize across the fat stalk. When one is sure the entire stalk has been cauterized, scissors are used to cut across the cauterized area. Others, notably Cook, reduce fat volume with electrocautery, minimizing surgical excision. Many surgeons feel that the lateral fat pocket should be explored initially because its volume contribution becomes more difficult to assess after removal of its adjacent and interconnected central fat pad.[11,23] After excess fat has been removed from each compartment, the field is examined to make sure there is no bleeding. Although CO_2 laser fat excision has been advocated based on the advantages of hemostatic efficiency, precision, and reduced tissue trauma, the increased costs, requirements for highly trained personnel, and additional laser precautions have led us and others to abandon laser incisions for lower lid surgery.[24,25]

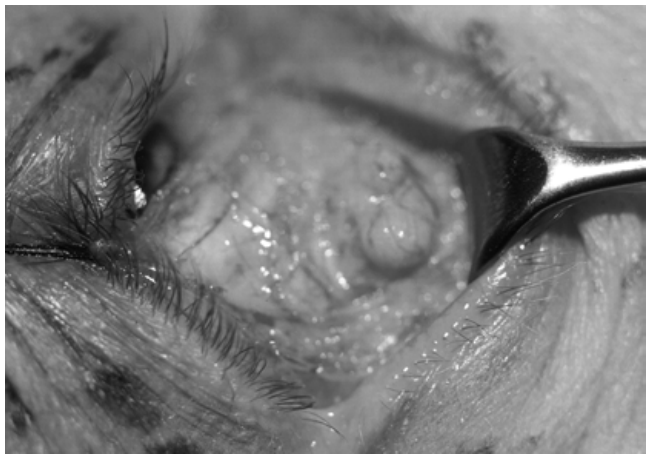

Figure 18–10 Fat appearing through orbital septum.

The Desmarres retractor should be removed periodically and the lower eyelid redraped over the fat that remains in place to facilitate examination of the contour of the eyelid. The fat that is removed is retained on a gauze on the surgical field in order from lateral to medial, allowing for comparison with the fat removed from the opposite side. For example, if preoperatively the surgeon felt that the right lateral fat pad was much larger than all others, then intraoperatively that compartment would have the most fat removed.

The medial and central fat compartments are separated by the inferior oblique muscle. This muscle must be clearly identified prior to the excision of excess fat from these compartments to prevent muscle injury. The medial fat pad is whiter than the central and lateral fat pads. This helps in its identification. The lateral compartment is usually isolated

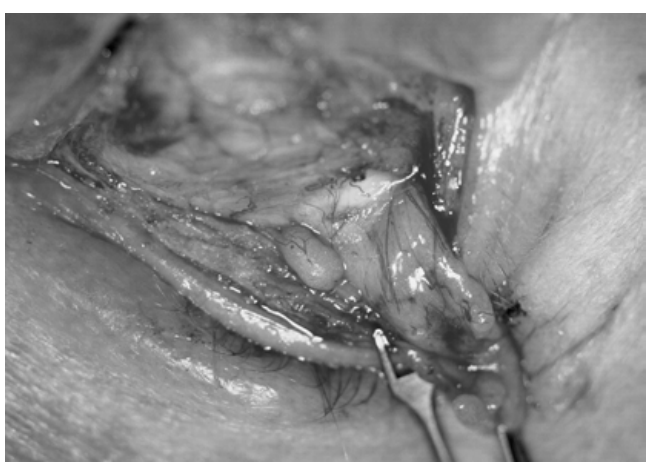

Figure 18–11 Fat of medial compartment, partially excised.

Figure 18–12 Fixation forceps used to create ridge or mound for pinch excision.

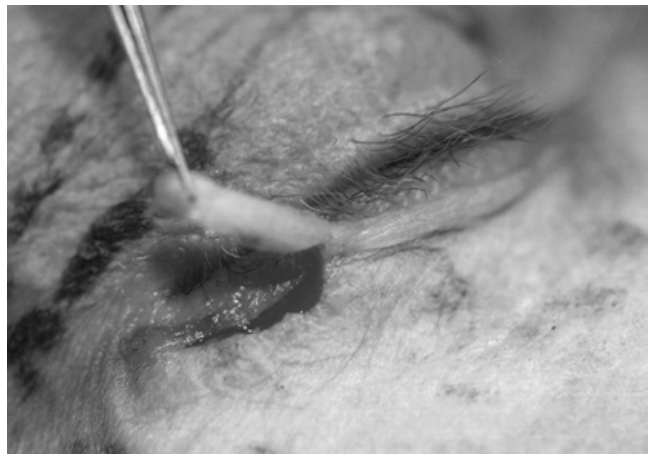

Figure 18–13 Pinch excision progression.

from the central one by a fascial band off the inferior oblique muscle. This fascial band can be cut safely.

After each successive fat compartment is treated, the entire field must again be examined for bleeding. After all of the bleeding has been cauterized with the bipolar, the Desmarres and the retraction sutures are removed. The lower lid is gently elevated upward and outward and then allowed to snap back into its proper position. This allows for proper realignment of the edges of the transconjunctival incision. No suture is required, although some surgeons feel more comfortable closing the incision with one buried 6-0 fast-absorbing gut stitch. Both eyes should then be irrigated with sodium chloride (Ophthalmic Balanced Salt Solution).

In an older patient with skin excess, a lower lid skin pinch or chemical peel may now be performed. Using fixation forceps or Brown–Adson forceps, a 2- to 3-mm raised fold of redundant skin is raised just below the ciliary margin (Fig. 18–12). The skin fold is excised with sharp scissors, with care taken not to cut the lower eyelashes (Fig. 18–13). The edges of the skin pinch are then brought together with interrupted 6-0 fast absorbing gut stitches. Several authors have closed this incision with cyanoacrylate (Histoacryl) or fibrin glue.[15,26]

Patients with crepey or fine lower eyelid rhytids are then treated with a 25 to 35% trichloroacetic acid (TCA) peel. The TCA is applied immediately below the skin pinch incision. A typical "frost" is generated (Fig. 18–14). Phenol is not used for lower lids in our hands because the erythema and inflammation phase is much longer than the TCA peel.

Postoperative Care

Immediately after surgery, the patient is kept quiet with head elevated at least 45 degrees. Cold compresses are placed on both eyes and changed every 20 minutes. The patient is observed closely for at least an hour for any signs of bleeding complications. The patient is given strict instructions to limit physical activity for the next week. The patient who is diligent about the cold compresses and head elevation during the first 48 hours will experience substantially less swelling. Some physicians place their patients on sulfacetamide ophthalmic drops during the first 5 postoperative days to help prevent an infection while the transconjunctival incision is healing.

Skin–Muscle Flap Approach

The skin–muscle flap approach was perhaps the most commonly used method in the 1970s and early 1980s. In patients with a large amount of excess skin and orbicularis oculi as well as fat pseudoherniation, this is an excellent procedure. The advantages of this approach are related to the safety and facility of dissecting in the relatively avascular submuscular plane and the ability to remove redundant lower eyelid skin. One must realize that even with the skin–muscle flap one is limited by how much skin can safely be removed without risking scleral show and even an ectropion. Persistent rhytids often remain despite attempts to safely resect redundant eyelid skin.

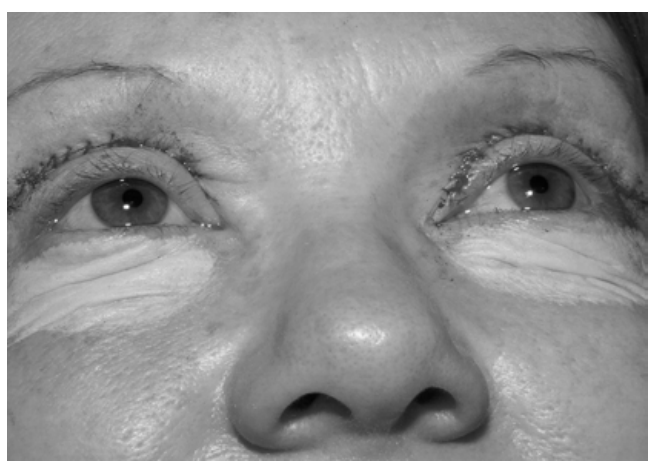

Figure 18–14 Thirty percent trichloroacetic acid (TCA) lower lid peel frost. (Different patient in whom no pinch excision was done.) When the pinch technique is used, the TCA must not be applied any closer than 1 mm below the suture line.

Preparation

Preparation for this method is similar to that for the transconjunctival approach, except that tetracaine drops are not necessary. A subciliary incision is planned 2 to 3 mm beneath the eyelid margin and is marked with a marking pen or methylene blue with the patient in the sitting position. Any prominent fat pads are also marked. The importance of marking the patient in the upright position before injection relates to the changes in soft-tissue relationships that occur as a result of dependency and infiltration. The medial extent of the incision is marked 1 mm lateral to the inferior punctum to avoid potential damage to the inferior canaliculus, whereas the subciliary extension is carried to a point approximately 8 to 10 mm lateral to the lateral canthus (to minimize potential for rounding of the canthal angle and lateral scleral show). At this point, the lateral-most portion of the incision achieves a more horizontal orientation and is planned to lie within a crow's-foot crease line. Care should be exercised in planning the lateral extension of this incision to allow at least 5 mm, and preferably 10 mm, between it and the lateral extension of the upper blepharoplasty incision to obviate prolonged lymphedema.

Our patients typically receive intravenous sedation composed of midazolam and meperidine hydrochloride after the preoperative marking has been accomplished and intravenous dexamethasone is in. Before surgical prepping and sterile draping, the incision line (beginning laterally) and entire lower lid down to the infraorbital rim are infiltrated (superficial to orbital septum) with our anesthetic mixture previously described.

Incision

The incision, which is begun medially with a no. 15 scalpel blade, is only through skin to the level of the lateral canthus, but through skin and musculus orbicularis oculi lateral to this point. Using a blunt-tipped, straight-dissection scissors, the incision is undermined in a submuscular plane from lateral to medial and is then cut sharply by orientation of the blades in a caudal direction (optimizing the integrity of the pretarsal muscle sling). A Frost type of retention suture, using 5-0 nylon, is then placed through the tissue edge above the incision to aid in counterretraction. Using blunt dissection (with scissors and cotton-tipped, applicators), a skin–muscle flap is developed down to, but not below, the infraorbital rim to avoid disruption of important lymphatic channels.[27] Any bleeding points up to this point should be meticulously controlled with the hand-held cautery or bipolar cautery,[28] with conservatism exercised in the superior margin of the incision to avert potential thermal trauma to the eyelash follicles.

Fat Removal

If preoperative assessment suggests the need for fat-pad management, selective openings are made through the orbital septum over the areas of pseudoherniation and are guided by gentle digital pressure of the closed eyelid against the globe. Although alternatives aimed at electrocauterizing a weakened orbital septum exist[29] that may obviate violation of this important barrier, we are comfortable with the long-term results and predictability of our technique of direct fat-pocket management.

After opening the septum (usually 5 to 6 mm above the orbital rim), the fat lobules are gently teased above the orbital rim and septum using forceps and a cotton-tipped applicator. The fat resection technique is very much as described in the transconjunctival technique and is not repeated.

Access to the medial compartment may be limited in part by the medial aspect of the subciliary incision. This incision should not be extended; instead, the fat should be gently teased into the incision, taking care to avoid the inferior oblique muscle. The medial fat pad is distinguished from the central pad by its lighter color.

Closure

In preparation for skin excision and closure the patient is asked to open the jaw widely and gaze in a superior direction. This maneuver creates a maximal voluntary separation of the wound edges and assists the surgeon in performing accurate resection of the skin–muscle flap. With the patient maintaining this position, the inferior flap is redraped over the subciliary incision in a superotemporal direction. At the level of the lateral canthus, the extent of skin muscle overlap is marked and incised vertically. A tacking stitch of 5-0 fast-absorbing gut is then placed to maintain the position of the flap. Using straight scissors, the areas of overlap are conservatively resected (medial and lateral to the retention suture) so that edge-to-edge apposition can be maintained without the need for reinforcement. It is important to bevel the blades caudally to allow for a 1- to 2-mm strip resection of orbicularis oculi on the lower flap edge to avoid a prominent ridge at the time of closure. Some surgeons refrigerate the resected skin (viable for at least 48 hours) in sterile saline in case replacement tissue graft is needed after an overzealous resection eventuating in ectropion. It is far better to prevent such complications by performing a conservative resection.

After fat removal from the second eyelid, simple interrupted 6-0 fast-absorbing gut sutures are placed to close the incision on the initial eyelid. Attention can then be redirected back to redraping, trimming, and suturing the second eyelid. Finally, $\frac{1}{4}$ in. sterile strips are placed to aid in temporal support, and a light application of antibiotic ointment is applied to the sutured incision after irrigating the eyes with sodium chloride (Balanced Salt Solution).

Postoperative Care

Postoperative care after the skin–muscle approach is essentially identical to the aftercare used in the transconjunctival approach. Bacitracin ophthalmic ointment is given to the patient for the subciliary incision. Iced saline compresses, head elevation, and limited activity are stressed to all patients.

Skin Flap Approach

The skin flap approach is perhaps the oldest and the least frequently used. This method allows independent resection and redraping of lower eyelid skin and underlying orbicularis oculi and is effective in repositioning and redraping excessively wrinkled, redundant, or deeply creased skin.[30] In cases involving hypertrophy or festooning of the orbicularis oculi, direct access is provided for management, which allows for a greater

and safer resection than would otherwise be tolerated if the flap were raised as a conjoined musculocutaneous unit. Disadvantages of this approach include a more tedious dissection that is associated with greater skin trauma (manifested by increased bleeding and eyelid induration), an increased risk of vertical eyelid retraction, and a higher demand placed on preoperative assessment of the fat pockets because of obscured subseptal observation by the overlying orbicularis oculi.[31,32]

The initial incision through skin is made only through the lateral extension of the subciliary marking to facilitate undermining. With an assistant maintaining downward traction on the lower eyelid skin (by placing a hand near the orbital rim), the lateral skin edge is grasped and pulled superiorly while sharp-scissors dissection carefully undermines the skin flap to a point just below the orbital rim. With the undermining accomplished, the subciliary incision is completed with the scissors. All bleeding points are precisely cauterized.

If the problem is skin redundancy or excessive wrinkling only, the skin flap is simply redraped in the manner described for skin–muscle flap. If access to the orbital fat compartments is required, these are approached by incising the orbicularis oculi approximately 3 to 4 mm inferior to the initial skin incision or via the transconjunctival approach. However, when orbicularis hypertrophy or festooning is present, optimal management is achieved by development of independent skin and muscle flaps. In this case, the muscle is incised (beveling caudally) across the extent of the incision, beginning approximately 2 mm below the skin incision to preserve the pretarsal muscle sling. Undermining of the muscle flap is carried to just below the most dependent muscle roll (with festooning) or to a point that will allow effacement of a prominent muscle bulge (with hypertrophy) after muscle resection. After fat-pad management, the muscle flap is reinforced by suturing of its lateral end to orbital periosteum with 5-0 Vicryl and reapproximation of its pretarsal muscle edges with a few interrupted 5-0 chromic sutures. Again, skin closure follows the pattern previously described.

COMPLICATIONS

Complications after blepharoplasty are usually the result of overzealous skin or fat resection, lack of hemostasis, or an inadequate preoperative assessment.[33,34] Less commonly, an individual's physiologic response to wound repair may lead to undesirable sequelae despite execution of the proper technique. The goal in minimizing complications consequent to blepharoplasty must therefore focus on prevention by identifying and managing known risk factors.

Ectropion

One of the most common complications after lower lid blepharoplasty is eyelid malposition, which may range in presentation from a mild scleral show or rounding of the lateral canthal angle, to a frank ectropion with actual eyelid eversion. In most cases resulting in permanent ectropion, a failure to address excessive lower lid laxity is the etiologic culprit. Other causes include excessive skin or skin–muscle excisions; inferior contracture along the plane of the lower lid retractors and orbital septum (greater in skin flap technique); inflammation of the fat pockets; and, rarely, destabilization of the lower lid retractors (a potential yet uncommon complication of the transconjunctival approach). Temporary ectropion has been associated with lid loading from reactionary edema or hematoma and muscle hypotonicity.

A conservative approach to management may include the following: (1) a short course of perioperative steroids with cold compresses and head elevation to manage edema; (2) warm and cool compresses alternated to hasten resolution of minor established hematomas and improve circulatory status; (3) repeated squinting exercises to improve muscle tonus; (4) gentle massage in an upward direction, and (5) supportive taping of the lower lid (upward and outward) to assist in corneal protection and tear collection.

When skin excisions are recognized to be excessive within the first 48 hours, the banked eyelid skin should be used as a replacement graft. If recognition is delayed, conservative measures to protect the eye should be used to allow the scar to mature and a full-thickness graft (preferably upper eyelid skin or, alternatively, postauricular skin, or foreskin in males) used to replace the deficit. In many cases, a lid-shortening procedure is combined with the tissue grafting and is the mainstay of treatment when an atonic lid is present. Management of persistent indurations, resulting from hematoma formation or inflammatory responses of the fat pockets, generally involves direct depot injections of corticosteroid.

Hematomas

Collections of blood beneath the skin surface can usually be minimized before surgery by optimizing coagulation profiles and normotensive status during surgery through delicate tissue handling and meticulous hemostasis and after surgery through head elevation, cold compressing, a controlled level of activity, and appropriate analgesic support. Should a hematoma develop, its extent and time of presentation will guide management.

Small, superficial hematomas are relatively common and are typically self-limiting. If organization occurs with the development of an indurated mass and resolution is slow or nonprogressive, conservative steroid injections may be used to hasten the healing process. Moderate or large hematomas recognized after several days are best managed by allowing the clot to liquify (7 to 10 days) and then evacuating the hematoma through large-bore needle aspiration or by creating a small stab wound over it with a no. 11 blade. Hematomas that are large and present early, that are expanding, or that represent symptomatic retrobulbar extension (decrease in visual acuity, proptosis, ocular pain, ophthalmoplegia, progressive chemosis) demand immediate exploration and hemostatic control. In the case of the latter, urgent ophthalmologic consultation and orbital decompression are the mainstays of treatment.

Blindness

Blindness, though rare, is the most feared potential complication of blepharoplasty. It occurs with an incidence of approximately 0.04%,[35] typically presents itself within the first 24 hours

after surgery, and is associated with orbital fat removal and the development of a retrobulbar hematoma (medial fat pocket most commonly involved). Commonly implicated causes of retrobulbar hemorrhage include the following: (1) excessive traction on orbital fat resulting in disruption of small arterioles or venules in the posterior orbit; (2) retraction of an open vessel beneath the septum after fat release; (3) failure to recognize an open vessel because of vasospasm or epinephrine effect; (4) direct vessel trauma resulting from injections done blindly beneath the orbital septum; and (5) rebleeding after closure resulting from any maneuver or event that leads to an increased ophthalmic arteriovenous pressure head.

Early recognition of a developing orbital hematoma can be facilitated by delaying intraoperative closure (first side), avoiding occlusive-pressure eye dressings, and extending the postoperative observational period. Although many methods of management have been described to manage threatened vision resulting from elevated intraocular pressures (reopening the wound, lateral canthotomy, steroids, diuretics, anterior chamber paracentesis), the most effective definitive treatment is immediate orbital decompression, which is usually accomplished through medial wall and orbital floor resections.[8,36] Certainly, ophthalmologic consultation is advisable.

Epiphora

Assuming dry-eye syndrome was ruled out before surgery or managed appropriately intraoperatively (conservative and staged resections), a dysfunctional lacrimal collecting system rather than a high glandular output state is typically responsible for postoperative epiphora (although reflex hypersection may be a contributing factor because of coexistent lagophthalmos or vertical retraction of the lower lid). This response is common in the early postoperative period and is usually self-limited. Causes include the following: (1) punctal eversion and canalicular distortion secondary to wound retraction and edema; (2) impairment of the lacrimal pump resulting from atony, edema, hematoma, or partial resection of the orbicularis oculi sling; and (3) a temporary ectropion resulting from lid loading. Outflow obstructions, secondary to a lacerated inferior canaliculus, are preventable by keeping the lower lid incision lateral to the punctum. Should laceration injury occur, primary repair over a silastic stent (Crawford tube) is recommended. Persistent punctal eversion can be managed by cauterization or diamond excision of the conjunctival surface below the canaliculus.

Suture Line Complications

Milia or inclusion cysts are common lesions seen along the incisional line resulting from trapped epithelial debris beneath a healed skin surface or possibly from the occlusion of a glandular duct. They are typically associated with simple or running cuticular stitches. Their formation is minimized by subcuticular closure. If they develop, definitive therapy is aimed at uncapping the cyst (no. 11 blade or epilation needle) and teasing out the sac. Granulomas may develop as nodular thickenings within or beneath the suture line and are typically treated by steroid injections if small and by direct excision if large. Suture tunnels develop as a result of prolonged suture retention and epithelial surface migration along the suture tract. Preventive treatment includes early suture removal (3 to 5 days), and definitive treatment involves unroofing the tunnel. Suture marks are also related to prolonged suture retention and their formation can usually be avoided by using a rapidly absorbing suture (fast-absorbing gut or mild chromic), by removing a monofilament suture early, or by employing a subcuticular closure.

Wound Healing Complications

Although rare, hypertrophic or prominent lower eyelid scars may develop because of improper placement of the lower lid incision. If extended too far medially in the epicanthal region, bow-string or web formation may occur (conditions usually amenable to correction by Z-plasty technique). A lateral canthal extension (which normally overlies a bony prominence) that is oriented too obliquely downward or is closed under excessive tension predisposes an incision to hypertrophic scarring, and during healing the vertical contraction vectors act on the lateral lid to favor scleral show or eversion. If the lower lid incision is oriented too far superiorly or too close to the lateral aspect of the upper lid incision, the forces of contraction (now favoring a downward pull) provide conditions that predispose the patient to lateral canthal hooding. Again, proper treatment should be aimed at reorienting the direction of contracting vectors.

Wound dehiscence may develop as a result of closure under excessive tension, early removal of sutures, extension of an infectious process (unusual), or hematoma (more commonly). Skin separation is seen most often in the lateral aspect of the incision with the skin–muscle and skin techniques, and treatment is directed to supportive taping or resuturing. If tension is too great for conservative management, then a lid suspension technique and lateral grafting should be considered. Skin slough may develop as a result of devascularization of the skin segment. It is almost exclusively seen in the skin-only technique and typically occurs in the lateral portion of the lower eyelid after wide undermining and subsequent hematoma formation. Treatment consists of local wound care, evacuation of any hematomas, establishment of a line of demarcation, and early skin replacement to obviate scar contracture of the lower lid.

Skin Discoloration

Areas of skin undermining frequently evidence hyperpigmentation in the early recovery period secondary to bleeding beneath the skin surface with subsequent hemosiderin formation. This process is usually self-limiting and often takes longer to resolve in darkly pigmented individuals. It is imperative during the healing process, and particularly in this patient population, to avoid direct sunlight because this may lead to permanent pigment changes. Refractory cases (after 6 to 8 weeks) may be considered for camouflage, periorbital peeling, or depigmentation therapy (e.g., hydroxyquinone, kojic acid). Telangiectasias may develop after skin undermining, particularly in areas beneath or near the incision, and most commonly occur in patients with preexisting telangiectasias. Treatment options may include chemical peeling or dye laser ablation.

Ocular Injury

Corneal abrasions or ulcerations may result from inadvertent rubbing of the corneal surface with a gauze sponge or cotton applicator, instrument or suture mishandling, or desiccation developing as a result of lagophthalmos, ectropion, or preexistent dry-eye syndrome. Symptoms suggestive of corneal injury, which include pain, eye irritation, and blurred vision, should be confirmed by fluorescein staining and slit-lamp examination by an ophthalmologist. Therapy for mechanical injury typically involves use of an antibiotic ophthalmic drop with lid closure until epithelialization is complete (usually 24 to 48 hours). Treatment for dry-eye syndrome includes the addition of ocular lubricants, such as Liquitears and Lacri-lube.

Extraocular muscle imbalance, manifested by gaze diplopia, may be seen and is often transitory, presumably reflecting resolution of an edematous process. However, permanent muscle injury may result from blind clamping, deep penetration of the fat pockets during sectioning of the pedicle, thermal injury resulting from electrocauterization, suture incorporation during closure, or ischemic contracture of the Volkman type. Patients with evidence of refractory and incomplete recovery of muscle function should be referred to an ophthalmologist for evaluation and definitive treatment.

Contour Irregularities

Contour irregularities are generally caused by technical omissions. Overzealous fat resection, particularly in a patient with a prominent infraorbital rim, results in a lower lid concavity and contributes to a sunken-eye appearance. Failure to remove enough fat (common in lateral pocket) leads to surface irregularities and persistent bulges. A ridge that persists beneath the incision line is usually the result of inadequate resection of a strip of orbicularis oculi before redraping. Areas of induration or lumpiness below the suture line usually can be attributed to unresolved or organized hematoma, tissue reaction or fibrosis secondary to electrocauterization or thermal injury, or soft-tissue response to fat necrosis. Treatment in each case is directed at the specific cause. Persistent fat bulges are managed by resection, whereas areas of lid depression can be managed by sliding fat-pad grafts, free-fat or dermal fat grafts,[37] or orbicularis oculi flap repositioning. Some patients with such bulges or prominences respond to direct injections of triamcinoline (40 mg/cm^3). In selected cases, infraorbital rim reductions distract noticeability from a hollow-eye appearance and may be used as an adjunctive technique. Unresolved hematomas and areas of heightened inflammatory response may be managed with conservative injections of steroids.

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Chapter 19

Liposuction of the Face and Neck

The Art of Facial Sculpture

Russell W. H. Kridel and Paul E. Kelly

Facial rejuvenation surgery in all its forms—from the browlift to simple liposuction—strives to create a more refreshed appearance. The desire for a younger appearance has its beginning in the youthful facial features immortalized in ancient Grecian and Romanesque statues. Evaluation of the idealized statue of Venus or David, for example, shows acute angles and crisp facial structure.

Surgeons have manipulated the ptotic orbicularis oculi muscle, resuspended the falling buccal fat pad, and tightened the hypertrophied and weakened platysmal sling for many years. All of these maneuvers are an attempt to redefine the natural facial angles through resuspension or removal of the ptotic or excessive soft tissue envelope. Facial adiposity is a significant hurdle that over the years has thwarted achievement of the ideal surgical result. In the early 1970s, Schrudde[1] discussed the concept of "lipoexeresis." Manipulation of fatty deposits was first performed as an adjunctive procedure to facelift and was designed to improve aesthetic outcomes of primary rejuvenation surgeries.

The concept of fat removal continued to evolve with Fischer and Fischer[2] and Kesselring's[3] suggestion of placing a tube connected to a suction device through small incisions in a covered field to access fat deposits. Illouz described the technique of lipolysis in which he injected hypotonic saline in the proposed surgical site and then used a blunt-tipped cannula with a high vacuum for fat aspiration.[4] Today facial liposuction is used as a primary facial sculpting or rejuvenating procedure and in combination with other regional aesthetic operations. In contrast to earlier methods, suction lipectomy offers important advantages of minimal scarring, reduced tissue trauma, shorter recuperative periods, and hidden incisions. Some feel that liposuction has revolutionized aesthetic surgery.[5–9] The advent of smaller cannulas, the use of tumescence of the adipose tissue, the application of ultrasonographic techniques, and the use of the liposhaver are the latest advances in this field.

GENERAL PRINCIPLES

Localized adiposity may be attributed to hereditary factors, hormonal imbalance, or poor dietary and exercise habits. Evenly distributed fat stores, unlike isolated facial deposits,[8,10] diminish with exercise and diet. Frequently and unfortunately, the localized deposits are the first to hypertrophy with weight gain.

Illouz, one of the pioneers in liposuction, did extensive studies on the physiology of the human adipocyte. He was determined that human adipocytes multiply from birth until puberty and then are stable in number. Based on histologic study, he described obese children as having a large number of adipocytes (a hyperplastic state) versus the obese adult simply having "large" fat cells (a hypertrophic state).[4] Through the incorporation of triglycerides and fatty acid deposits, the overall volume of the fat cell increases. Weight loss is a reduction not in the number of fat cells but rather in their volume.[4,11] Surgical intervention should be directed at eliminating localized fat cells, ideally in a permanent fashion. Recreating an aesthetic contour by reducing unattractive fat deposits is the underlying goal and function of suction lipectomy.

The majority of new technological interventions, with one exception, take seed from body contouring research, which can frequently be applied to facial surgery. The use of a rigid, blunt-tipped aspiration cannula that is attached to a suction device continues to be the mainstay for suction lipectomy.

Inconspicuous cervicofacial liposuction incisions may be placed in the submentum, the infralobular crease, the nasal vestibule, and the temporal hairline. Recontouring of the overlying soft-tissue envelope is achieved through elimination of fat cells by suction-assisted avulsion and by subdermal contraction seen during the healing phase. Changes have been seen in the mode in which the fat cell is mobilized—by the addition of the tumescent technique, ultrasound technique, or with simple mechanical disruption.

Traditional liposuction permits a relatively precise reduction in fat cell mass coupled with a low complication rate as compared with direct lipectomy.[2,7,18] Because with liposuction the neurovascular bundles to the skin are preserved, there is less bleeding and hematoma formation. A limitation of liposuction is seen in its incomplete removal of deeper midline submental fat that frequently requires direct midline excision. Recontouring takes place as healing progresses, with contraction of the subcutaneous tunnel network created by the liposuction tunneling technique. With a carefully designed and evenly distributed tunnel system, bulges and irregularities secondary to localized fat rarely recur. Early healing irregularities may be seen but are usually fleeting.[5,8,12–14]

Suction-assisted lipectomy (SAL) demonstrates numerous advantages over techniques designed for direct fat excision. SAL eliminates the need for large incisions, reduces operative and recuperative time, and rarely if ever causes permanent injury to nerves.[5,8] SAL allows preservation of the

neurovascular bundles to the skin through the tunnel network. Preservation of neural input means less numbness. By selecting patients with good skin elasticity and localized adiposity, and by using the appropriate operative and postoperative techniques, patients will be happier and the aesthetic results should be improved.

This chapter presents guidelines for the selection of appropriate candidates for liposuction. It will review the physiology and technique of liposuction, highlight necessary equipment, and suggest ways to avoid complications. Finally, most recent advances in the field are discussed.

PATIENT EVALUATION

Cervicofacial liposuction as a primary procedure is not for all patients. The successful use of this procedure is dependent on the surgeon's ability to select patients whose anatomic attributes and psychological profile indicate that they are appropriate candidates for liposuction. A succinct diagnosis of the prevailing pathology is paramount. Liposuction is not for the patient with unrealistic expectations or for the patient with excess skin and little fat.

When contemplating cervicofacial liposuction, the surgeon must consider the skin tone, as well as the muscular support of the neck, the skeletal configuration, and the patient's overall body habitus. Kamer and Lefkoff[13] have developed a submental evaluation algorithm that assesses anatomic properties and equates these findings with the most appropriate surgical option. Conley[15] showed that the position of the hyoid bone in relation to the mentum is the most significant determinant of a desirable cervicomental angle. A low, anterior hyoid position will produce a less favorable result in liposuction than a high, posteriorly placed hyoid (Fig. 19–1). Addressing the submentum with this system is a good starting place, but palpation and the physician's judgment are key factors. Ideal candidates for liposuction as a primary procedure have good skin elasticity and overall muscle tone and are of average weight for their height. Those who demonstrate localized adipose deposits that are out of proportion to the remainder of the body will benefit most from a localized fat removal procedure. Skin elasticity and muscle tone usually are good indicators of postoperative skin contraction and redraping of the soft tissue envelope; therefore, younger patients are generally more appropriate candidates. Overweight patients should be at the lower end of their usual range, with any planned weight loss taking place 6 months prior to the procedure. In general, women have greater elasticity to the skin and are better candidates for closed cervicofacial liposuction as a primary procedure (Fig. 19–2). Women tend to have thinner, less sebaceous skin that contracts over the reduced subcutaneous bed. This is not to say that men are not to be considered for this procedure but rather that expectations for this subset must be tempered. Women also tend to show more dramatic and earlier changes.[10,16] Patient selection is less of an issue when liposuction is used as a secondary procedure, when its addition enhances a favorable outcome from another procedure, especially a chin implant or facelift.

Inappropriate candidates for cervicofacial liposuction are those who present with prominent wrinkling of the skin, significant ptosis to the muscular sling, and prominent platysmal bands. Redundant and inelastic skin often fails to redrape appropriately after the removal of moderate to large amounts of subcutaneous fatty deposits.[5,16–20] Exceptions certainly do occur and these patients may have remarkable results (Fig. 19–3). Whereas too much extra skin may impede appropriate skin redraping, some extra skin is necessary to allow for recontouring of the newly created cervicomental angle. The problem of platysmal banding will not be eliminated with cervical liposuction and may be exacerbated by fat resection. The patient with significant submental fat may have postliposuction exposure of previously masked platysmal banding. The patient with significant banding or cording should be informed preoperatively of the need for either a playtsmal plication or a full rhytidectomy for optimal results.

Finally, skin irregularities and asymmetries, hyoid position, and chin projection should be noted and discussed with the patient. Such irregularities such as dimpling,

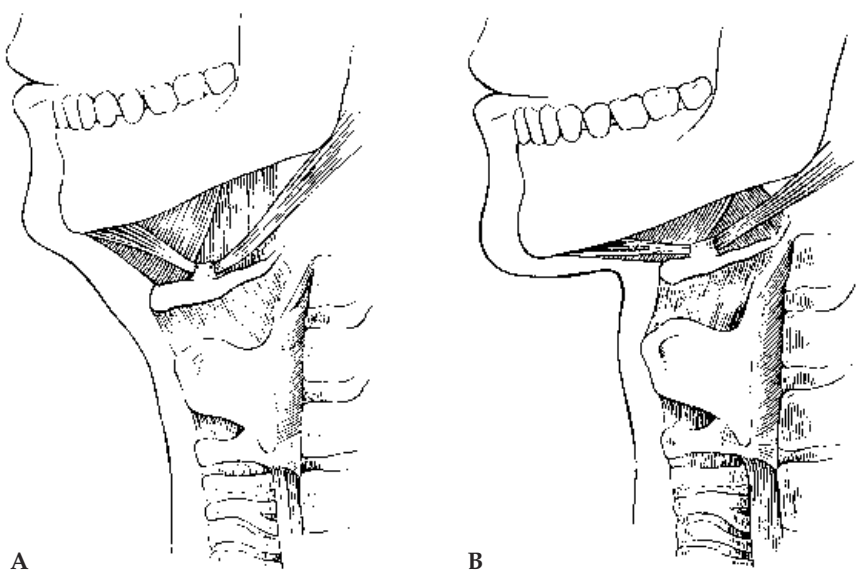


Figure 19–1 Liposuction of the neck and submentum produces the most well-defined cervicomental angle if the hyoid bone is positioned high and posterior **(A)**. However, a low and anterior hyoid limits the desired appearance of the neck in liposuction and should be noted preoperatively and discussed with the patient as a limitation **(B)**. (From Conley J. *Facelift operation.* Springfield, IL: Charles C Thomas, 1968:40–41. With permission.)

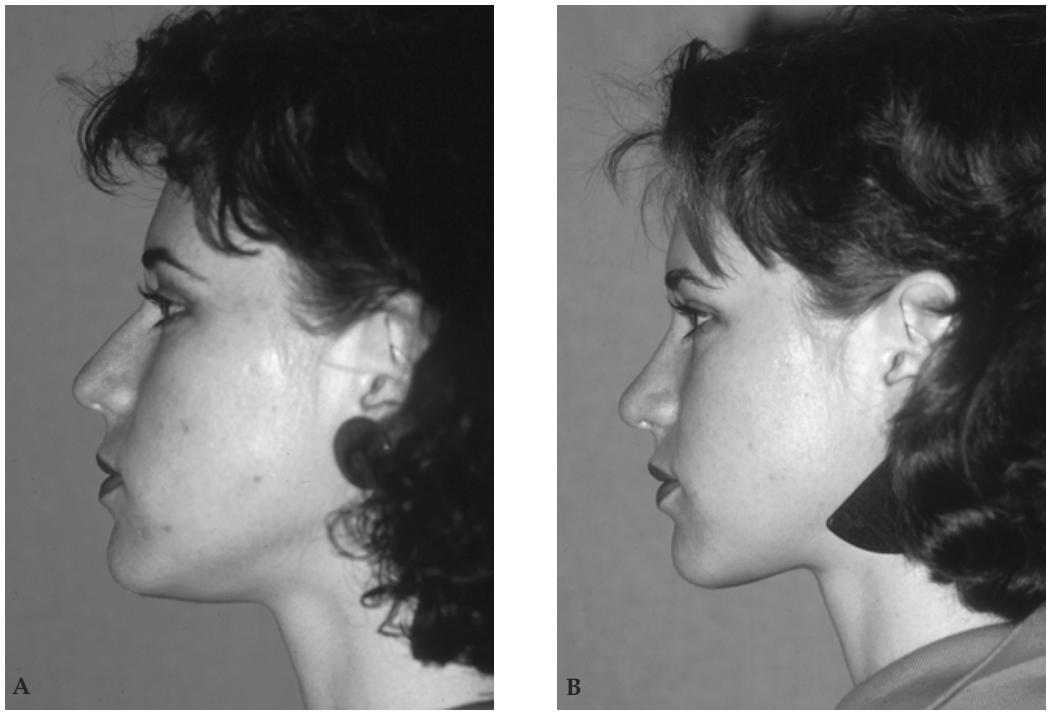


Figure 19–2 **(A)** Preoperative. Ideal candidate with a high posterior hyoid with submental liposis and elastic and healthy skin envelope. **(B)** Six months postoperatively, after submental liposuction and rhinoplasty. (Copyright © R. Kridel, MD. With permission.)

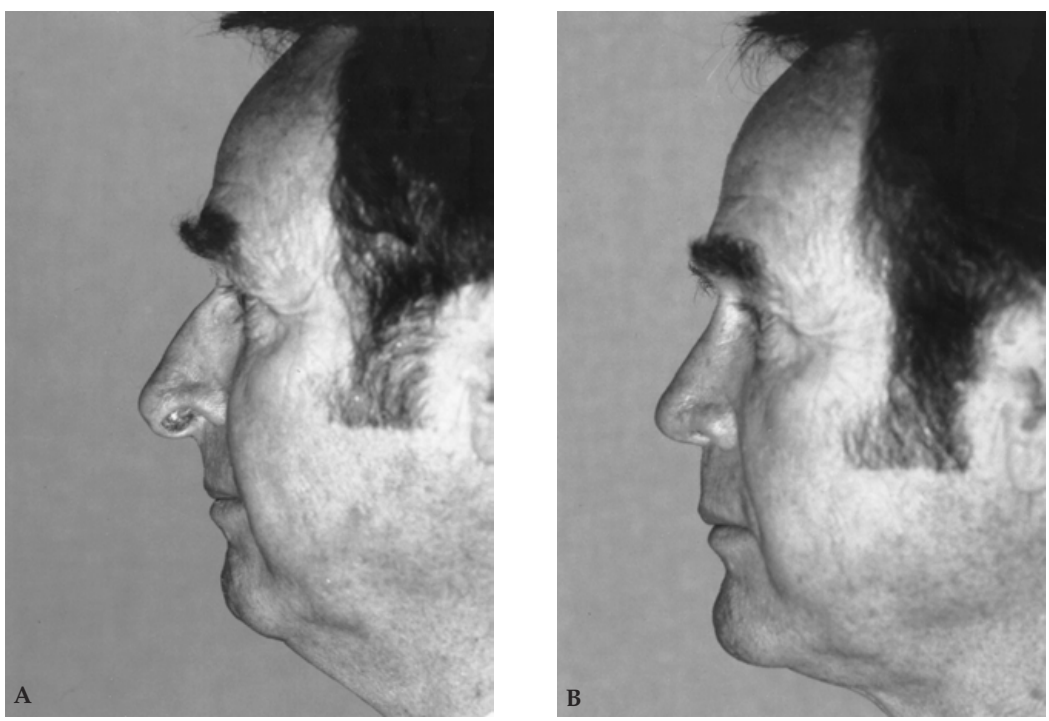


Figure 19–3 **(A)** Preoperative. Older patient with cervicofacial fat as well as redundant skin who refused rhytidectomy. **(B)** Two months postoperatively, after liposuction and nasal surgery only. Excess skinfolds persist, but with dramatic cosmetic result. (From Kridel R, Konior R, Buchwach K. Suction lipectomy. In: Krause CJ, Mangat DS, Pastorek N (eds). *Aesthetic facial surgery*. Philadelphia: JB Lippincott, 1991. With permission.)

depressions, and scarring will not improve with liposuction alone and may be more pronounced. Hyoid bone position and chin projection will dictate the acuity of the cervicomental angle, and patients should be aware of the limitations imposed by anatomic structures. Ideally, a high and posteriorly positioned hyoid and a strong chin will allow for better creation of the acute submental angle deemed youthful.

INDICATIONS

Although the focus of this chapter is the aesthetic use of liposuction in the head and neck area, liposuction as a technique may also be used to manage a variety of other surgical problems. It can be used to elevate soft tissue facelift flaps atraumatically[9] or to defat pedicled or free flaps,[21] and is effective for removal of benign fatty tumors.[22,23]

When used as a closed technique, with absence of muscle or superficial musculoaponemotic system (SMAS) manipulation, liposuction's greatest effectiveness is seen in creating contour changes in the cervicomental angle and, when used judiciously, in the jowl region. The open technique implies suction-assisted fat extraction under direct vision generally in association with rhytidectomy. The nasolabial folds and the lower jowl fat pads have both been addressed with the use of closed liposuction with less predictable results and absence of controlled long-term follow-up. Nasolabial fold prominence is usually a gravity problem, and although liposuction results vary, judicious liposuction here may be helpful. The natural tendency for progressive atrophy of facial fat[5,8,17] makes midface liposuction risky. The concept of improving the facial contour may even necessitate increasing facial dimensions; in the patient with low body fat or the older patient with significant fat atrophy, facial fat injections or submalar implants may provide the appropriate rejuvenating maneuvers.

Ideal candidates for primary liposuction of the cervicofacial region exhibit sufficient skin elasticity to promote skin contraction. In those patients with moderate or poor skin elasticity, removal of localized adiposity may predispose to an increased appearance of sagging skin. Some erroneously promote liposuction as a procedure to reduce sagging skin[24] whereas it can compound the problem. Dedo suggests that after the age of 40 years the contractile ability of skin may become unsatisfactory.[5] Others suggest that age be taken into consideration but rely on actual tissue assessment as the predictive factor.[10,25] Occasionally, the young patient with apparently good skin elasticity may have limited results. Patients should be aware that good results are not totally predictable.

As an adjunctive procedure in facelift surgery or when combined with chin augmentation, liposuction enhances the cosmetic result. As a primary procedure, cevicofacial liposuction has also led to marked improvement in facial rejuvenation by redefining the youthful angles and contours of localized adiposity with minimal recuperation time and morbidity. The scholarly work in the field of liposuction has decreased complications markedly and has continued to provide improvement in operative outcomes.

METHODOLOGIC AND PHYSIOLOGIC CONSIDERATIONS

There are a number of different methods to accomplish the primary goal of liposuction. The techniques used in the face and neck, as compared with those used in the body, although very similar in mechanics must differ because of differing anatomy and physiology. When considering liposuction of the face and neck, the surgeon must be cognizant of the thinness of the facial skin, the proximity of sensory and motor nerves (mainly the marginal mandibular branch of the facial nerve), the depth of fat to be aspirated, and the natural effects of aging on facial fat deposits.

Liposuction, as it was introduced in the 1970s, makes use of a rigid cannula and a suction device.[1,2] The cannula is rapidly advanced and retracted through the fatty deposits via subcutaneous tunnels. Fat cells are sharply avulsed by being drawn into the perforated cannula by the negative pressure created by the suction device. If the suction pressure is high enough, the fat cells are actually lysed and destroyed. Results were good and continue to be so with this technique.

The addition of tumescence—the infiltration of hypotonic saline combined with local anesthetic—to the liposuction regimen had great applicability for body contouring. It allowed larger body area liposuction to be performed under intravenous sedation, and physiologically the infiltrated saline served to disrupt fat cell membranes and facilitate high-volume fat aspiration.[26–28] Tumescence effectively allows infiltration of the vasoconstrictive fluid across the entire liposuction bed. Waiting the suggested 15 minutes prior to initiation of the procedure allows the epinephrine to work and markedly decreases bleeding. Some in facial plastics use tumescence in smaller volumes not only for fat aspiration but for tissue plane dissection as well. Tumescence may be detrimental in small areas, such as the face and neck, secondary to the distortion produced by the fluid.[5,29] This distortion can make assessment of symmetrical fat removal difficult. For the body, anticipated large-volume procedures benefit from tumescence to ease fat removal and dissipate heat generated, especially when ultrasonic energy is used.[29] A recognized drawback with use of the tumescent solution is the problem of third-space volume shifts.

The demand for body liposuction and the continued quest for better results with low morbidity have led to the development of another relatively new technique. The technique makes use of ultrasonic energy either internal or external to the fatty deposit, for fat cell disruption and facilitated aspiration. Although the use of ultrasonography for tissue aspiration dates to the late 1960s, only recently has it been utilized for fatty liposuction purposes. Many of the more common areas of localized *body* adiposity have a high fibrous content,[26] and advancement of the liposuction cannula with the internal or external ultrasound device is not only less strenuous for the surgeon but reportedly more efficient for fat aspiration.[27, 28, 30] Some studies of body liposuction with ultrasonographic assistance also report less swelling and less bruising postoperatively.[31]

Physiologically, the ultrasonic energy is transformed into mechanical vibrations that create a "micromechanical effect, a cavitational effect (expansion and compression cycles form microcavities in adipose tissue) which then implode, resulting in cellular destruction, i.e., liquefaction of fat, and a thermal

effect on fat cells."[28] Numerous studies show potential problems with use of subcutaneous ultrasonic energy, such as excess heat generated by the ultrasound device at the skin incision site,[8,28,32] and the potential heat-related complications generated at more distant subdermal sites.[20,33] Use of the external ultrasonic liposuction device is discussed less frequently in today's literature. When it is discussed, it is touted as having similar benefits as internal ultrasonography in terms of surgical facilitation and recovery period but is still considered an area warranting greater study.[26,27,34] The most recent literature discussing this technique is unable to offer definitive guidelines for use of the external device but rather suggests ranges of safety.[34]

The facial plastic surgeon should be cautious when considering use of internal ultrasonography-assisted liposuction in the cervicofacial area second to the close proximity of neural structures—both sensory and motor—and the thinness of the overlying dermal and epidermal cover. An animal-based study by Howard evaluated the effects of ultrasonic energy on neural tissue. The study results showed that low amplitude ultrasonic energy applied directly to the nerve induced visible injury to the nerve.[29] No functional evidence of nerve injury was noted, however, until higher amplitude settings were reached. The majority of literature that discusses ultrasound-assisted liposuction recommends following manufacturers' guidelines for power settings and suggests a range of settings considered safe. Our Medline search has failed to show any controlled studies demonstrating the safety or added benefit of ultrasound-assisted liposuction in the face or neck as compared with the standard microcannula liposuction procedure.

The final newcomer to the liposuction forefront is the liposhaver, as advocated by Gross and Becker[35,36] for direct lipectomy or for use in a closed technique in the cervicofacial area. A similar tool has made great strides in the endoscopic sinus arena[37] and has also been advocated by some for use in nasal dorsal rhinoplasty.[38] The liposhaver is a guarded, motorized blade that is reported to remove fat via sharp excision either under direct vision or under a subdermal flap. Trauma is reportedly less than with standard techniques because of the excision-versus-avulsion principle. However, it is interesting historically to recognize that liposuctioning, as originally proposed by Schudde,[1] made use of sharp curet-type instruments that excised rather then avulsed fatty deposits. This technique fell from favor following reports of tissue death and even loss of an extremity secondary to vascular damage.

The shaver differs from the traditional, the tumescent, and the ultrasonographic liposuction techniques in that it does not require high suction pressures and actively excises rather than avulses the fatty deposit.[35,36] This method, although based on a similar principle as the sharp curet technique, is different in that a tunnel network is created with the liposhaver cannula much like the network seen in traditional methods. The tunnel network preserves the neurovascular network. Multi-institutional comparison trials[36] have shown successful use of the device and offer it simply as an alternative to conventional liposuction, with perhaps less postoperative bruising and in experienced hands precise lipolysis. Greater care must be exercised when using this device to ensure that only subcutaneous fat is excised and aspirated and that no dermal contact is made. When used in a closed procedure, the tent and superficial projection of the cannula tip—accomplished by the surgeon's nondominant hand—allow even fat extraction and prevent vessel or nerve injury. Concerns with seromas and hematomas may be slightly increased with use of the liposhaver as compared with the traditional liposuction method.

INSTRUMENTATION

Successful execution of any operative procedure requires not only competence and confidence but also the appropriate tools to do the job properly. The basic tools for liposuction are few, but they have continued to evolve since their introduction in the early 1970s.[2,3] With the exception of the liposhaver, the physiologic base for liposuction remains the same: subcutaneous fat is avulsed into a cannula by the back-and-forth motion of the instrument and the negative pressure created by a suction device.[35,36] Today the advent of the 1-mm, 2-mm, and 3-mm blunt-tipped liposuction cannulas as well as the liposhaver allows for better control and precision in the art of "liposculpting."

Some of the innovations in cannula design include the use of light-weight metals and a variety of grip sizes. Some cannulas are equipped with a variable number of suction apertures. Tip designs range from sharp to the more blunted and spatulated endings. As will be explained in the technique section of this chapter, the various cannulas should be used in the different phases of liposculpting. These phases include active fat removal, sculpting, and feathering. Some cannulas have more than one opening and different shapes of the openings. The larger the opening, the more the suction force will increase. In addition, the tip of the cannula should be blunt so as not to perforate the skin or damage the dermis.

The physician who is a proponent of fat injection for soft-tissue filling will frequently use the Luer lock aspiration cannula for the removal of small deposits of fat, which are then washed and injected elsewhere. This method may be used in primary liposuction of the face and neck and requires a minimal equipment budget.[39,40] The methodology is similar to traditional liposuction, with the exception being that the suction pressure is created by a hand-held vacuum in the form of a 10- or 20-cm^3 syringe for modest fatty accumulations.[39,40] Fat aspiration under less suction pressure is used when the fat is to be used for augmentation purposes. Use of less suction pressure is thought to preserve adipocyte structure and increase graft survival rates. The cannula of the hand-held device differs in design by being slightly smaller—about 14 to 17 gauge.

The tumescence technique and internal or external ultrasonic energy are used less frequently in the cervicofacial regions, but they certainly do have a following.[20,33,34] Tumescent cannulas are narrow and blunt-tipped, and serve simply as a conduit for the rapid infusion of the hypotonic/anesthetic saline solution.

The ultrasonography equipment consists of either an external hand-held device used external to the skin, or a cannula (hollow or solid bore) with an incorporated ultrasonography system. The hollow-bored cannula has lipoextraction capabilities, whereas the solid cannula (favored by most) requires standard lipoextraction once the ultrasonographic

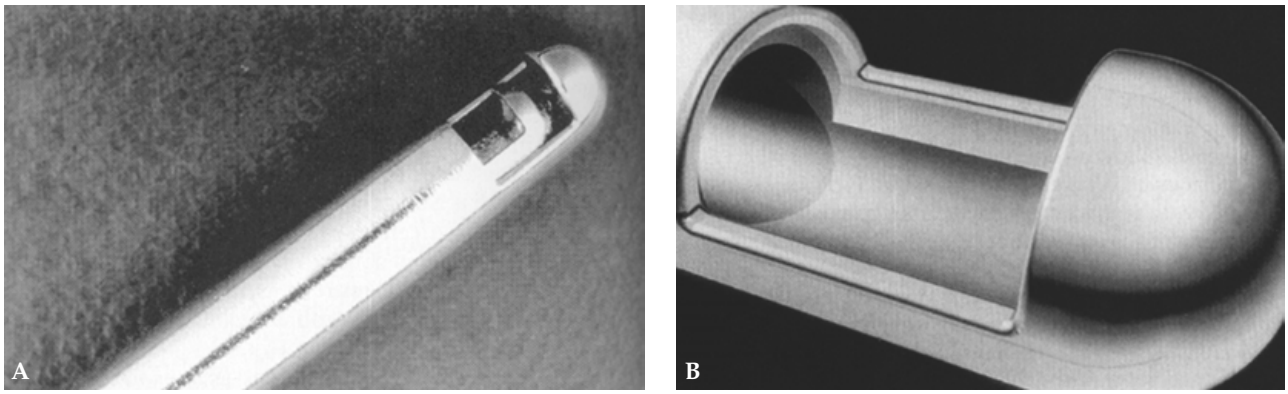


Figure 19–4 The liposhaver with oscillating and protected inner blade and blunt-tipped cannula for direct lipectomy. (From Becker DG, Weinberger MS, Miller PJ, et al. The liposhaver in facial plastic surgery. A multi-institutional experience. *Arch Otolaryngol Head Neck Surg* 1996;122(11): 1161–1167. With permission.)

function is utilized. These ultrasound cannulas are manufactured and look similar to the traditional liposuction cannulas. They are slightly larger and only slightly heavier.

When ultrasonography-assisted procedures are utilized in the recontouring quest, the amount of necessary equipment and the cost of that equipment increases drastically. Long-term results for internal ultrasonographic liposuction are not yet definitive and the physician must weigh the cost–benefit ratio as well as the potential complications associated with internal or external ultrasonography of the face and neck. Use of the ultrasound cannulas with an incorporated cooling irrigation system is decreasing thermal and friction burns at the incision site and more distally.[30,33] Less expensive polyethylene sleeves are available that essentially decrease incision site burns but do nothing for distal site protection.

One of the newer innovations in liposuction is the use of the liposhaver. This device (Fig. 19–4) is similar to the nasal polyp shaver used in endoscopic sinus surgery and the arthroscopic shaver used for delicate soft-tissue joint work.[37,38] The liposhaver functions in a similar manner to these, relying on rapid excision of fat tissue by a protected oscillating blade.[35,36] Conventional liposuction devices rely on fat avulsion, whereas this tool sharply excises fat and requires minimal suction pressure. The device relies on a subcutaneous tunnel network for preservation of the subdermal vascular network. Use of this instrument, with its numerous interchangeable and disposable blades, is being advocated to allow more precise adipose contouring. The device may be used in a closed or open field with the inherent risks, as will be discussed shortly.

A basic requirement for liposuction is a suction device capable of generating enough negative pressure for fat avulsion and aspiration. When utilizing the liposhaver as advocated by Gross and Becker,[36] the suction is less important in terms of fat extraction but still necessary for removal of fat from the field.

Negative pressure in liposuction may be generated by a commercially available unit or from a hand-held syringe. The electrical units may generate up to at least 1 atm of negative pressure (960 mm Hg), and a hand-held syringe creates close to 700 mm Hg with initial aspiration, which then drops to a stable pressure closer to 600 mm Hg.[39,40] Larger areas are more easierly addressed with a commercial machine, although the hand-held unit can certainly accomplish the same task. Suction pressure should always be checked prior to initiation of the procedure to ensure that the pressure is not too high. Theoretically, the higher the suction pressure the greater the chance of neural or vascular structures being aspirated and avulsed.

PREOPERATIVE MARKING

For submental contouring, the areas of liposis and important facial landmarks, including the sternocleidomastoid muscle, the hyoid bone, and the angle of the mandible, are marked in the preoperative holding area with the patient in a sitting position (Fig. 19–5). Preoperative marking is imperative because when the patient lies supine on the operative table fatty accumulations tend to shift and even disappear. Submental and infralobular incision sites are also marked prior to infiltration of anesthetic solution. Patients with prominent submandibular glands should be aware that these will not be reduced in size and may appear after submental and submandibular liposculpting.

In most cervical liposuction cases, the subcutaneous tunnel dissection extends to the sternocleidomastoid laterally, and at least to the hyoid bone inferiorly. Submental fat is generally located centrally, so that dissection and suction extending to these borders serves as more of a feathering function, with the most fat aspirated in the area of greatest concern. Graduated markings should reflect the area in which the function of liposuction is to blend and not necessarily to recontour. When the jowl areas require recontouring, approach to this site may be gained from an infralobular or transnasal approach, utilizing very small-bore cannulas under lower pressure to avoid oversuctioning or neural damage.

The importance of preoperative marking is not to be understated. Careless marking may result in asymmetries and undesirable contour deformities. Similar to cervicofacial

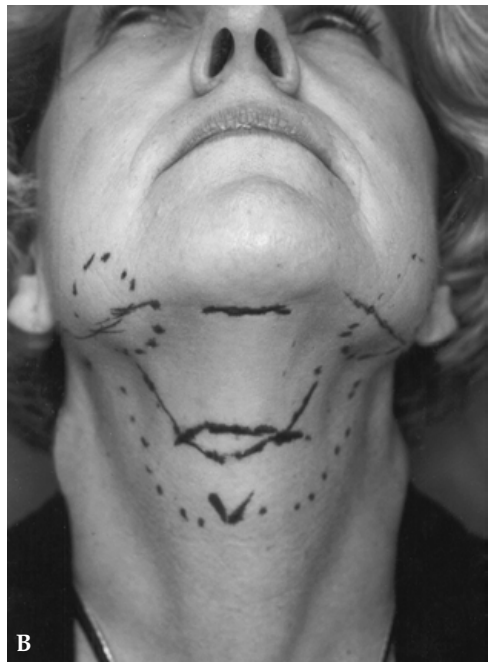


Figure 19–5 **(A)** Preoperative. Patient on three-fourths view with submental fullness and early jowls outlined, with the posterior earlobe and submental incisions marked. **(B)** Preoperative marking on base view of the mandibular angle, border of the mandible, hyoid bone, thyroid notch, area of greatest submental liposis, and area of planned feathering.

fat collections, prominent platysmal bands or hanging folds of skin must also be marked preoperatively to guide their management.

ANESTHESIA

Cervicofacial liposuction is usually performed with local infiltrative anesthesia and in addition may require intravenous sedation. Patients have a choice, however, and some even elect for a general anesthetic. When the technique is combined with other facial rejuvenation procedures, such as rhinoplasty or rhytidectomy, patients have usually already elected for a general anesthetic.

A tumescent technique in the face and neck—although not frequently used in our practice—consists of varied mixtures of 0.5% lidocaine with 1:200,000 epinephrine and hypotonic saline. If the patient is under a general anesthetic, a dilute epinephrine solution is infused. In addition to local infiltration, regional blocks with 0.25% bupivacaine hydrochloride (Marcaine) with epinephrine at Erb's point, in the area of the mental nerve , and circumferential to the planned treatment area will provide longer term definitive anesthesia. It is important to allow 15 minutes by the clock for the vasoconstrictive and anesthetic effects of the tumescent solution to be effective. Anesthesia and suitable vasoconstriction in the nontumescent technique are provided by injection of 1% lidocaine with 1:100,000 epinephrine as field infiltration. Regional blocks are also used in this technique. It is not uncommon in the neck to infiltrate 15 to 20 cm^3 of anesthesia and an additional 10 cm^3 for any areas of concern in the face proper. Pre-procedure planning should include detailed medication lists noting the patient's maximum local anesthetic dose, keeping the basic resuscitation drugs available as well. If an assistant prepares the anesthetic solutions, all syringes should be labeled at the time of preparation.

TECHNIQUE

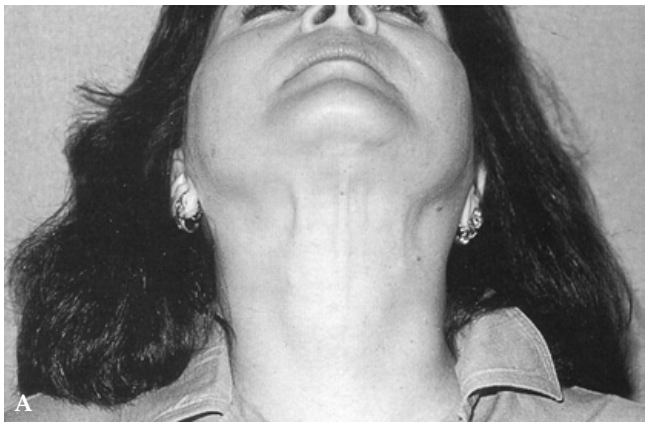
The goal of liposuction regardless of methodology is to recontour areas of adiposity by precise reduction in localized collections of fat while minimizing external irregularities or scars. The technique looks relatively easy and is not difficult to perform. Several details of the procedure, however, must be appreciated to obtain an optimal result and to ultimately produce smooth-surface contours and minimize the chance of any postoperative problems.

Accurate overall reduction of cervicofacial fat is essential. The face and neck are not areas that are easily camouflaged, so that use of techniques to create as symmetrical a result as possible is important. Underestimating the amount of fat reduction necessary to meet aesthetic goals may be the lesser of two evils—the greater evil being overaggressive fat resection with creation of an unnatural concavity or hollowing. If too much fat is removed, unmasking of platysmal banding may result, requiring an open plastysmaplasty with or without facelift to correct the problem (Fig. 19–6). For example, overaggressive fat liposuction in the cervicomental region in the female rhytidectomy patient may create a masculinized appearance by skeletonization of the thyroid notch. Skeletonization here creates a "pseudolaryngeal prominence," characteristic of the male neck.

Cervicofacial liposuction may be performed in an open or closed fashion. If the patient's optimal aesthetic result would be obtained with the addition of a facelift, a combination of the closed and open techniques may be in order.

Liposuction as a Primary Procedure

Incisions in the submental crease, in the posterior lobular crease, or in the nasal vestibule are well hidden and give excellent access to the entire cervicofacial region. If internal ultrasonography systems are being used, the incision may



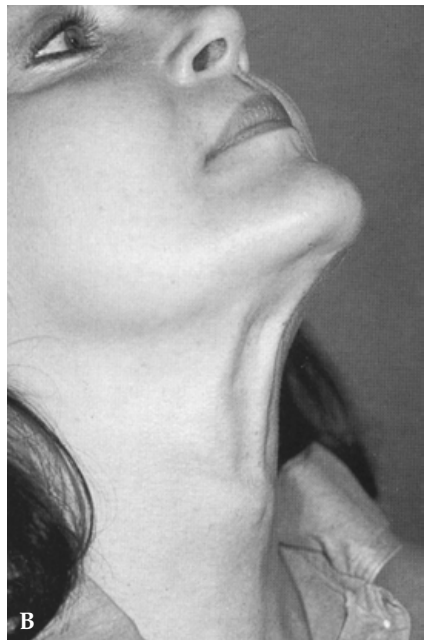


Figure 19–6 Unmasking of the platysmal bands **(A)** and masculinization **(B)** of the thyroid notch after overaggressive submental liposuction. (From Kridel RWH, Pacella BL. Complications of liposuction. In Eisele D (ed). *Complications of head and neck surgery.* St. Louis: Mosby–Year Book, 1992:791–803. With permission.)

require greater length to allow for insertion of the slightly larger cannula and the skin-protecting unit. Too small an incision regardless of technique may predispose to friction burns or skin excoriation at the incision site, simply from the back-and-forth motion of the suction cannula. The incision is generally 4 to 8 mm long. The incision should accommodate a 4- or 6-mm cannula, (i.e., the largest cannula diameters suggested in cervicofacial liposuction procedures.)[5,8,41]

The incision is created and the immediate surrounding skin is sharply undermined with a small tenotomy scissors to allow appropriate placement of the cannula in the proper plane and to prevent postoperative irregularities at the incision site. The appropriate plane is just deep to the dermal–subcutaneous interface. Pretunneling (passage of the cannula through the area to be treated without suction pressure) is frequently done prior to active aspiration. The proper plane in the fibrotic or previously operated neck is elusive, and pretunneling is helpful in ensuring proper dissection depth. Once the dissection is initiated, the aspiration cannula is introduced through this site. Suction pressure should be briefly suspended each and every time that the cannula is removed from or inserted into the incision site so as to decrease the potential for entrance site injury from the suction pressure. An assistant or scrub technician should focus attention on this task, thus allowing the surgeon to concentrate on the task at hand. A simple pinch of the suction tubing and release technique is adequate to prevent entrance site injury.

Entrance of the cannula lumen through the incision site is done in such a way that the lumen opening is always directed toward the subcutaneous tissues and away from the dermis. When performing liposuction in the cervicofacial region, there are few if any indications for directing the cannula lumen aperture to the dermal surface.[18] Vigorous suction against this surface may cause injury to the subdermal plexus, with the result being scar formation and significant postoperative irregularities.

Lipoextraction begins by pretunneling the lipodystrophic site with a spatulated single-lumen 2-, 3-, or 4-mm liposuction cannula. These cannulas are the "workhorses" of cervical liposuction. When addressing the submental liposis, the dissection will fan across the neck from jowl to jowl. The tunnels will circumscribe an arc that extends to the sternocleidomastoid muscles laterally and to the thyroid cartilage inferiorly. The radiating tunnels will fulcrum or center at the incision site in the submental crease (Fig. 19–7). The most vigorous suction should be performed in the area of greatest liposis, delineated by preoperative marks. The larger cannulas (3-, 4-, or rarely 6-mm) are then used here for fat volume reduction, but they may be too large and are not appropriate for all patients, especially those with minimal or moderate fat deposits. Sculpting with a blunt-tipped small-lumen cannula may allow for added definition at the mandibular border or full-neck dissection in those with minimal fat deformities. Liposuction more distal to the primary sites of concern should be aimed at blending or feathering the newly recontoured area. Feathering is best accomplished with use of a smaller lumened cannula having a single or double aperture.

After pretunneling is accomplished, the cannula is connected to the suction device. Fat is removed by directing the cannula throughout the pretunneled area in the same radially directed manner used initially. The relatively atraumatic tunnel system preserves neurovascular and lymphatic continuity between skin and deeper subcutaneous tissues. A superficial tunnel is maintained by tenting the skin away from the deeper tissues with the cannula tip. The left hand (for the right-handed surgeon) is the dominant one during this procedure. It serves to guide the cannula, direct the fat into the lumen, and maintain the correct tissue plane. The right hand is the motor, advancing the cannula through the space. Evenness of cannula motion and a fan-type pattern ensures the correct dissection plane and even fat extraction. Fat extraction continues in this preplatysmal plane until the desired result is achieved. As the main fat accumulation is

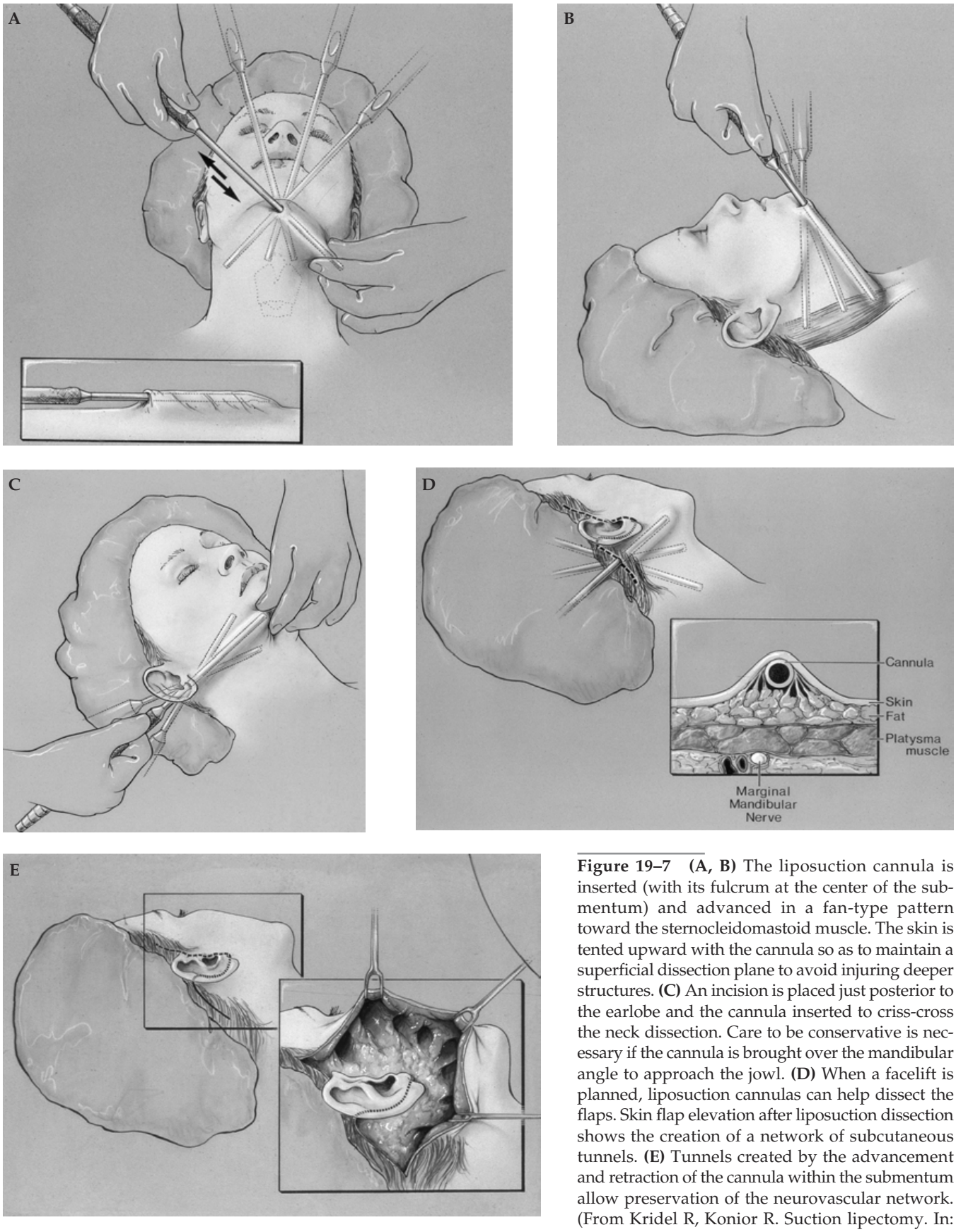


Figure 19–7 **(A, B)** The liposuction cannula is inserted (with its fulcrum at the center of the submentum) and advanced in a fan-type pattern toward the sternocleidomastoid muscle. The skin is tented upward with the cannula so as to maintain a superficial dissection plane to avoid injuring deeper structures. **(C)** An incision is placed just posterior to the earlobe and the cannula inserted to criss-cross the neck dissection. Care to be conservative is necessary if the cannula is brought over the mandibular angle to approach the jowl. **(D)** When a facelift is planned, liposuction cannulas can help dissect the flaps. Skin flap elevation after liposuction dissection shows the creation of a network of subcutaneous tunnels. **(E)** Tunnels created by the advancement and retraction of the cannula within the submentum allow preservation of the neurovascular network. (From Kridel R, Konior R. Suction lipectomy. In: Krause CJ (eds). *Aesthetic facial surgery.* Philadelphia: JB Lippincott, 1991. With permission.)

removed, sculpting and feathering are performed with smaller and less aggressive cannulas. Numerous cannula choices exist for this purpose; the authors prefer a single- or double-aperture 2-mm spatulated cannula.

Redefining the jaw line may necessitate two additional incisions, one behind each ear lobe, hidden in the infralobular crease. These incisions should be vertically oriented and just long enough to accommodate a 2- or 3-mm cannula. Development of the subdermal dissection plane is again initiated with use of a small scissor and pick-up.

The 2- and 3-mm cannulas may have one, two, or three suction apertures. The more aggressive has multiple openings and may be used initially for greatest fat extraction. Feathering with the single- or double-aperture cannula will create better postoperative contour.

The lateral infralobular approach, in addition to the submental approach, allows better access to the area below the mandibular angle. This multidirectional approach creates an extensive overlapping subcutaneous tunnel network that encourages maximal contour enhancement. As the cannula is advanced into the subdermal plane, the arc-and-fan technique is used. Care should be taken to ensure that the cannula lumen is never directed upward, that suction in this closed setting is performed only below the angle of the mandible in most situations, and that suction pressure is suspended when the cannula aperture is inserted or withdrawn from the incision site. Some feel that in the fatter face, the surgeon can judiciously extend the liposuction area up over the mandible with very small cannulas.

Frequent inspection of the site and use of the pinch-and-roll technique helps the surgeon to avoid overextraction. In this maneuver, the skin is gently pinched between the thumb and forefinger and rolled. A sufficient amount of fat has been extracted when the surgeon can feel a thin layer of adipose tissue remaining between the opposing deep surfaces. Extraction volumes vary from person to person, but most require 10 to 100 cm^3.

Occasionally, fat deep to the surface of the platysmal muscle is responsible for loss of the youthful cervicomental angle. In these cases, the cannula can be directed to the deeper plane through the submental access site. Removal of fat here poses little risk to neural structures, such as the marginal mandibular nerve, but small-vessel injury is possible. Cannula direction should stay within the central midline to avoid neural injury more laterally. In facelift patients, the authors have often followed what was thought to be effective and aggressive neck liposuction with open inspection and have found much fat still left in the midline, which required open excision. The liposhaver may ultimately provide a solution in this area, but the submental midline can be a vascular area and care must be exercised.

If direct lipectomy is necessary in the midline, then under direct vision additional fat may be excised. Excision may be performed with scissors or with the use of the liposhaver. More definitive undermining and a slightly larger incision are required for sharp lipectomy, and neurovascular bundles are sacrificed. The undermining can be done with the facelift scissors or the suction bovie cautery on a low setting. If using the cautery to complete flap undermining, the overlying skin is tented away and protected with the Converse retractor. The plane of dissection is then developed under direct vision.

Addressing the lower fullness in the jowl area with liposuction as the primary procedure should be done with extreme caution. The posterior earlobe-crease incisions will allow access to this area. Unless the entire region between the incision site and the fat collection is to be contoured, suction should not be applied until the cannula tip enters the offending adipose deposit. Failure to observe this detail may result in an obvious linear depression between the incision site and the distant fat pocket.

When deciding on jowl fat extraction, patient selection is of utmost importance. The patient with excess skin and poor elasticity will be left postoperatively with unattractive bags of skin where once there was fat. Even in the appropriately selected younger person, excess fat extraction may result in concavities that will only worsen with age as facial fat atrophies.

Isolated liposuction of the midface alone can be disastrous if overaggressive suctioning is carried out, creating marked depression and visible irregularities that are difficult to correct (Fig. 19–8). Conservative suctioning of full nasolabial mounds may be helpful and can be accomplished with small cannulas via an intranasal approach.

The surface contour of the neck must now be carefully inspected before the procedure can be concluded. Dimpling generally implies residual attachments between the subcutaneous fat and overlying skin. Release of these isolated attachments usually resolves the problem. Subtle platysmal banding that may not have been evident preoperatively may now be more noticeable. Through the submental incision these bands may be plicated with or without direct excision to prevent postoperative visibility. If the bands are anticipated preoperatively, the fat extraction may be tempered to prevent increased notice. Lengthening of the submental incision may be necessary to allow suture closure of the diastatic platysmal muscles. Lengthening of the incision should entail a gentle lateral curve so that the incision does not relocate up over the mandible with healing.

After the procedure is complete and final assessment (by pinching and rolling the skin between the fingers) reveals good symmetry, the incision sites are closed in layers with 6-0 stitches and the wounds covered with antitension tape.

Figure 19–8 Overaggressive isolated liposuction of the buccal midface area caused marked depressions that necessitated a facelift with acellular dermal sheeting implants and injections for correction. (See also Fig. 19–12.)

The dissection pocket is milked to ensure that no blood collects and no loose fat globules remain. In patients with larger fat volume removal, and prior to closure, irrigation of the area may be carried out to remove as much loose or liquified fat as possible to prevent postoperative irritation. Closed liposuction as a primary procedure does not require suction drainage but does require a light pressure wrap to reduce tissue edema and to immobilize and reshape the skin over the recontoured soft-tissue facial framework. More pressure should be applied if direct sharp lipectomy was also required. The skin overlying the dissection is first covered with a smooth piece of cotton or Telfa (Kendall Company, Mansfield, MA) and then may be wrapped with Kerlix (Johnson and Johnson, Arlington, TX) gauze. The dressing is completed with either Coban (3M Healthcare, St. Paul, MN) elastic dressing or a facial sling. The elastic sling is comfortable, may be repositioned, and allows easy access to the surgical site. The patient is instructed to limit head and neck mobility for 36 to 48 hours to allow reattachment of the skin to the underlying soft-tissue bed.

Liposuction as an Adjunctive Procedure

Choosing the appropriate candidate for liposuction may also entail selecting a different primary procedure and using liposuction as a secondary or refining technique. Although the patient's purpose in seeing the doctor may have been to have a discussion about liposuction, the surgeon may need to explain why a better avenue for facial rejuvenation may be, for example, chin augmentation, rhytidectomy, or platysmaplasty. Appropriate patient evaluation for an optimal surgical result is extremely important, and the skills involved in this must be learned and reinforced with each and every patient visit.

Liposuction Combined with Chin Augmentation

When microgenia or retrognathia (two different entities) coexist with submental liposis, results of chin augmentation or orthognathic surgery, or submental liposuction alone, are less than optimal. When combined, the result may be dramatic (Fig. 19–9). The overlying goal is recreation of the acuity of the cervicomental angle. Patients who have a recessed chin or low and anterior hyoid position are those who benefit from extraction of submental fat and increased projection of the chin.

Placement of the incisions for a combined submental liposuction and chin augmentation procedure is similar to that for liposuction as a primary procedure, with one exception. If the chin is augmented from an external approach, the submental incision is extended slightly to accommodate the chin implant. If the surgeon prefers, a separate gingivolabial incision may be used for placement of the implant through the oral approach. In this case, care should be taken to keep the two surgical sites—chin and submentum—separate from one another. Salivary contamination of the neck is an unwanted outcome. The tendency for intraorally placed implants is to migrate superiorly, whereas those implants placed externally are apt to fall inferiorly, creating a witch's-chin deformity. Suture fixation and precise pocket techniques are helpful in maintaining chin implant position.

Liposuction-Assisted Rhytidectomy

Liposuction can significantly enhance the results of rhytidectomy by removing the unwanted fat not only in the submentum but in the pretragal and jowl areas as well. The benefit is seen with the addition of this technique in its ability to recontour with little risk to underlying neurovascular structures. Fat removal prior to the advent of liposuction from areas such as the jowls was either not done or was looked on unfavor-

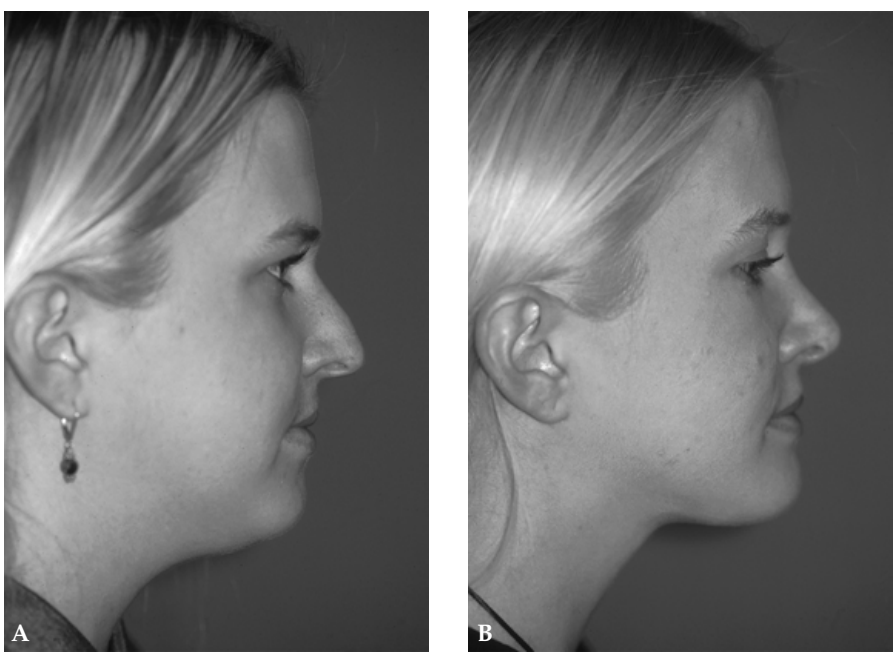


Figure 19–9 **(A)** Preoperative. Patient with submental fullness, microgenia, and young elastic skin. **(B)** Favorable postoperative result from submental liposuction, nasal surgery, and chin augmentation.

ably because of the risk of neural injury or contour irregularity that could result from overaggressive suctioning or tracking. Access to the jowl region was difficult from the standard facelift incisions, and the thought of additional incisions was antithetical to the well-concealed-incision techniques of established facelift protocols.

Three key maneuvers are required to fully appreciate the benefits of liposuction during a facelift. First, closed liposuction is used to reduce the prominent facial fatty deposits with minimal bleeding. Next, the cannula, with or without employment of the suction, facilitates facial flap elevation. Finally, open liposuction fully refines the region under direct visualization.

The standard closed-liposuction technique is used first to remove any prominent adipose accumulations in the submental, submandibular, and jowl regions. The incision in the submentum is 5 to 8 mm long, and the initial dissection is initiated with use of a small scissors. A 3- or 4-mm cannula may be used for initial fat extraction, with pretunneling helpful but not absolutely necessary. Infralobular incisions and preauricular incisions allow further access to facial fatty deposits, with the understanding that excess skin will be addressed in the rhytidectomy part of the procedure. Despite this fact, a conservative approach to fat extraction in the midface and jowl regions is still recommended. Unwanted postoperative irregularity or depressions can result from overaggressive midface liposuction (Fig. 19–10).

After reducing the bulk of the cervicofacial adipose accumulations with the closed technique, undermining of the facial flaps is completed with the standard scissors technique. Undermining after use of the blunt-tipped cannula in the closed liposuction technique is easy and quick. The subcutaneous bands created with the tunneling technique of liposuction are simply identified and divided, and flap elevation is finished. The relatively atraumatic nature of this blunt dissection process allows undermining to proceed up to the nasolabial fold without concern for neurovascular injury.

After flap elevation is complete, initial flap inset incisions are created, and plication or imbrication of the SMAS or a deep-plane lift (surgeon's choice) is performed. Open liposuction may be used as a refining final step. Usually, a blunt-tipped 4- or 6-mm cannula is chosen, and any areas of fullness or irregularity are addressed. A spatula-shaped tip maximizes contact between the suction cannula and the soft-tissue bed, which is required to maintain a seal with continuous suction in an open environment. Unwanted fat deposits are removed by placing the suction cannula aperture directly on the subcutaneous bed and moving it rapidly with a to-and-fro motion along the open face of the dissection pocket. Liposuction before plication or embrication in the pretragal/preauricular area can be used to ensure less immediate postoperative fullness in the area where much of the SMAS is secured with resuspension sutures. After final assessment is performed to determine whether additional liposculpting

Figure 19–10 **(A)** Postoperative result from outside institution (front view). Patient with concave deformity in the inframalar area from overaggressive midface liposuction during facelift procedure. **(B)** Postoperative result from outside institution (lateral view). Poor patient result after bilateral lower jowl liposuction with resultant concavity and laxity to skin.

Figure 19–11 This patient had a combination of facelift and liposuction: **(A)** before and **(B)** $1\frac{1}{2}$ years postoperative.

is necessary, the remainder of the rhytidectomy, including skin excision, should proceed in a routine fashion (Fig. 19–11). Access to the jowl fat pad is also facilitated after the routine facelift flaps are developed; a very small (1- or 2-mm) cannula can be inserted under the facelift flaps directly into the jowl fat under direct visualization.

POSTOPERATIVE COURSE

Patients should be counseled preoperatively regarding the natural postoperative changes encountered after liposuction surgery. Bruising and discoloration are variable after closed-liposuction technique and last for 7 to 21 days. Although rare, prolonged pigment changes in the form of hemosiderin deposits can occur. Postoperative edema and induration may persist for weeks to months, and at times this swelling may be sufficient to mimic the original contour problem. A wide elastic band (with padding, to prevent ear injury) is used for a week, day and night, and then at night for an additional 4 weeks. This band seems to effectively limit the majority of swelling and improves irregularities. As the edema resolves, it is not uncommon to find subtle irregularities. Irregularities that become evident are almost always transient and treated with reassurance, gentle massage, and, occasionally, dilute steroid injection. Short-term numbness and tingling are frequently described and are always discussed in the preoperative visit. This is most important in male patients, who must exercise extra caution with shaving in the early postoperative period.

Postoperative discomfort after primary liposuction is variable. Most patients resume their normal activities within 2 to 3 days of the procedure. Patients are reminded to refrain from active head and neck movement for 2 weeks to ensure that the newly undermined soft-tissue envelope readheres to the subcutaneous bed. Final results with liposuction are varied, and upward of 6 months may be needed for skin contracture and shrinkage.

COMPLICATIONS

Minor and transient irregularities are the rule with liposuction of the cervicofacial regions as compared with the potentially serious complications after whole-body liposuction procedures. Unlike body liposuction procedures where large-volume fat reductions can cause rapid fluid shifts, blood loss, and blood pressure problems, liposuction in the head and neck rarely influences the patient's hemodynamic status. As indicated earlier, typical volumes extracted range from 10 to 100 cm^3 of fat.

Infections are rare, occurring in less than 1% of patients.[8] Preoperative antibiotics are not required, but most surgeons in the private-practice arena are utilizing at least one dose of

perioperative intravenous antibiotic. Hematoma, seroma, or sialocele is seen in less than 1% of patients when liposuction is used as a primary procedure. Sialocele is more common when liposuction is done over the parotid bed, and treatment may require a pressure wrap, use of anticholinergics, or drainage. When liposuction is used as an adjunctive technique, the more invasive procedure, such as rhytidectomy, may increase the rate of fluid collection. Effective treatment of a fluid collection is usually done with simple needle aspiration or expression from an incision line.

Longstanding irregularities may exist in the form of saggy skin or dermal scarring. Extra sagging skin may result from poor patient selection or unexpected senile or presenile skin changes, and may require a rhytidectomy. Scarring may be the result of poor healing, poor operative technique, or infection. Excessive thinning of the dermal fat cover or misdirection of the cannula lumen may create this problem. Options for correction of dermal scarring are limited.

Uneven aspiration may create asymmetry and usually diminishes with surgical experience. A touch-up procedure may be accomplished in the office under local anesthesia with the syringe-assisted suction technique, coupled with a small sculpting cannula. Areas that are too small for even sculpting may be addressed with cautious injection of 0.1 to 0.2 cm^3 of 10 mg/mL triamcinolone acetate solution at 4- to 6-week intervals. Overinjection or too frequent injections may result in dermal thinning, dimpling, and formation of spider telangiectasias.

Small, localized postoperative depressions usually require a soft-tissue filler. Collagen or autologous fat may be effective for this purpose but is usually a temporary fix. Larger deficiencies may require use of synthetic materials, such as submalar cheek implants, or dermal graft materials, such as an acellular dermal sheeting graft (AlloDerm) (Fig. 19–12). Obviously, the best treatment is prevention, and this cannot be emphasized enough.

Figure 19–12 Operative intervention in the form of facelift and placement of acellular dermal grafting material, for the correction of buccal/jowl defects after liposuction.

Permanent injury to the marginal mandibular branch of the facial nerve is rare as is hypesthesia secondary to injury to the great auricular nerve. When paresis, paresthesia, or paralysis occurs, it is almost always short-lived and resolves with the tincture of time.

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Chapter 20

Dermabrasion and Chemical Peels

Stephen H. Mandy and Gary D. Monheit

DERMABRASION

Dermabrasion is a mechanical, "cold steel" method of removing the epidermis and creating a papillary to upper reticular dermal wound. The subsequent manufacture of new collagen and a resurfaced epidermis germinated from deeper, less sun-damaged cells yields excellent cosmetic improvement in actinically damaged, aged, or scarred skin. The pre- and postoperative management that optimizes wound healing is well established and predictable, and morbidity and complications are encountered infrequently.

Modern dermabrasion began when Kurtin,[1] in the late 1940s, modified the technique first described by Kronmayer[2] at the turn of the century. Kurtin's development of the wire-brush technique, which was modified by Burke[3] in the mid-1950s, led to the techniques used today. The basics of a rapidly rotating wire brush or diamond fraise skillfully applied to chilled skin are recognized as effective therapy for a wide range of indications.[4–5]

Anatomy and Healing in Dermabrasion

It is essential to understand the basic macroscopic anatomy of the skin when applying the techniques of dermabrasion that yield beneficial results. For all practical purposes, the skin is divided into three layers: (1) epidermis, (2) dermis, and (3) subcutaneous tissue. Most important in dermabrasion is the dermis, which is composed of two layers: the superficial papillary layer and the deeper reticular layer. Injuries to the epidermis and papillary dermis heal without scarring, whereas injuries that extend into the reticular dermis always result in scar tissue. The purpose of dermabrasive surgery is to reorganize or restructure the collagen of the papillary dermis without injuring the reticular dermis. The thickness of these dermal layers varies greatly from one area to another, and though all areas may be dermabraded without scarring, it is the face that is ideally suited to dermabrasion. This is partly because of the manner in which dermabrasion wounds heal. Reepithelialization begins from the wound margins and from within the epidermal appendages that remain after dermabrasion. The pilosebaceous follicle is the primordial germ for this reepithelialization, and the face is richly endowed with sebaceous glands. Nelson at al.[4,5] have shown that this injury results in significant increases in type I procollagen, type III procollagen, and transforming growth factor β_1 in the papillary dermis. Their results suggest that increased fibroblast activity and consequent collagen I and III synthesis underlie the clinical improvement in collagen reformation seen in dermabrasion.

The preoperative application of tretinoin 0.5% for several weeks before partial-thickness dermabrasive wounds has been shown clinically and in the laboratory to accelerate healing.[21–22] Patients placed on tretinoin at least several weeks before dermabrasion heal in 5 to 7 days. Patients without pretreatment heal in 7 to 10 days (Fig. 20–1). Another significant factor in promoting healing of dermabrasive wounds is the use of occlusive dressings. Since the work of Maibach and Rovee,[23] it has been understood that wounds managed with occlusive dressings heal up to 40% faster than wounds left to air-dry. This is especially true with the dermabrasive wounds covered with an appropriate biosynthetic dressing, which heal much more rapidly than those left to form crusts.[24] Furthermore, biosynthetic dressings alleviate postoperative pain almost immediately when applied after surgery. Biosynthetic dressings act to keep wounds moist, thereby allowing free epithelial migration across the surface. They also cause wound fluids, which contain growth factors that stimulate wound healing, to remain in constant contact with the wound surface. There is also increasing laboratory evidence to suggest that the presence of occlusive dressings modulates collagen synthesis and results in a cosmetically more satisfying scar.[10]

Patient Selection and Indications

Among the many indications for dermabrasion, those most common today are the treatment for acne scars, facial wrinkles, premalignant solar keratoses, rhinophyma, traumatic and surgical scars, and tattoos. Acne scars represent the single

Figure 20–1 Tretinoin applied preoperatively to right side of face produced prompter healing at 5 days.

greatest application of the dermabrasive technique. Dramatic improvement may be achieved with facial scars resulting from acne, but perfection is impossible. Patients must have realistic expectations of surgical results. In patients who have deep, ice-pick scarring, punch excision followed by suture closure of these scars 4 to 6 weeks before dermabrasion is most likely to yield a good result. Patients who have extensive acne scarring should be warned of the possibility of further scarring as a result of dermabrasion. Patients with dark pigmentation should be warned of the possibility of hypopigmentation or hyperpigmentation postoperatively. This is frequently transitory, and pigment returns to normal over the course of several months. Occasionally, if scarring and dermabrasion are deep, pigmentation may be altered permanently. This is especially likely in patients of Asian descent.

Dermabrasion patients have often been treated for their acne with systemic 13-*cis*-retinoic acid. This potent antiacne agent causes sebaceous gland atrophy, and from the early days of its use, concern was expressed that it might delay wound healing in dermabrasion patients. Initial reports in the literature indicated that dermabrasion patients were unaffected by previous treatment with isotretinoin (Accutane).[6] However, later reports suggested that patients who were dermabraded after Accutane therapy exhibited atypical scarring postdermabrasion.[7,25] Subsequent to those reports, other authors have cited numerous cases of patients who had been treated with Accutane and then dermabraded without sequelae.[14] This unsettling controversy clearly has significant medical and legal implications. A clear-cut cause-and-effect relationship has not been established between use of Accutane and atypical scarring. In fact, laboratory studies have failed to substantiate any abnormalities in fibroblast activity or collagen synthesis in Accutane-treated skin.[8–9] Until an answer to this question is found, it is probably prudent for physicians to suggest that patients treated with Accutane wait at least 6 months before undergoing dermabrasion.

Acquired immune deficiency syndrome (AIDS) virus has been the latest factor to consider when selecting patients for dermabrasion. Of all surgeries performed, dermabrasion is most likely to aerosolize blood and tissue products and live infective viral particles. A recent study by Wentzell et al.[11] indicated that aerosolized particles produced during dermabrasion were of sufficient size for access and retention by mucosal and pulmonary surfaces. Furthermore, their study indicated that commonly used personal protection devices, such as operatory masks, goggles, and scatter shields, do not prevent the respiration of these particles. In addition, the settling velocities of such small particles may extend the exposure for many hours after the procedure has been performed, thereby endangering personnel not directly involved in the procedure. Another problem of the AIDS virus is the inability to determine if a patient is in the latent period between the infection and the positive antibody test. There is also the legal implication of refusing a patient who has had a positive blood test. It is clear that the risk to the physician, assistants, and other personnel does exist. Dermabrasion certainly should not be performed without a thorough history of high-risk behavior; protection of gloves, masks, goggles; and the awareness that even with protective devices a certain degree of risk remains. Similar precautions pertaining to hepatitis are also prudent.

One of the growing indications for dermabrasion is aging skin, especially that which has been actinically damaged and shows pathology such as premalignant solar keratoses. Dermabrasion has been shown to be as effective, if not more effective, than topically applied 5-fluorouracil (5-FU) in the management of precancerous skin lesions.[12] In a study of half-face planing of actinically damaged skin, Burke showed that precancerous lesions were substantially reduced and their future development retarded over a 5-year period.[13] These facts, combined with dramatic improvement in rhagades, makes dermabrasion a viable modality in the treatment of aging skin (Figs. 20–2 and 20–3). This work has more recently been corroborated by Coleman et al.[21]

Yarborough demonstrated that dermabrasions performed on traumatic or surgical scars approximately 6 weeks after injury often result in complete disappearance of the scars (Fig. 20–4).[15] In fact, surgical scars respond so well to dermabrasion that most patients who have excisional surgery are told that they may have dermabrasion 6 weeks postoperatively. Although this is usually not necessary, forewarning the patient eases its introduction. Dermabrasion is especially likely

Figure 20–2 **(A)** Predermabrasion for actinic keratoses. **(B)** Postdermabrasion.

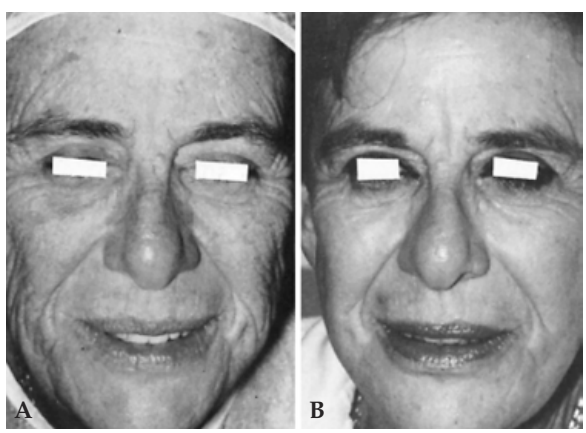

Figure 20–3 **(A)** Predermabrasion for wrinkles. **(B)** Postdermabrasion for wrinkles.

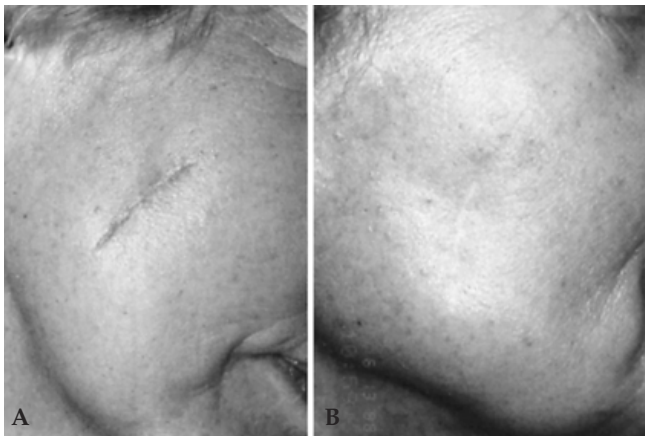

Figure 20–4 **(A)** Predermabrasion of 6-week-old scar. **(B)** Postdermabrasion of scar.

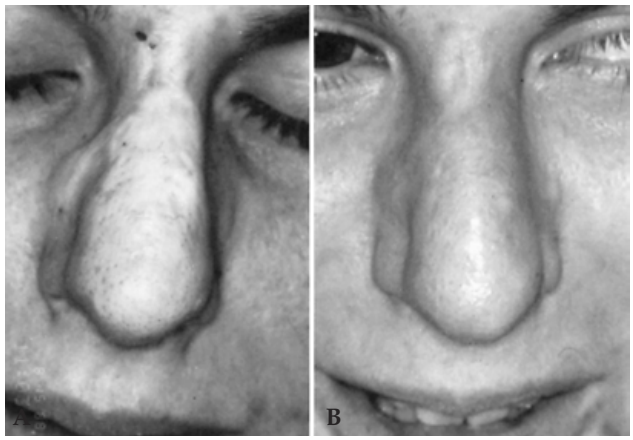

Figure 20–5 **(A)** Scar preabrasion. **(B)** Postabrasion and biosynthetic dressings.

in patients who have sebaceous skin or in facial areas such as the nose where improvement after dermabrasion is most dramatic. Improvement in scars after dermabrasion is further enhanced by the postoperative use of biosynthetic dressings, which significantly affect collagen synthesis, resulting in cosmetic improvement of the surgical scar[10] (Fig. 20–5).

Removal of tattoos can be accomplished with superficial dermabrasion, followed by application of 1% gentian violet and a petrolatum (e.g., Vaseline) gauze dressing daily for 10 days. The gentian violet delays healing, causing pigment to leach out into the dressing and creating continued inflammation that causes phagocytosis of the remaining pigment. Abrading only to the upper papillary dermis avoids scarring. Do not attempt to remove the pigment by abrasion. Professional tattoos are more responsive than amateur or traumatic tatoos but all can be improved. Usually 50% resolution can be achieved with one procedure, which can be repeated every 2–3 months until the desired result is achieved. Tatoos are a good training procedure for the novice in dermabrasion.

Benign tumors, such as adenoma sebaceum and syringomas, may be successfully dermabraded for marked cosmetic improvement, but gradual recurrence is the rule. Dramatic improvement may also be achieved with rhinophyma when dermabrasion is combined with electrofulguration (Fig. 20–6).

Figure 20–6 **(A)** Predermabrasion for rhinophyma. **(B)** Postdermabrasion.

Instrumentation

A wide variety of abrading instruments are commercially available. They vary from hand engines to cable-driven power sources and battery-operated units. More recently, air-driven "microdermabraders" that blow small aluminum or glass particles over the skin have appeared. The important consideration, in terms of the power source, is that it have the torque necessary to continue a sustained and even drive over the abrading surface, either a wire brush or a diamond fraise. Excellent reviews by Yarborough[15–16] and Alt[17] of the wire brush and diamond fraise dermabrasive techniques require little elaboration. However, it cannot be overemphasized, that no article can be substituted for thorough hands-on experience in a preceptorship environment, where the student is able to watch and assist someone experienced in the art of dermabrasion. Most authors agree that the wire-brush technique requires more skill and runs a higher risk of potential injury because it involves cutting more deeply and more quickly than the diamond fraise technique. With the exception of the extra-coarse diamond fraise, superior results are achieved with the wire brush.

One of the continuing controversies surrounding dermabrasive surgery is the use of preabrasive chilling of the skin. Animal and clinical work reviewing various cryanesthetic materials available to chill the skin before sanding has shown that materials that freeze the skin below −30°C, and more especially below −60°C, have the potential to cause substantial tissue necrosis and subsequent scarring.[18–20] It is necessary to freeze the skin before dermabrasion to have a rigid surface that will abrade evenly and preserve anatomical markings that might otherwise be distorted when tissue is thawed. As thermal injury may result in excessive scarring, caution would suggest that use of cryanesthetic agents that do not freeze below −30°C is prudent and as effective as use of those that freeze more deeply. Because regulation of fluorocarbons is making cryanesthetic agents more difficult to obtain, many surgeons are employing tumescent anesthesia instead of chilling to induce turgor.

Technique

Anesthesia

Preoperative staged analgesia has made dermabrasion a feasible technique in the outpatient setting. Diazepam administered approximately 45 minutes to an hour preoperatively, in conjunction with 0.4 mg of intramuscular (IM) atropine as an amnestic and antivagal agent, tends to make the patient more comfortable and less anxious. Before administering regional block anesthesia with xylocaine–bupivacaine mixture, 1 mL of intravenously administered fentanyl or IM meperidine and midazolam gives the patient a great sense of euphoria and relieves the discomfort associated with regional anesthesia. Once analgesia has taken effect, the administration of regional anesthesia to the supraorbital, infraorbital, and mental foramina usually results in anesthesia to 60 to 70% of the entire face. When this is coupled with the use of refrigerant spray, most patients can be dermabraded without pain. The use of nitrous oxide analgesia to supplement anesthesia if the patient becomes uncomfortable during the procedure allows the procedure to progress without interruption.

Sanding Procedure

Once the skin has been rendered solid by the refrigerant spray, the sanding procedure begins in areas that can be abraded in approximately 10 seconds or approximately 1-in.^{2} areas. The dermabrasion instrument, which should be grasped firmly in the hand, should be pulled only in the direction of the handle and perpendicular to the plane of rotation. Back-and-forth or circular movements may gouge the skin. The wire brush requires almost no pressure and produces multiple microlacerations, which are a sign of adequacy of the depth of the procedure. Adequate depth is recognized by several landmarks progressing through the skin. The removal of skin pigmentation signifies passage through the basal layer of the epidermis. Advancing into the papillary dermis, the small capillary loops of the papillary dermis are identified as the tissue thaws and punctate bleeding results. As the papillary dermis is entered further, faintly visible, small parallel bands of collagen become apparent. It is the fraying of these parallel strands that signifies that dermabrasion has been carried to the correct level. Going further may result in scarring.

Many authors suggest the use of cotton towels or cotton gloves as absorbant material for blotting instead of gauze, which may become ensnared in the dermabrading instruments. Entanglement of gauze in the instruments results in a loud flapping that frightens the patient and may compromise the function of the instrument.

It is easiest to begin the dermabrasion centrally beside the nose and work outward. As these are usually the areas of greatest disfigurement and the greatest anesthesia, this process allows the patient the least discomfort and the surgeon the most time to proceed. Special attention must be paid to fixing the lip by traction when dermabrading the lip, which can be ensnared in the machine causing significant laceration. Staying constantly parallel to the surface is essential, especially in areas of complex curvature such as the chin and the malar eminences. Dermabrasion should always be carried out within the facial units to avoid demarcation by pigmentation. Dermabrading to just beneath the jawline out to the preauricular area and up to the suborbital areas ensures that a uniform texture and appearance will be achieved. Next, 35% trichloracetic acid (TCA) can be applied to any unabraded skin, the eyebrows, and the first few centimeters of the hairline to blend pigmentation even better.

Postoperative Care

Pain relief is achieved when biosynthetic dressings are applied at the end of the procedure. Postoperatively patients are put on prednisone 40 mg/d for 4 days, which greatly reduces the postoperative edema and discomfort. One of the most important recent advances has been the use of acyclovir in patients with a history of herpes simplex virus (HSV) infection. Begun 24 hours preoperatively at a dose of 400 mg 3 times/d for 5 days, no patients on this regimen have developed postoperative HSV infection even with a preexisting history of that problem. Many authors now recommend routine prophylaxis with acyclovir or similar derivatives in all patients regardless of history.

Most patients reepithelialize completely between 5 and 7 days postoperatively when biosynthetic dressings have been used. Some of the dressings, such as Vigilon, must be changed daily. Others may be applied at the time of dermabrasion and left intact until they peel off spontaneously. Biosynthetic dressings need to be covered initially with gauze held in place with a flexible surgical netting. After the skin is reepithelialized, daily use of sunscreens is mandatory, and the patients are usually restarted on tretinoin between 7 and 10 days postoperatively.[26] If a patient has a history of pigment problems, such as melasma, he or she is also started on topical hydroquinone at the same time as the tretinoin. If by the tenth to fourteenth day the patient shows signs of disproportionate erythema, a topical 1% hydrocortisone is begun. Patients are cautioned after surgery that it will take at least a month for their skin to return to normal appearance. However, most patients are able to return to work within 7 to 10 days of surgery if light makeup is applied.

Complications

Milia are one of the most common complications of dermabrasion and usually appear 3 to 4 weeks postoperatively. If tretinoin has been used postoperatively, milia are rarely encountered. When milia do occur, they usually respond quickly to tretinoin therapy. Acne flares are another common complication in patients who are prone to acne. If the patient has had active acne in proximity to the dermabrasion, the acne flare can often be prevented by tetracycline starting in the immediate postoperative period. When acne does occur, tetracycline usually causes its prompt resolution. Although erythema is expected after dermabrasion, persistent or unusually severe erythema after 2 to 4 weeks should be managed with topical steroids to avoid hyperpigmentation and scarring. The daily use of sun screens should begin when healing has occurred and should continue for several months postoperatively. If hyperpigmentation begins to appear several weeks postoperatively, topical application of hydroquinone and tretinoin will cause its resolution.

Although uncommon, postoperative infection can occur as a result of dermabrasion. The most common organisms are *Staphylococcus aureus*, HSV, and *Candida*. Staphylococcal infection usually manifests itself within 48 to 72 hours of dermabrasion with unusual facial swelling and honey crusting, as well as systemic symptoms such as fever. HSV infections frequently occur if the patient was not pretreated with acyclovir and are recognized by severe disproportionate pain, usually 48 to 72 hours postoperatively. *Candida* infections usually result in delayed healing and are recognized somewhat later at 5 to 7 days with exudation and facial swelling as clinical symptoms. Appropriate treatment with a staphylococcal antibiotic, acyclovir, or ketoconazole usually results in resolution of the infection without sequelae.

Comparison to Other Modalities

All resurfacing techniques result in an upper to mid-dermal wound. Dermabrasion relies on mechanical cold-steel injury, acid peels result in a "caustic" injury, and lasers result in a thermal injury. Recent studies in a porcine model comparing CO_2 laser, TCA, and dermabrasion by Fitzpatrick et al.[27] and Campell et al.[28] have shown that histologic and ultrastructural changes seen following these procedures are comparable. Giese et al.[29] revealed that when dermabrasion is compared to chemical peels, significant differences are seen in the alteration of elastic fibers in histologic and mechanical properties. At 6 months following phenol treatment, the skin was stiffer and weaker than dermabraded skin. Holmkvist[30] reported that half-face perioral dermabrasion contrasted to half-face CO_2 laser resurfacing yielded identical clinical results but that dermabrasion healed in approximately half the time and with significantly less postoperative erythema and morbidity. Similar results were obtained by Gin et al.[31] Most surgeons practicing resurfacing agree that extended postoperative erythema and delayed hypopigmentation are much more common with phenol or laser than with dermabrasion. A review by Baker[32] points out that dermabrasion equipment is inexpensive, portable, and widely available, requiring no specialized accessory equipment and posing no fire hazard in the operating room.

Conclusion

In this era of computer-generated pulsed lasers and a potpourri of acid peels, there are those who might choose to recognize dermabrasion as an archeologic curiosity. However, dermabrasion is a well-understood procedure with established pre- and postoperative protocols and a highly predictable and reproducible result. Healing is prompt, with a minimum of morbidity and few complications. Equipment is simple and the cost reasonable. Dermabrasion offers a practical means of addressing a significant number of indications with the expectation of a positive outcome.

CHEMICAL PEELS

The explosion of interest in chemical peeling and laser resurfacing on the part of cosmetic surgeons has paralleled the general public's interest in acquiring a youthful appearance by rehabilitating the photoaged skin. The public's interest has been further heightened by advertising for cosmetic agents, over-the-counter chemicals, and treatment programs that have entered the general market of products meant to rejuvenate skin and erase the marks of sun damage and age. Most of these over-the-counter do-it-yourself programs have been tried by patients who, by the time they consult their dermatologist, are ready for a more definitive procedure performed with either chemical peeling or laser resurfacing. It is the role of the physician to analyze the patient's skin type and degree of photoaging, and to prescribe the correct facial rejuvenation procedure that will give the greatest benefit with the lowest risk and morbidity. The dermatologist should make available to the patient the options of medical or cosmoceutical topical therapy, dermabrasion, chemical peeling, and lasers for selective skin destruction and resurfacing. Each of these techniques has a place in the armamentarium of the cosmetic surgeon.

Chemical peeling involves the application of a chemical exfoliant to wound the dermis and epidermis for the removal of superficial lesions and to improve the texture of skin. Various acidic and basic chemical agents are used to produce the varying effects of light to medium to deep chemical peels through differences in their ability to destroy skin. The level of penetration, destruction, and inflammation determines the level of peeling. The stimulation of epidermal growth through the removal of the stratum corneum without necrosis consists of light superficial peel. Through exfoliation the peel thickens the epidermis with qualitative regenerative changes. Destruction of the epidermis defines a full superficial chemical peel inducing the regeneration of the epidermis. Further destruction of the epidermis and induction of inflammation within the papillary dermis constitutes a medium-depth peel. Then further inflammatory response in the deep reticular dermis induces production of new collagen and ground substances, which constitutes a deep chemical peel. These have now been well classified for various conditions associated with photoaging skin based on levels of penetration.[33] Thus, the physician has tools for solving problems that may be mild, moderate, or severe with agents that are very superficial, medium-depth, and deep peeling chemicals. The physician must choose the right agent for each patient and condition.

Indications and Patient Selection

Analysis of patients with photoaging skin must take into account skin color and skin type as well as degree of photoaging. Various classification systems have been available, and I will present a combination of three systems so as to simplify and to help the physician define the right program or therapeutic procedure for a patient. The Fitzpatrick skin typing system classifies degrees of pigmentation and ability to tan. Graded I through VI, it prognosticates sun sensitivity, susceptibility to photodamage, and ability for facultative melanogenesis (one's intrinsic ability to tan). In addition, this system classifies skin in terms of risk factors for complications during chemical peeling. Fitzpatrick divides skin types I through VI, taking into account both color and reaction to the sun.[34] Skin types I and II are pale white and freckled with

TABLE 20–1 Fitzpatrick's Classification of Skin Types

Skin type	Color	Reaction to sun
I	Very white or freckled	Always burns
II	White	Usually burns
III	White to olive	Sometimes burns
IV	Brown	Rarely burns
V	Dark brown	Very rarely burns
VI	Black	Never burns

a high degree of potential to burn with sun exposure. Three and four can burn but usually are an olive to brown coloration. Five and six are dark brown to black skin that rarely ever burns and usually does not need sunscreen protection (Table 20–1). The patient with type I or II skin with significant photodamage needs regular sunscreen protection prior to and after the procedure. However, such an individual has little risk for hypopigmentation or reactive hyperpigmentation after a chemical peeling procedure. The patient with type III through VI skin has a greater risk for pigmentary dyschromia— hyper- or hypopigmentation—after a chemical peel and may need pre- and posttreatment with both sunscreen and bleaching to prevent these complications.[35] Pigmentary risks are generally not a great problem with very superficial and superficial pigment chemical peeling, but they may become a significant problem with medium and deep chemical peeling. It can also be a significant risk when regional areas, such as lips and eyelids, are peeled with a pulsed laser, creating a significant color change in these cosmetic units. This has been classified as the "alabaster look" seen with taped deep chemical peels in regional areas. The physician must inform the patient of this potential problem (especially if the patient with skin type III through VI), explain the benefits and risks of the procedure, and plan for the appropriate techniques to prevent these unwanted changes in color.

The peeling agent is a chemical escharotic that damages the skin in a therapeutic manner. It is important that the physician understand the patient's skin and its ability to withstand this damage. Certain skin types withstand the damage to a greater degree than others, and certain skin disorders have a greater tendency to promote side effects and complications of chemical peels. Patients with extensive photodamage may require stronger peeling agents and repeated applications of medium-depth peeling solutions to obtain therapeutic results. Patients with skin disorders such as atopic dermatitis, seborrheic dermatitis, psoriasis, and contact dermatitis may find their disease exacerbated in the postoperative period or may even develop problems with postoperative healing, such as prolonged healing, posterythema syndrome, or contact sensitivity during a postoperative period. Rosacea is a disorder of vasomotor instability in the skin and may be associated with an exaggerated inflammatory response to peeling agents. Other important factors include a history of radiation therapy to the proposed facial skin as chronic radiation dermatitis decreases the body's ability to heal properly.[36] A general rule of thumb is to examine the facial hair in the area treated by radiation; if it is intact, there are enough pilosebaceous units to heal the skin properly after medium or even deep chemical peeling. However, this is not absolute and one should establish from the history the dates of radiation treatment and the dosage used in each separate treatment. Some of our patients with the greatest amount of radiation dermatitis had had acne-related treatments in the mid-1950s but over the years the skin developed the resultant degenerative changes.

Herpes simplex fascia can be a postoperative problem with significant morbidity. Susceptible patients should be pretreated with antiherpetic agents such as acyclovir or valcyclovir to prevent herpetic activation. These patients can be identified in the preoperative consultation and placed on appropriate therapy at the time of the chemical peel. All antiherpetic agents act by inhibiting viral replication in the intact epidermal cell. The significance of this in peeling is that the skin must be reepithelialized before the agent has its full effect. Thus, the antiviral agent must be continued in deep chemical peeling for the entire 2 weeks or in medium-depth peeling for at least 10 days.[37] The authors rarely use antiviral agents in light or superficial chemical peeling, as the injury pattern usually is not enough to activate the herpes simplex virus.

The chief indications for chemical peeling are associated with the reversal of actinic changes such as photodamage, rhytides, actinic growths, pigmentary dyschromias, and acne scars.[38] The physician thus can use classification systems to quantitate and qualitate the level of photodamage and prescribe the appropriate chemical peeling combination (Table 20–2).

Superficial Chemical Peeling

Superficial chemical peeling is truly an exfoliation of the stratum corneum or the entire epidermis to encourage regrowth with less photodamage and a more youthful appearance. It usually takes repetitive peeling sessions to obtain maximal results. These agents have been broken down into very superficial chemical peels, which will remove the stratum corneum only, and superficial chemical peels, which will remove stratum corneum and damaged epidermis as well. It is to be noted that the effects of superficial peeling on photoaging skin are subtle, and the procedure will not produce a prolonged or very noticeable effect on dermal lesions such as wrinkles and furrows. Agents used include trichloroacetic acid (TCA) 10 to 20%, Jessner's solution, glycolic acid 40 to 70%, salicylic acid–β-hydroxy acid, and tretinoin[39] (Table 20–3). Each of these agents has its own characteristics and methodologic requirements, and a physician must be thoroughly familiar with the chemicals, the methods of application, and the nature of healing. The usual time for healing is 1 to 4 days, depending on the chemical and its strength.

Very-light-peeling agents include glycolic acid in low concentrations, 10% TCA, and salicylic acid (a β-hydroxy acid).

Ten to twenty percent TCA produces a light whitening or frosting effect on the skin with a result of sloughing of the upper one half to one third of the epidermis. Skin preparation prior to this peel comprises washing the face thoroughly and using acetone to remove surface oils and excessive stratum corneum. TCA is applied evenly with sat-

TABLE 20–2 Index of Photoaging

Texture changes	Points				Score
Wrinkles (% of potential lines)	1 <25%	2 <50%	3 <75%	4 <100%	
Cross-hatched line (% of potential lines)	1 <10%	2 <20%	3 <40%	4 <60%	
Sallow color	1 Dull	2 Yellow	3 Brown	4 Black	
Leathery appearance	1	2	3	4	
Crinkley (thin and parchment)	1	2	3	4	
Pebbly (deep whitish nodules) (% of face)	2 <25%	4 <50%	6 <75%	8 <100%	

Lesions	Points				Score
Freckles-mottled skin (# present)	1 <10	2 <25	3 <50	4 >100	
Lentigenes (dark and irregular) and SKs (Size)	2 <5 mm	4 <10 mm	6 <15 mm	8 >20 mm	
Telangiectasia–erythema flush (# present)	1 <5	2 <10	3 <15	4 >15	
AKs and SKs (# present)	2 <5	4 <10	6 <15	8 >15	
Skin cancers (# present, now or by history)	2 1 ca	4 2 ca	6 3 ca	8 >4 ca	
Senile comedones (in cheekbone area)	1 <5	2 <10	3 <20	4 >20	

Total Score _____

Corresponding Rejuvenation Program	
Score	**Needs**
1–4	Skin care program with tretinoin, glycolic acid peels
5–9	Same plus Jessner peels; pigmented lesion laser and/or vascular laser
10–14	Same plus medium peels—Jessner/TCA peel; skin fillers and/or Botox
15 or more	Above plus laser resurfacing

Staff Signature _____ Date _____ Patient Signature _____ Date _____

AK, actinic keratosis; SK, seborrheic keratosis; TCA, trichloroacetic acid.

urated 2 × 2 gauze or a sable brush, and it usually takes 15 to 45 seconds for the frosting to become evident. This would be categorized as a level I frosting with the appearance of erythema and streaky whitening on the surface. Level II and III frosting is seen in medium-depth and deeper peels (Fig. 20–7). The patient experiences stinging and some burning during the procedure, but this subsides very rapidly and the patient then can resume normal activities. There is erythema and resulting desquamation, which last for 1 to 3 days. Sunscreens and light moisturizers are permitted, and minimal care is needed in this superficial chemical peel.

Jessner's solution is a combination acid (escharotic) that has been used for more than 100 years in the management of

TABLE 20–3 Agents Used for Superficial Chemical Peeling

Agent	Concentration	Mechanism of action
Trichloracetic Acid	10–25%	Protein precipitation
Jessner's Solution	Formulated	Keratolysis
Glycolic Acid	Keratinocyte	Protein precipitation
Jessner's Solution	Formulated	Keratolysis
Glycolic Acid	40–70%	Keratinocyte dyscohesion Epidermolysis
Salicylic Acid	5–15%	Keratolysis

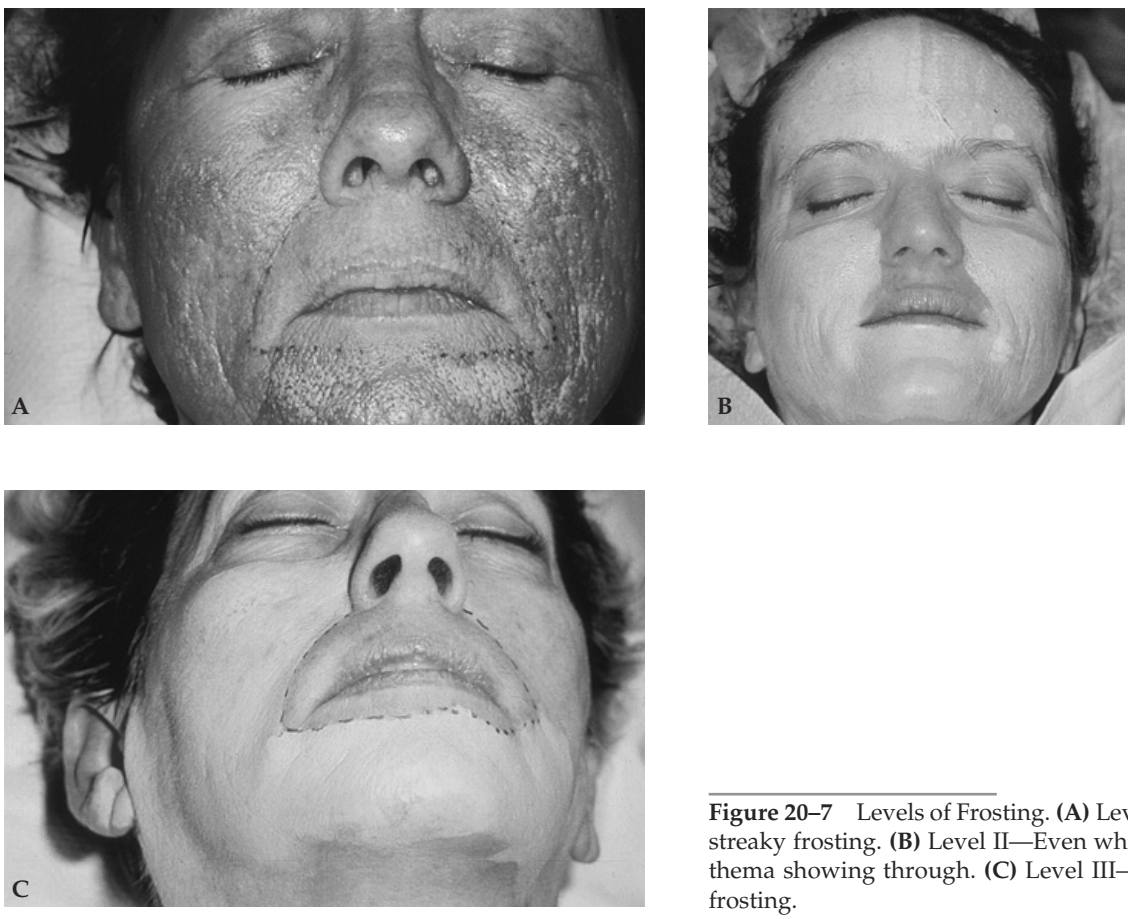

Figure 20–7 Levels of Frosting. **(A)** Level I—Erythema with streaky frosting. **(B)** Level II—Even white frosting with erythema showing through. **(C)** Level III—Solid white enamel frosting.

hyperkeratotic skin disorders (Table 20–4). It has been used as part of acne treatment for the removal of comedones and signs of inflammation. In superficial peeling it performs as an intense keratolytic agent. The application is similar to that for superficial TCA application with wet gauze, sponges, or a sable brush, producing an erythema with blotchy frosting. Tentative applications are done on an every-other-week basis, and the levels of Jessner's solution coatings can be increased with repetitive applications. The visual end point is predictable, that is, epidermal exfoliation and regrowth. This usually occurs within 2 to 4 days and is followed by use of with mild cleansers, moisturizing lotion, and sunscreen protection.

TABLE 20–4 The Jessner's Solution Formula

Resorcinol	14 g
Salicylic Acid	14 g
Lactic Acid	14 mL
Ethanol (qs)	100 mL

α-Hydroxy Acids

α-hydroxy acids, specifically glycolic acid, have become the wonder drug of the early 1990s with promises of skin rejuvenation with home use and topical therapy. Hydroxy acids are found in foods (e.g., glycolic acid is naturally present in sugar

cane, lactic acid in sour milk, malic acid in apples, citric acid in fruits, and tartaric acid in grapes). Lactic acid and glycolic acid are widely available and can be purchased for physician use. Glycolic acid is found in unbuffered concentrations of 50 to 70% for use as a chemical peel. Weekly or biweekly applications of 40 to 70% unbuffered glycolic acid treatments have been used for wrinkles by applying the solution to the face with a cotton swab, sable brush, or saturated 2 × 2 gauze. The time of application is critical for glycolic acid, as it must be rinsed off with water or neutralized with 5% sodium bicarbonate after 2 to 4 minutes. Mild erythema may persist for about an hour with slight stinging and minimal scaling. Wrinkle reduction and removal of benign keratoses have been reported to result from repeated applications of these peeling solutions.[40]

Superficial chemical peels can be used for comedonal acne and postinflammatory erythema or to correct pigmentation problems caused by acne, treatment for mild photoaging, and melasma.

To treat melasma effectively, the skin must be pretreated and posttreated with sunscreen, hydroquinone 4 to 8%, and retinoic acid. Hydroquinone is a pharmacologic agent that blocks tyrosinase from developing melanin precursors for the production of new pigment. Its use essentially blocks new pigment formation as the new epidermis heals after a chemical peel. Thus, it is needed when peeling for the treatment of pigmentary dyschromias as well as when applying chemical peels in type III to VI Fitzpatrick's skin (the skin type most prone to development of pigmentary problems).[41]

When using superficial chemical peels, the physician must understand that repetitive peeling will not summate into medium-depth or deep peels. A peel that does not affect the dermis will have very little effect on textural changes that originate from dermal damage. The patient must understand this preoperatively so as not to be disappointed with the results. On the other hand, repetitive peeling procedures are necessary for maximal benefits to be obtained with superficial chemical peeling. These are carried out once a week or for a total of six to eight chemical peels and enhanced by the appropriate cosmoceutical agents.

Medium-Depth Chemical Peeling

Medium-depth chemical peeling is defined as controlled damage from a chemical agent to the papillary dermis resulting in specific changes that can be performed in a single setting. Agents currently in use include combination products—Jessner's solution, 70% glycolic acid, and solid carbon dioxide with 35% TCA (Table 20–5). The hallmark for this level peel is 50% TCA. It has traditionally achieved acceptable results in ameliorating fine wrinkles, actinic changes, and preneoplastic conditions. However, since TCA itself is an agent more likely to be fraught with complications, especially scarring, in strengths of 50% or higher, it has fallen out of favor as a single-agent chemical peel.[42] It is for this reason that the combination products along with a 35% TCA formula have been found to be just as effective in producing this level of control damage without the risk of side effects.

Brody developed the use of solid CO_2 applied with acetone to the skin as a freezing technique prior to the application of 35% TCA. This appears to break the epidermal barrier for a more even and complete penetration of the 35% TCA.[43]

Monheit demonstrated the use of Jessner's solution prior to the application of 35% TCA. Jessner's solution was found to be effective in destroying the epidermal barrier by breaking up individual epidermal cells. This allowed deeper penetration of the 35% TCA and a more even application of the peeling solution.[44] Similarly, Coleman demonstrated the use of 70% glycolic acid prior to the application of 35% TCA. Its effect has been very similar to that of Jessner's solution.[45]

All three combinations have been proven more effective and safer than 50% TCA. The application and frosting are more controlled with the combination so that the "hot spots" with higher concentrations of TCA, which can produce dyschromias and scarring, are not a significant problem with lower concentration TCA as used in this combination medium-depth peel. The Monheit version of Jessner's solution–35% TCA peel is a relatively simple and safe combination. The technique is used for mild to moderate photoaging, including pigmentary changes, lentigines, epidermal growths, dyschromias, and rhytides. It is a single procedure with a healing time of 7 to 10 days. It is useful also to remove diffuse actinic keratoses as an alternative to chemical exfoliation with topical 5-FU chemotherapy. It significantly reduces the morbidity and gives the cosmetic benefits of improved photoaging skin.[46]

The procedure is usually performed with mild preoperative sedation and nonsteroidal anti-inflammatory agents. The patient is told that the peeling agent will sting and burn temporarily; aspirin is given before the peel and continued through the first 24 hours if the patient can tolerate the medication. Its anti-inflammatory effect is especially helpful in reducing swelling and relieving pain. If given before surgery,

TABLE 20–5 Agents for Medium-Depth Chemical Peel

Agent	Comment
1. TCA–50%	Not recommended because of risk of scarring
2. Combination–35% TCA–solid CO_2 (Brody)	The most potent combination
3. Combination–35% TCA–Jessners (Monheit)	The most popular combination
4. Combination 35% TCA–70% Glycolic (Coleman)	An effective combination
5. 89% Phenol	Rarely used

it may be all that the patient requires during the postoperative phase. However, for full-face peels it is useful to give a preoperative sedative (diazepam 5 to 10 mg orally) and a mild analgesic [meperidine 25 mg (Demerol), and hydroxyzine hydrochloride 25 mg IM (Vistaril)]. The discomfort from this peel is not long lasting, so that short-acting sedatives and analgesics are all that is needed.[46]

Vigorous cleaning and degreasing are necessary to achieve even penetration of the solution. The face is scrubbed gently with ingasam (Septisol) (4 × 4 in. gauze pads) and water, then rinsed and dried. Next a masetol preparation is applied to remove residual oils and debris. It is necessary to perform a thorough degreasing for an even and fully penetrant peel. A splotchy peel is usually the result of uneven penetration of peel solution due to residual oil or stratum corneum from inadequate degreasing.

Jessner's solution is then applied with cotton-tipped applicators or 2 × 2 in. gauze. The frosting achieved with Jessner's solution is much lighter than that produced by TCA, and the patient is usually not uncomfortable. A mild erythema appears with a faint tinge of frost evenly over the face (Fig. 20–8)

TCA is then applied evenly with one to four cotton-tipped applicators that can be used on different areas with light or heavier doses of the acid. Four cotton-tipped applicators are used with broad strokes over the forehead as well as on the medial cheeks. Two mildly soaked cotton-tipped applicators can be used across the lips and chin, and one damp cotton-tipped applicator on the eyelids. Thus, the dose of TCA is contingent on the amount used, and the number of cotton-tipped applicators used, and the clinician's technique. The cotton-tipped applicator is useful in controlling the amount of peel solution to be applied (Fig. 20–9)

Figure 20–8 Jessner's solution. Appearance of frosting with erythema with blotchy frosting.

White frost from the TCA application appears on the treated area after a few minutes. Even application should eliminate the need to go over areas a second or third time, but if frosting is incomplete or uneven, the solution should be reapplied. TCA takes more time to frost than Baker's formula or straight phenol, but less time than the superficial peeling agents. The surgeon should wait at least 3 to 4 minutes after the application of TCA to ensure the frosting has reached its peak. He or she then can analyze the completeness of a frosted cosmetic unit and touch up the area as needed. Areas of poor frosting should be carefully retreated with a thin application of TCA. The physician should achieve

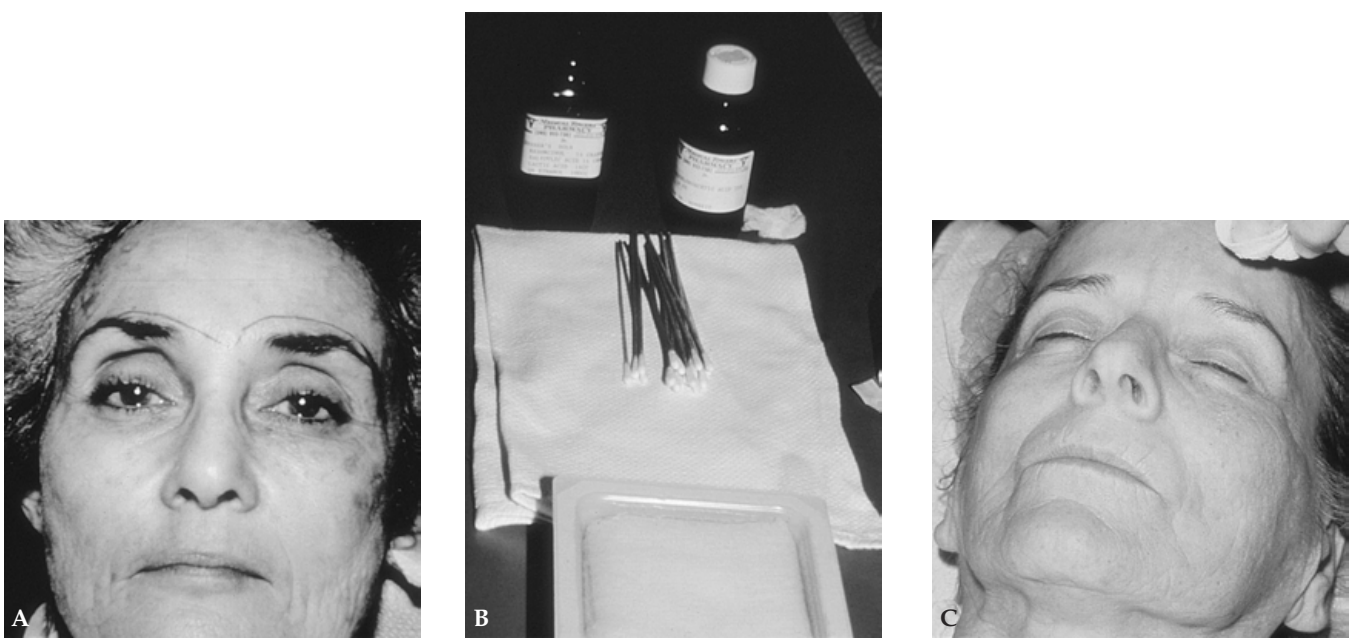

Figure 20–9 Chemical peeling for photoaging skin. **(A)** Preoperative appearance of Glogau II photoaging facial skin. **(B)** Peel solutions with cotton tips, 2 × 2 gauze and saline. **(C)** Jessner's solution applied with 2 × 2 gauze pads.

a level II to level III frosting. Level II frosting is defined as white-coated frosting with erythema showing through. A level III frosting, which is associated with penetration to the dermis, is a solid white enamel frosting with no background of erythema.[47] Most medium-depth chemical peels use a level II frosting; this is especially true for eyelids and areas of sensitive skin. Those areas with a greater tendency to scar, such as the zygomatic arch, the bony prominences of the jawline, and the chin, should only receive up to a level II frosting. Overcoating TCA increases its penetration, so that a second or third application will dry the acid further, causing more damage. One must be careful in overcoating only areas in which the take-up was not adequate or the skin is much thicker.

Anatomical areas of the face are peeled sequentially from forehead to temple to cheeks and, finally, to lips and eyelids. The white frosting indicated keratocoagulation, and at that point the reaction is complete. Careful feathering of the solution into the hairline and around the rim of the jaw and brow conceals the line demarcation between peeled and nonpeeled areas. The perioral area has rhytids that require a complete and even application of solution over the lip skin to the vermilion. This is best accomplished with the help of an assistant who stretches and fixates the upper and lower lips while the peel solution is applied.

Certain areas and lesions require special attention. Thicker keratoses do not frost evenly and thus do not pick up peel solution. Additional applications rubbed vigorously into the lesion may be needed for peel solution penetration. Wrinkled skin should be stretched to allow an even coating of solution into the folds and troughs. Oral rhytides require peel solution to be applied with the wood portion of a cotton-tipped applicator and extended into the vermilion of the lip. Deeper furrows, such as expression lines, will not be eradicated by peel solution and thus should be treated like the remaining skin.

Eyelid skin must be treated delicately and carefully. A semidry applicator should be used to carry the solution to within 2 to 3 mm of the lid margin. The patient should be positioned with the head elevated at 30 degrees and the eyelids

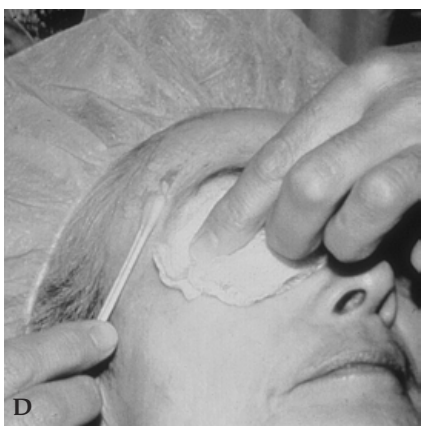

Figure 20–9 *(continued)*
(D) Application of TCA with level II–III frosting. **(E)** Full-face frosting. **(F)** Appearance 4 days postoperative. **(G)** Appearance 6 months postoperative.

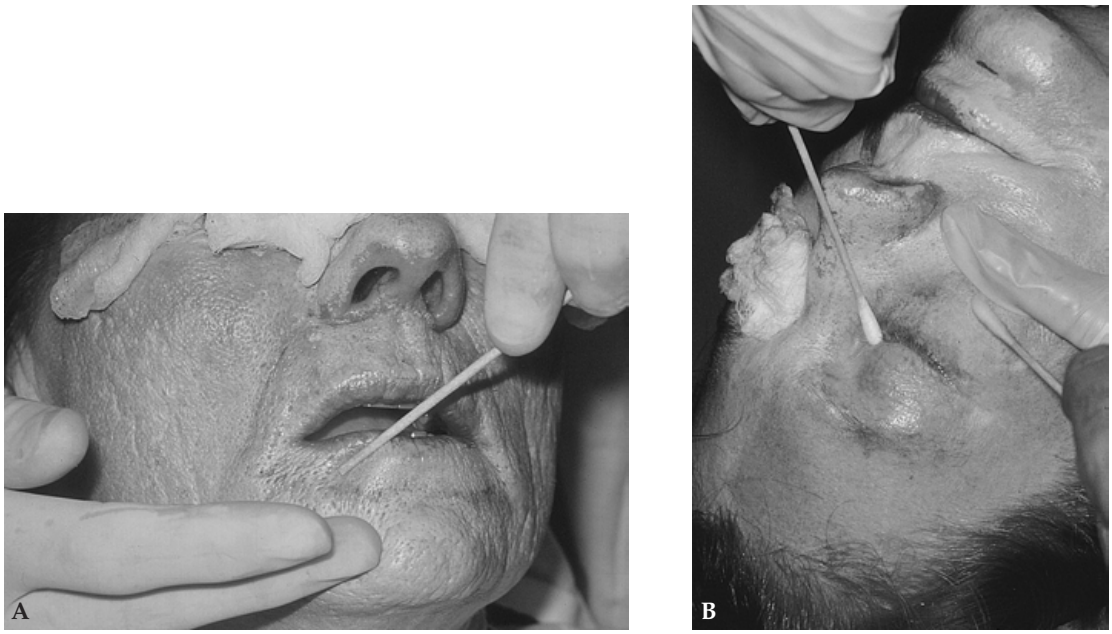

Figure 20–10 **(A)** Oral rhytides are treated with wood portion of cotton tip for deeper penetration. **(B)** Eyelids are painted cautiously with damp cotton-tipped applicators; dry cotton tips are used to blot the tears.

closed. Excess peel solution on the cotton tip should be drained gently on the bottom before application. The applicator is then rolled gently on the lids and periorbital skin. Never leave excess peel solution on the lids because the solution can roll into the eyes. Dry tears with a cotton-tipped applicator during peeling because they may pull peel solution to the puncta and eye by capillary attraction (Fig. 20–10) The Jessner's–TCA peel procedure is as follows:

1. The skin should be cleaned thoroughly with Septisol.
2. Acetone or acetone alcohol is used to further debride oil and scale from the surface of the skin.
3. Jessner's solution is applied.
4. Thirty-five percent TCA is applied until a light frost appears.
5. Cool saline compresses are applied to neutralize the solution.
6. Healing is facilitated by 0.25% acetic acid soaks and a mild emollient cream.

There is an immediate burning sensation as the peel solution is applied, but this subsides as frosting is completed. Cool saline compresses offer symptomatic relief for a peeled area as the solution is applied to other areas. Following the peel, the compresses are placed over the face for several minutes until the patient is comfortable. The burning has subsided fully by the time the patient is ready to be discharged. By then most of the frosting has faded and a brawny desquamation is evident.

Postoperatively, edema, erythema, and desquamation are expected. With periorbital peels and even forehead peels, eyelid edema can be severe enough to close the lids. For the first 24 hours, the patient is instructed to soak four times a day with a 0.25% acetic acid compress made of 1 tablespoon white vinegar in 1 pint of warm water. A bland emollient is applied to the desquamating areas after soaks. After 24 hours, the patient can shower and clean gently with a mild nondetergent cleanser. The erythema intensifies as desquamation becomes complete within 4 to 5 days. Thus, healing is completed within 1 week to 10 days. At the end of 1 week, the bright red color has faded to pink and has the appearance of a sunburn. This can be covered by cosmetics and fades fully within 2 to 3 weeks.

The medium-depth peel is dependent on three components for therapeutic effect: (1) degreasing, (2) Jessner's solution, and (3) 35% TCA. The amount of each agent applied creates the intensity and thus the effectiveness of this peel. The variables can be adjusted according to the patient's skin type and the areas of the face being treated. Therefore, the medium-depth peel is the workhorse of peeling and resurfacing in my practice as it can be individualized for most patients.

The medium-depth chemical peel thus has five major indications: (1) destruction of epidermal lesions–actinic keratoses (Fig. 20–11); (2) resurfacing of the level II moderately photoaging skin (Fig. 20–12), (3) correction of pigmentary dyschromias (Fig. 20–13), (4) repair of mild acne scars; and (5) blending of photoaging skin with laser resurfacing and deep chemical peeling[48] (Fig. 20–14)

Deep Chemical Peeling

Level III photodamage requires deep chemical peeling. This entails the use of either TCA above 50% or the Gordon–Baker phenol peel. Laser resurfacing can also be used to reliably reach this level of damage. TCA above 45% has

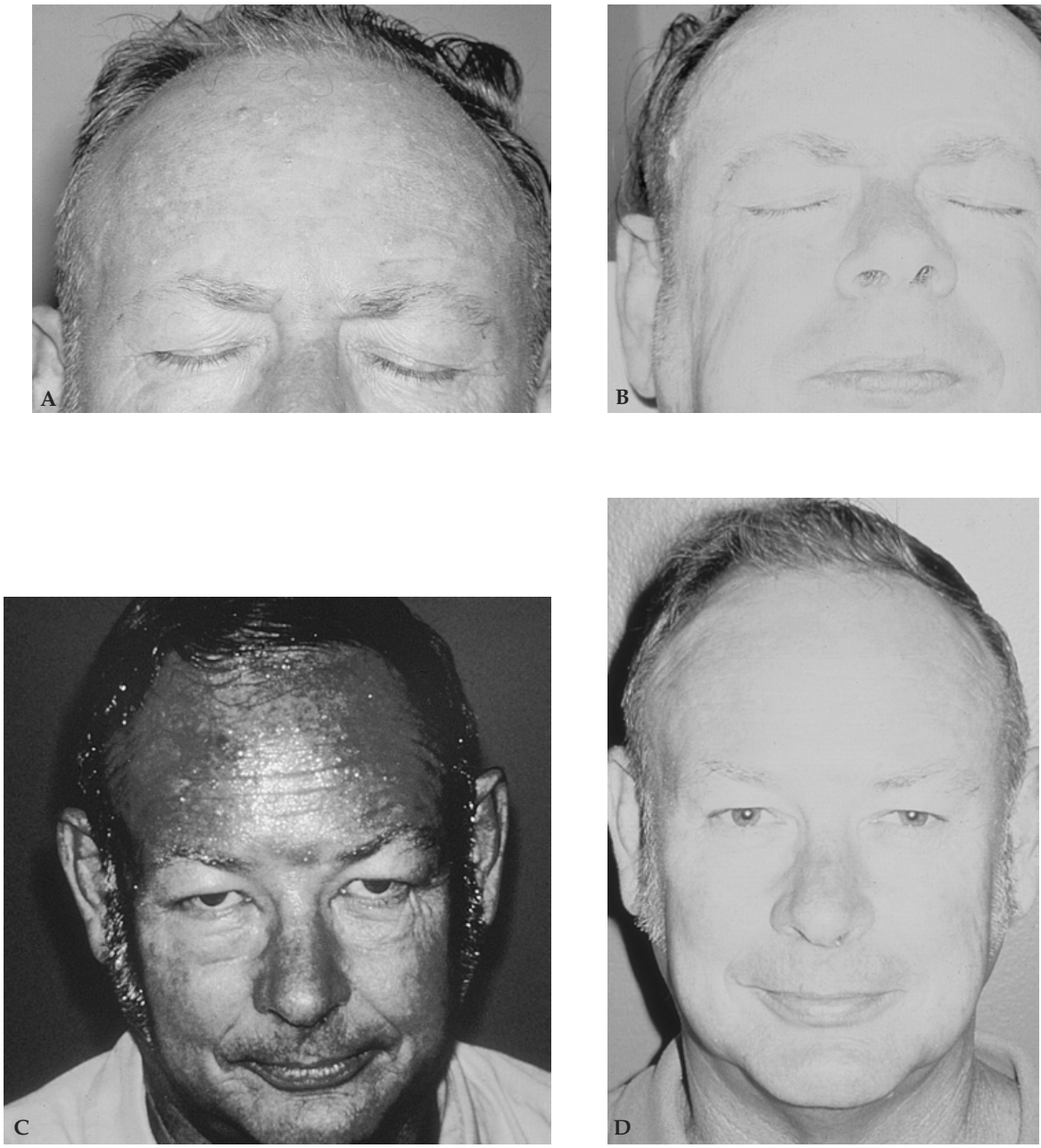

Figure 20–11 Treatment of actinic keratoses with Jessner's 35% TCA peel. **(A)** Preoperative appearance—actinic keratoses forehead and temples. **(B)** Application of Jessner's solution with 35% TCA—level II frosting. **(C)** Jessner's solution with 35% TCA, 3 days postoperative. **(D)** Six weeks postoperative.

been found to be unreliable, with a high incidence of scarring and postoperative complications. For this reason it is not included as a standard treatment for deep chemical peeling. The Baker–Gordon phenol peel has been used successfully for more than 40 years for deep chemical peeling and produces reliable results (Table 20–6). It is a labor-intensive procedure that must be taken as seriously as any major surgical procedures. The patient requires preoperative

TABLE 20–6 The Formula for the Baker–Gordon Phenol Peel

3 mL USP liquid phenol 88%
2 mL tap water
8 drops liquid soap (Septisol)
3 drops croton oil

Figure 20–12 The Jessner's + 35% TCA peel for moderately photoaging skin and acne scars. **(A)** Preoperative appearance. **(B)** Six months postoperative.

Figure 20–13 Treatment of pigmentary dyschromias with medium-depth chemical peel and cosmoceutical treatment with tretinoin and hydroquinone 4%. **(A)** Preoperative appearance. **(B)** Postoperative appearance, 6 months.

sedation with an intravenous line and preoperative intravenous hydration. Usually a liter of fluid is given preoperatively and, in addition, a liter of fluid is given during the procedure. Phenol is both a cardiotoxin and a hepatotoxin, and it is nephrotoxic. For this reason, one must be concerned with the serum concentration of phenol through cutaneous absorption. Methods to limit this include the following:

1. *Giving intravenous hydration prior to and during the procedure* to flush the phenolic products through the serum.
2. *Extending the time of application for a full-face peel to more than 1 hour.* Cosmetic units are applied for the 15-minute wait between units. That is, the forehead, cheeks, chin, lips, and eyelids are each given a 15-minute period for a total of 60 to 90 minutes for the procedure.
3. *Monitoring of the patients.* If there is any electrocardiographic abnormality (i.e., premature ventricular contraction or premature aortic contraction), the procedure is stopped and the patient watched carefully for other signs of toxicity.

Figure 20–14 Combination deep chemical peel—perioral area with medium-depth peel over remaining face. **(A)** Preoperative. **(B)** Peel solution applied. **(C)** Postoperative, 4 days. **(D)** Postoperative, 6 weeks.

4. *Administration of oxygen.* Many physicians believe that O_2 given during the procedure can be helpful in preventing rhythm complications.
5. *Proper patient screening.* Any patient with a history of cardioarrhythmia, hepatic or renal compromise, or on medications that give a propensity for arrhythmias should not undergo the Baker–Gordon phenol peel.[49]

Patients who are undergoing deep chemical peeling must recognize the significant risk factors, the increased morbidity, and possible complications involved in this procedure so that the benefits can be weighed positively against these particular factors. In the hands of those who perform this technique regularly, it is a reliable and safe way to rejuvenate severely photoaged skin that may show deep perioral rhytids, periorbital rhytids and crow's feet, forehead lines and wrinkles, as well as the other textural and lesional changes associated with the more severe photoaging process.

There are two modalities for deep chemical peeling: Baker's formula phenol unoccluded, and Baker's formula phenol occluded. Occlusion is accomplished with the application of waterproof zinc oxide tape, such as 0.5-in. Curity tape. The tape is placed directly after the phenol is applied to each individual cosmetic unit. Tape occlusion increases the penetration of the Baker's phenol solution and is particularly helpful for deeply lined, "weather-beaten" faces. A taped Baker's formula phenol peel creates the deepest damage in midreticular dermis, and this form of chemical peeling should only be performed by the most knowledgeable and experienced cosmetic surgeons who understand the risks of overpenetration and deep damage to the reticular dermis.[50] These complications include hyper- and hypopigmentation, textural changes such as "alabaster skin," and the potential for scarring.

The unoccluded technique as modified by McCollough involves more skin cleansing and application of more peel

solution. On the whole, this technique does not produce as deep a peel as the occluded method.[51]

The Baker–Gordon formula for this peel was first described in 1961 and has been used with success for more than 40 years. The formula (Table 20–6) penetrated further into the dermis than full-strength undiluted phenol because full-strength phenol allegedly causes an immediate coagulation of epidermal keratin proteins and self-blocks further penetration. Dilution to approximately 50 to 55% in the Baker–Gordon formula causes keratolysis and keratocoagulation, resulting in greater penetration. The liquid soap Hibiclens is a surfactant that reduces skin tension, thus allowing a more even penetration. Croton oil is a vesicant epidermalytic agent that enhances phenol absorption. The freshly prepared formula is not miscible and must be stirred in a clear-glass medicine cup immediately before application to the patient. Although the mixture can be stored in an amber glass bottle for short periods, this is usually unnecessary. It is preferable to reformulate the mixture on a regular basis.

Techniques

Before the administration of anesthesia, the patient is seated and the face marked, noting such landmarks as the mandibular angle, the chin, the preauricular sulcus, the orbital rim, and the forehead. This is done to extend the peel thoroughly throughout the limits of the face and slightly over the mandibular rim to blend any color change. This peel does require sedation. An intravenous combination such as fentanyl citrate (Sublimaze) and midazolam (Versed) can be administered intravenously by an anesthetist while the patient is monitored and given intravenous sedation. It is helpful to use local nerve blocks along the supraorbital nerve, infraorbital nerve, and mental nerve with bupivacaine hydrochloride (Marcaine), which should provide some local anesthesia for up to 4 hours. The entire face then is cleansed and degreased with a keratolytic agent, such as hexochlorophene with alcohol (Septisol), with emphasis placed on oily areas such as the nose, the hairline, and the midfacial cheeks.

The chemical agent is then applied sequentially to six aesthetic units: forehead, perioral, right and left cheeks, nose, and periorbital areas. Each cosmetic area takes 15 minutes for application, allowing 60 to 90 minutes for the entire procedure. Cotton-tipped applicators are used with a similar technique as discussed on the medium-depth Jessner's–35% TCA peel. However, less agent is used because frosting becomes evident much more quickly. An immediate burning sensation is present for 15 to 20 seconds and then subsides; however, pain returns in 20 minutes and persists for 6 to 8 hours. The last area for the peel is the periorbital skin to which the chemical is applied with only damp cotton-tipped applicators. Great care is taken to keep the drops away from the eye and the tears off the skin, as tearing may allow the peel solution to reach the eye by capillary attraction. It is important to remember that water dilution of a chemical may increase the absorption; therefore, if the chemical does get into the eye, flushing should be done with mineral oil rather than water.

Following the full application of peel solution, the frosting becomes evident and the tape can be applied for an occluded peel. Ice packs can be applied at the conclusion of the peel for comfort; and if this is an untaped peel, petrolatum is used. A biosynthetic dressing, such as Vigilon or Flexzan, is applied for the first 24 hours.[52] The patient is usually seen in 24 hours for removal of the tape or the biosynthetic dressing and to monitor the healing. At this time the patient is reinstructed regarding the use of compresses and occlusive ointments or dressings. It is important to keep the skin crust free.

The four stages of wound healing are apparent after a deep chemical peel. They include (1) inflammation, (2) coagulation, (3) reepithelializaiton, and (4) fibroplasia.[53] At the conclusion of the chemical peel, the inflammatory phase has already begun with a brawny, dusky erythema that progresses for the first 12 hours. This is an accentuation of pigmented lesions on the skin as the coagulation phase separates the epidermis, producing serum exudation, crusting, and pyoderma. During this phase it is important to use debridant soaks and compresses as well as occlusive salves. These will remove the sloughed, necrotic epidermis and prevent the serum exudate from hardening as crust and scab. These authors prefer the use of 0.25% acetic acid soaks found in the vinegar-water preparation (1 teaspoon white vinegar, 1 pint warm water), as it is antibacterial, especially against pseudomonas and other gram-negative organisms. In addition, the mildly acidic nature of the solution is physiologic for the healing granulation tissue, and mildly debridant, as it will dissolve and cleanse the necrotic material and serum. We prefer to use bland emollients and salves such as petrolatum (Vaseline), Eucerin, or Aquaphor, as the skin can be monitored carefully day by day for potential complications.

Reepithelialization begins on day 3 and continues until day 10–14. Occlusive salves promote faster reepithelialization and less tendency for delayed healing. The final stages of fibroplasia continue well beyond the initial closure of the peeled wound and continue with neoangiogenesis and new collagen formation for 3 or 4 months. Prolonged erythema may last 2 to 4 months in unusual cases of sensitive skin or with contact dermatitis. New collagen formation can continue to improve texture and rhytides for up to 4 months during this last phase of fibroplasia.

Complications

Many of the complications seen in peeling can be recognized early on during healing stages. The cosmetic surgeon should be well acquainted with the normal appearance of a healing wound and its time frame for both medium and deep peeling. Prolongation of the granulation tissue phase beyond 7 to 10 days may indicate delayed wound healing. This could be the result of viral, bacterial, or fungal infection; contact dermatitis interfering with wound healing; or other systemic factors. A red flag should alert the physician to careful investigation, and prompt treatment should be instituted to forestall potential irreparable damage that may result in scarring.

Complications can be caused either intraoperatively or postoperatively. The two inherent errors that lead to intraoperative complications are (1) incorrect peel medication and (2) accidental solution misplacement. It is the physician's responsibility to ensure that the solution and its concentration are correct. TCA concentrations should be measured weight by volume as this is the standard for measuring depth of peel. Glycolic acid and lactic acid solutions as well as Jessner's solution must be checked for expiration date as the potency decreases with time. Alcohol or water absorption may inappropriately increase the potency, so one must ensure that the

shelf life is appropriate. The peel solution should be applied with cotton-tipped applicators, and in medium and deep peels it is best to pour the peel solution in a secondary container rather than apply the solution spun around the neck of the bottle because intact crystals may give the solution a higher concentration as it is taken directly from its container. One should be careful to apply the solution to its appropriate location and not to pass the wet cotton-tipped applicator directly over the central face where a drop may inadvertently fall on sensitive areas, such as the eyes. Saline and bicarbonate of soda should be available to dilute TCA or neutralize glycolic acid if inappropriately placed in the wrong area. Likewise, mineral oil should be present for Baker's phenol peels. Postoperative complications most commonly result from local infection or contact dermatitis. The best deterrent for local infection is the continuous use of soaks to debride crusting and necrotic material. *Streptococcus* and *staphylococcus* infections can occur under biosynthetic membranes or thick occlusive ointments. The use of 0.25% acetic acid soaks seems to deter this as does the judicious removal of ointment with each soak. *Staphylococcus, Escherichia coli*, or even *Pseudomonas* infection may result from improper care during healing and should be managed promptly with the appropriate oral antibiotic.

Frequent postoperative visits are necessary to recognize the early onset of a bacterial infection. It may present itself as delayed wound healing, ulcerations, buildup of necrotic material with excessive scabbing, crusting, pirulent drainage, and odor. Early recognition allows peeling of the skin and prevents the spread of infection and scarring.

Herpes simplex infection is the result of reactivation of the herpes simplex virus (HSV) on the face and most commonly on the perioral area. A history of previous HSV infection should necessitate the use of prophylactic oral antiviral medications. Patients with a positive history can be treated with 400 mg of acyclovir three times a day beginning on the day of the peel and continuing for 7 to 14 days, depending on whether it is a medium-depth or deep chemical peel. The mechanism of action is to inhibit viral replication in the intact epidermal cell. This would mean that the drug would not have an inhibitory effect until the skin is reepithelialized, which is 7 to 10 days in medium and deep peels. In the past, these agents were discontinued at 5 days and clinical infection became apparent in 7 to 10 days.[54]

Active herpetic infections can easily be treated with antiviral agents. When treated early, they usually do not scar.

Delayed wound healing and persistent erythema are signs that the peel is not healing normally. The cosmetic surgeon must know the normal time table for each of the healing events to occur so that he or she may recognize when healing is delayed or the erythema is not fading adequately. Delayed wound healing may respond to physician debridement if an infection is present, to corticosteroids if due to contact allergic or contact irritant dermatitis along with a change of the offending contact agent, or to protection with a biosynthetic membrane such as Flexzan or Vigilon. When this diagnosis is made, patients must be followed daily with dressing changes and a close watch on the healing skin.

Persistent erythema is a syndrome where the skin remains erythematous beyond what is normal for the individual peel. A superficial peel loses its erythema in 15 to 30 days, a medium-depth peel within 60 days, and a deep chemical peel within 90 days. Erythema and/or pruritus beyond this period of time is considered abnormal and fits this syndrome. It may be contact dermatitis, contact sensitization, reexacerbation of prior skin disease, or a genetic susceptibility to erythema, but it may also indicate potential scarring. Erythema is the result of the angiogenic factors stimulating vasodilation which also includes the phase of fibroplasia is being stimulated for a prolonged period of time. For this reason, it can be accompanied by skin thickening and scarring. It should be managed promptly and appropriately with topical steroids, systemic steroids, intralesional steroids if thickening is occurring, and skin protection to eliminate the factors of irritancy and allergy. If thickening or scarring becomes evident, other measures that can be helpful include the daily use of silicone sheeting and dye-pulsed laser treatment of the vascular factors. With prompt intervention, scarring can often be averted.

Conclusion

It is the physician's responsibility to choose the appropriate modality for management of such skin conditions as photoaging, scarring, dyschromia, and neoplasia. Many modalities are available, including the three levels of chemical peel reviewed. The physician must have thorough knowledge of all of these tools so as to offer each patient the optimal treatment.

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Chapter 21

Laser Facial Resurfacing

Paul J. Carniol and Christopher B. Harmon

The carbon dioxide (CO_2) laser was invented in 1964 by Patel.[1] In the mid-1980s, CO_2 lasers were used by some physicians for the removal of exophytic skin lesions and limited cutaneous skin resurfacing. The usefulness of the continuous-wave CO_2 laser (10,600 nm) was limited by its long pulse duration, which had the potential to produce unwanted thermal damage and scarring.[2–5] As laser technology improved, higher energy laser systems were developed that offered much shorter pulse durations more suitable for resurfacing. One of the first reported resurfacing treatments with a pulsed CO_2 laser was performed by Larry David.[6] In 1993, Fitzpatrick reported use of the Ultrapulse CO_2 (Coherent Medical Products, Palo Alto, CA), which boasted much shorter pulse duration (1000 microseconds) than earlier pulsed or superpulsed CO_2 lasers. This ultrashort pulse duration proved ideal for the removal of superficial skin tumors and a cutaneous resurfacing.[7]

Initially, in describing CO_2 laser resurfacing it was recommended that resurfacing be performed until a "chamois" appearance of the tissues was achieved. In 1995, Carniol recommended the first modification of this technique to decrease post-resurfacing complications and facilitate healing.[8] Other pulsed and scanned lasers, such as Silktouch and Feathertouch (Sharplan Lasers, Allendale, NJ) and Paragon (Lasersonics), have been developed for facial resurfacing. Most of these lasers utilize a 900- to 1000-microsecond pulse duration. Some systems, such as Tru-Pulse (Tissue Technology), have shorter pulse durations at 900 to 1000 microseconds.

Many laser systems employ a computerized scanner generator, which allows larger surface areas to be treated in a very systematic fashion.[9] More recently; a generation of erbium:YAG (YAG = yttrium aluminum garnet) lasers, wavelength 2940 nm, have also been developed for resurfacing. Typically, erbium lasers produce a more superficial ablation per pass with less postoperative erythema and a quicker recovery phase than other lasers. Technology has continued to advance with resurfacing systems that combine erbium and CO_2 lasers as well as dual erbium lasers for coordinated ablation and coagulation.[10,11]

Other lasers, such as the flashlamp dye-pulsed laser and the neodymium (Nd):YAG laser, have also been useful in resurfacing with rhytid improvement and collagen growth stimulation.[12] Whereas dermabrasion and chemical peeling have been the standard bearers of resurfacing treatments, nonlaser resurfacing devices have now become available that utilize a bipolar radiofrequency. These ablation devices create a plasma from a saline solution; they resurface by causing cell dissociation rather than using heat for vaporization.[13]

LASER BIOPHYSICS

The concept of selective photothermolysis allows the surgeon to select a laser wavelength that is maximally absorbed by the targeted tissue component, the tissue chromophore. The primary chromophore for the CO_2 lasers and erbium:YAG lasers is water. A curve can be plotted for water or other laser chromophores comparing the laser energy absorption with the laser wavelength. Consideration should also be given to other chromophores that may inadvertently absorb that wavelength. The other chromophore can be called a competing chromophore. For example, at a wavelength of 532 nm, there is absorption of laser energy by both oxyhemoglobin and melanin. The possibility of competing chromophores should be considered whenever a laser is being selected. The extra effect on the competing chromophore may be desirable or undesirable.

The current hair reduction lasers exert their effect on melanin, the target chromophore. These lasers may also be absorbed by hemoglobin, which is a competing chromophore. Absorption by hemoglobin can also result in injury to the blood vessels supplying the hair follicle, which is desirable.

Ninety percent of the epidermis is water. Consequently, water is the primary chromophore for current resurfacing lasers. During resurfacing treatments, the intercellular water absorbs laser energy and instantly boils or vaporizes. The amount of energy that a laser delivers to the tissue and the time over which it is delivered determines the amount of tissue vaporized. For skin resurfacing, the objective is to vaporize the primary chromophore, water, while transferring minimal heat to the surrounding collagen and other structures. This is because type I collagen is extremely heat-sensitive and becomes denatured at 60 to 70°C. Excessive thermal injury to the collagen can produce unwanted scarring.

The fluence of a laser represents the amount of energy (joules) that is applied to the surface area of tissue (centimeter squared). Therefore, fluence is expressed as J/cm^2. For CO_2

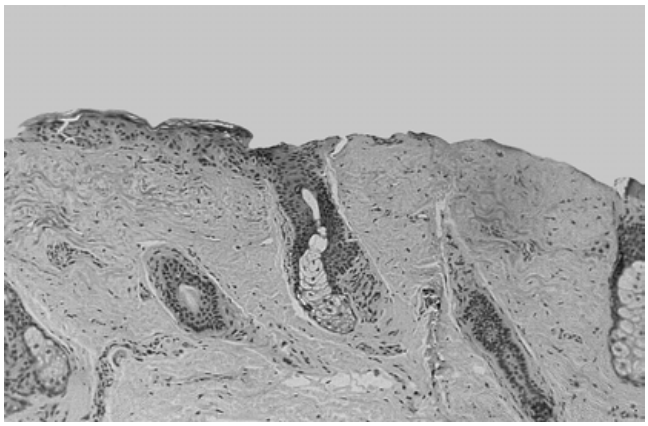

Figure 21–1 Immediately following a single pass with the coherent Ultrapulse laser, the epidermis has been ablated on the right half of the specimen. A thin layer of basophilic thermal necrosis can be seen beneath the ablated epidermis.

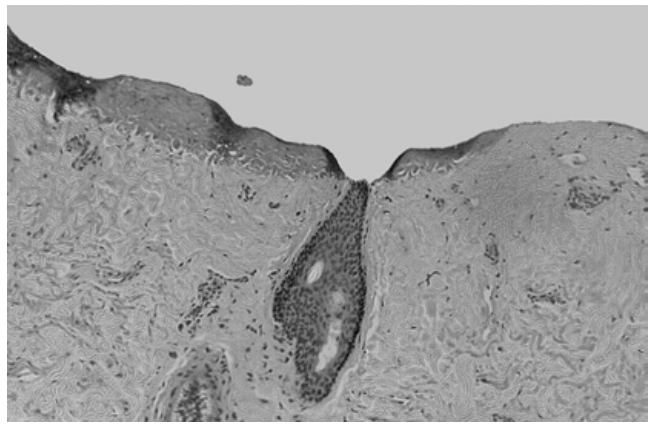

Figure 21–2 After five passes with the Tru-Pulse CO_2 laser, a broad zone of thermal necrosis can be seen beneath the ablated epidermis.

lasers, 0.04 J/mm^2 is the critical energy needed to overcome the tissue ablation threshold. For skin resurfacing, this is usually accomplished with 250 mJ per pulse using a 3-mm spot size. After each pulse the tissue is allowed to cool before the delivery of the next pulse. The tissue thermal relaxation time is the amount of time necessary between pulses for complete cooling to occur. With laser resurfacing, a very high energy is selected to vaporize target tissue almost instantly. This high energy allows very short pulse durations (1000 microseconds) to be used. Consequently, unwanted heat conduction to adjacent tissue is minimized. Power density, usually measured in watts, takes fluence, pulse duration, and treatment area into account (i.e., 60 W). A common misconception is that lower fluences or lower power densities will reduce the risk of scarring, when in reality the lower energy boils the water more slowly and causes greater nonspecific thermal injury.

Histologic studies of biopsies taken immediately after laser resurfacing demonstrate a zone of tissue vaporization and ablation beneath which lies a basophilic zone of thermal necrosis[14] (Fig. 21–1). The energy of initial laser pass is absorbed by the water within the epidermis. Once the dermis has been entered, there is less water to absorb laser energy, and heat transfer contributes to more thermal injury with each successive pass (Fig. 21–2). So ideally, a greater depth of ablation with a smaller number of passes and less thermal injury offers the least risk of scarring. Ultrastructural studies demonstrate smaller collagen fibers within larger collagen bundles in the papillary dermis (Fig. 21–3A,B). After laser resurfacing, wound-healing molecules, such as the glycoprotein tenascin, are expressed as new collagen that is produced in the papillary dermis (Fig. 21–4).

One of the current erbium lasers can fire two erbium lasers simultaneously. One of these can be adjusted to cause greater adjacent tissue injury by being set on coagulate. This laser achieves the greater thermal injury by increasing the pulse duration and therefore heating the tissues more slowly. Alternatively, too much energy can cause a deeper level of

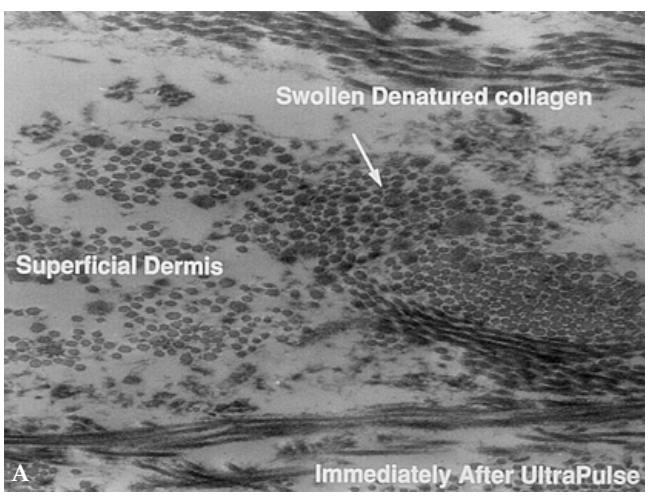

Figure 21–3 **(A)** A scanning electron micrograph demonstrates a partially ablated basement membrane zone overlying thermally altered collagen fibers. **(B)** A higher power electron micrograph reveals smaller denatured collagen fibers with the collagen bundles.

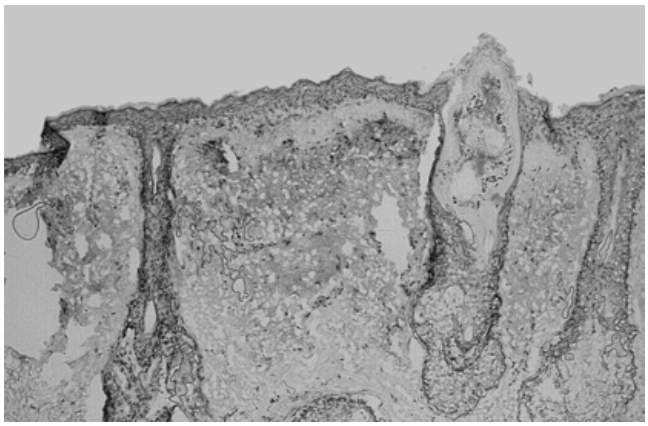

Figure 21–4 Immunoperoxidase staining demonstrates tenascin, a glycoprotein expressed during wound healing, throughout the newly regenerated papillary dermis.

evaporization than is desired. With current lasers, collagen is affected by the heat that is generated with resurfacing. The greater the thermal injury, the more new-collagen synthesis. In the future, resurfacing lasers that are well absorbed by water and collagen[15] may be used clinically.

LASER SAFETY

The importance of proper laser safety technique cannot be overemphasized. Laser safety includes, but should not be limited to, the current ANSI standards.[16]

Protective Eyewear

The first safety issue with any laser is avoidance of eye injury. Injury can occur with visible and invisible laser wavelengths. Most of the current invisible resurfacing lasers have a separate simultaneous low-energy laser, usually helium–neon, which serves as an "aiming beam." This beam is visible when the laser is in use.

The eyes of the patient, laser room staff, and surgeon must be protected from inadvertent injury by the laser. Everyone in the room must have eye protection. The eye-protective wear must be appropriate for the particular laser wavelength. The optical density (OD) and wavelength for which the eyewear is protective should be printed on the eyewear frame. Laser protective glasses or goggles should have an OD of at least 5. The OD scale is exponential. Thus, an OD of 5 means that for the specified wavelength noted on the side of the glasses or goggles, only one ten-thousandth of the laser energy will get through the lenses. Patients either should have protective eyewear, or keep their eyes closed and have wet eye pads over their closed lids when using either erbium or CO_2 resurfacing lasers. When working on the thinner eyelid skin inside the osseus orbital margin, eyes should be protected with nonreflecting metal eye shields.

Nonflammable Drapes

Wet drapes or reflective foil will reduce the risk of spark-induced combustion.

Skin Preparation

Alcohol-based skin preparations should be avoided. It is safer to use aqueous-based solutions, such as Phisohex. Proper precautions must be taken for all skin cleansers.

Smoke Evacuator

Smoke evacuators with specifically designed laser filters to trap laser plume contents should be used.

Laser Masks

Each person in the operating room should use a laser mask, which effectively filters infectious particles in the laser plume. These masks have a 0.1-μm filter pore size.

ANESTHESIA FOR RESURFACING

Resurfacing can be performed under topical, local, regional, intravenous, or general anesthesia. At times, a topical anesthetic, such as EMLA cream, can be used for a single superficial pass with the erbium laser for resurfacing. Any additional passes will require additional anesthesia. EMLA cream alone does not provide adequate anesthesia for carbon dioxide resurfacing. To optimize the laser surgeon's ability to visualize the depth of resurfacing when using local anesthesia for resurfacing, it is important that a local anesthetic be used without epinephrine, or with epinephrine at a maximum concentration of 1:400,000. Dilute solutions of lidocaine (0.05%), such as used in tumescent liposuction, can be used with central facial nerve blocks to provide excellent anesthesia. When resurfacing, the depth must be evaluated carefully. If too much epinephrine is used, the pink color that heralds entry into the papillary dermis may not be seen after an initial laser pass. Likewise, excessive epinephrine can obscure the pinpoint bleeding produced by erbium passes into the papillary dermis. If needed, local anesthesia can be supplemented with intravenous anesthesia. When using general anesthesia, there is a greater risk of fire associated with the use of oxygen and an endotracheal tube. There are now metal endotracheal tubes, and foil wrappings for plastic endotracheal tubes, that are designed specifically to be used with lasers to prevent endotracheal tube ignition.

PREOPERATIVE PATIENT CARE

Patients who undergo resurfacing require intensive prelaser and postlaser management. There is still controversy over whether skin preparation is needed for resurfacing. Some surgeons advocate pretreatment with hydroquinone, isotretinoin, or glycolic acids.[17–19] Other physicians do not use any formal preparation before the procedure. Most surgeons agree that avoidance of sun before resurfacing is important. Exposure to the sun before resurfacing can activate the melanocytes and predispose the patient to hyperpigmentation. The risk of activating a prior or new primary herpetic infection with resurfacing prompts almost all surgeons to initiate antiviral therapy 24 to 48 hours before resurfacing. This antiviral therapy should be continued for 10 to 14 days until all reepithelialization is complete.

The use of prophylactic antibiotics is much less universal, Many surgeons give antibiotics before and after the procedure to

diminish the incidence of bacterial infection with prolonged or closed-mask dressings. Some physicians believe that prophylactic antibiotics do not diminish the chance of post-resurfacing infection.[20] Physicians who use prophylactic antibiotics frequently give prophylactic antifungal medication to prevent yeast infections underneath the dressings.

INTRAOPERATIVE TECHNIQUES

Prior to resurfacing treatments, patients should be marked and cosmetic units outlined. It is important to mark the patient while he or she is sitting up as the skin moves when supine. Supine marking can cause an error in marking the margin of the mandible. Care must be taken not to place any marks on denuded skin because of the risk of permanent tattooing. Partial resurfacing treatments should be feathered along the boundary of a given cosmetic unit (i.e., orbital rim, nasolabial folds). The margin of a full-face treatment should be feathered along the mandible to produce a natural transition to the untreated skin of the neck (Fig. 21–5A, B).

In monitoring the depth of treatment with each pass, the laser energy and power settings are much less important than the clinical end points. With CO_2 laser resurfacing, a pink color can be seen as one enters the papillary dermis. As resurfacing progresses, this color changes to a yellow chamois within the reticular dermis. Most surgeons use saline gauze to remove vaporized tissue between each CO_2 pass. With erbium passes, pinpoint bleeding is seen with entry into the papillary dermis. As one proceeds more deeply into the dermis, bleeding spots are much larger.

Because of the hour-glass shape of the pilosebaceous unit, the diameter of the pores enlarges as the level of ablation deepens. Furthermore, variation of skin thickness from one cosmetic unit to another calls for an adjusted number of laser passes and settings. Obviously, less tissue penetration is tolerated in the thinner skin of the eyelid than the thicker, appendage-abundant skin of the midcheek (Fig. 21–6A, B). Likewise individual variation between patients requires less aggressive passes on thin, dry skin as opposed to deeper ablation on thicker, sebaceous skin. For example, the photodamaged thin skin of a 65-year-old female patient (Fig. 21–7A, B) will tolerate less laser energy than the skin of a 25-year-old male patient with acne scars. Many times the pathology (i.e., rhytids or scars) extends beyond the safety zone of treatment. The other important end point of laser resurfacing, which usually precedes entry into the reticular dermis, is the disappearance of photodamage, rhytids, or further tissue tightening.

POSTOPERATIVE PATIENT CARE

As recognized by previous dermabraders, semiocclusive wound dressings, such as Vigilon or Flexan, have rapidly decreased the time of reepithelialization to as short as 5 to 7 days by maintaining a place of critical humidity for epithelial cell migration.[21] More rapid healing, less pain, less scarring, and less erythema are seen with these dressings than open or desiccated wounds. Most surgeons change these dressings daily for 3 to 5 days. Open wound care with occlusive ointments can also be used.

Figure 21–5 **(A)** Extensive photodamage prior to full face CO_2 resurfacing. **(B)** One month after full-face resurfacing, a natural transition from the treated skin of the cheek to the untreated skin of the neck is created by feathering along the mandible.

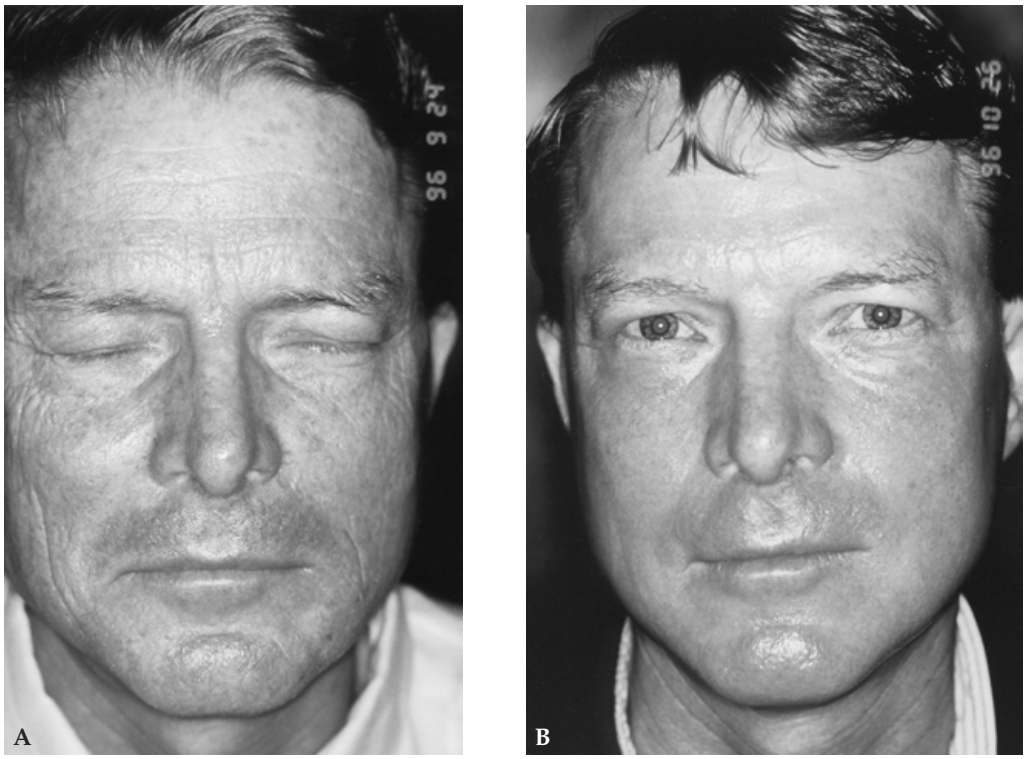

Figure 21–6 **(A)** Preoperative photoaging and rhytids can be seen extending onto the lateral and lower eyelids. The eyelid skin will be treated with one or two fewer passes than the lower face. **(B)** Following full-face laser surgery, a smaller number of passes over the eyelids prevents unwanted scarring or ectropion.

Figure 21–7 **(A)** Rhytids and photoaging in a thin-skinned 65-year-old woman. **(B)** Six months following full-face resurfacing, rhytids and photodamage have improved but postoperative erythema persists over the malar prominence.

Once reepithelialization is complete, strict sun avoidance is critical until all postoperative erythema has subsided (usually 2 to 3 months). Fragrance-free moisturizers will improve skin hydration while avoiding contact sensitization. Class I and II topical steroids may also be helpful in reducing postoperative edema. These should only be used for brief periods. Hypoallergenic, noncomedogenic makeup can be used once reepithelialization is complete to camouflage unwanted redness. Typically, green- or yellow-based foundations will neutralize the bright red postoperative erythema.

COMPLICATIONS

Transient postinflammatory hyperpigmentation occurs frequently at 2 to 6 weeks postoperatively. This darkening is sun-induced and usually clears nicely with sun avoidance, hydroquinones, retinoic acid, and mild topical steroids.

Hypopigmentation, on the other hand, is permanent and unpredictable. This complication usually has a delayed onset of several months. Fortunately, it only occurs in 10 to 30% of patients.

Scarring is the most feared problem, beginning with persisting hyperemia that becomes indurated and nodular. Treatment with intralesional steroids, steroid impregnated tape, or topical steroids is highly successful. Certain areas of the face, such as the malar prominence, upper lip, and mandible are prone to hypertrophic scarring.

Viral infections are heralded by intense pain and can occur despite the use of low-dose antiviral prophylaxis. They usually are seen 7 to 10 days following surgery as reepithelialization is concluding. A herpetic breakthrough should be treated aggressively with zosteriform dosages of medication.

Bacterial infections can also produce postoperative pain and greatly increase the risk of scarring. Furthermore, secondary fungal infections can occur when dressings are worn for more than 24 hours without being changed, or when tissue debridement and exudate removal are inadequately performed with dressing changes.

A much higher incidence of contact dermatitis occurs following laser resurfacing to ointments such as Neosporin, Polysporin, and even petrolatum. Discontinue the use of the offending agent and treat with midpotency topical steroids, as well as systemic steroids.

Careful attention to the patient's skin type, areas of treatment, and laser parameters can greatly maximize surgical benefits while minimizing potential side effects. Furthermore, close and attentive follow-up during the postoperative period will anticipate and reverse nearly all untoward outcomes and complications. The most important postoperative routine is constant encouragement and patient hand-holding.

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Chapter 22

Injectable and Implantable Materials for Facial Wrinkles

Nathan Monhian, Min S. Ahn, and Corey S. Maas

The quest to achieve facial harmony and rejuvenation has led to extensive research, with ultimate development of a variety of materials and new techniques for their use. These range from extensive surgical procedures to minimally invasive methods using injectable or implantable materials for soft tissue augmentation. Furthermore, the types of materials available cover a wide spectrum, from biologically derived to synthetically engineered.

Although a variety of excellent choices for soft tissue augmentation and management of facial wrinkles exist, no single material has been found to meet all of the criteria for an "ideal" implant.[1–3] Such material must be biocompatible and nonimmunogenic, producing minimal inflammatory response. It should also be biodegradable or easily retrievable. Persistent and predictable pattern of behavior after implantation with minimal migration is another essential requirement of such a substance. Clearly, the implant material must be free of carcinogenic, teratogenic, or infectious properties. Selection of a material depends on the inherent advantages and limitations of the material, the specific clinical indication, and personal experience.

PATHOGENESIS OF FACIAL WRINKLES

Facial wrinkles are the product of repeated and habitual contraction of the underlying muscles of facial expression. Contraction of the facial muscles is accompanied by a lack of shortening of the skin, producing a wrinkle. Other factors, such as the amount of subcutaneous fat, the water content of the skin, the distribution and ratio of collagen and elastic fibers, and the biochemical changes in the connective tissue and the interstitial spaces, can affect the skin texture and therefore facial wrinkling.[4,5] The major mechanisms affecting one or more of the above-mentioned factors are aging, actinic damage, and cutaneous disorders. With further tissue laxity and over time, the effects of gravity on facial tissues can lead to deepening of facial wrinkles, particularly in the areas of nasolabial and melolabial folds.

There is a large body of literature devoted to the aging process in human skin.[4–7] In general, the aging of skin is a process of atrophy. There is little change in the thickness of the stratum corneum, but there is loss of dermal papillae. There is a reduction in the number of Langerhans cells and melanocytes. The total amount of dermal connective tissue, composed of glycosaminoglycans and proteoglycans, diminishes with age.[4] There is significant loss of collagen fibers in aging skin, to the point that the ratio of elastin to collagen changes, and the elastic component may appear larger in older skin.[6] The skin appendages are also affected by aging. Sebaceous glands tend to increase in size, although their number remains relatively constant. Pacinian and Meissner's corpuscles decrease in number in aging skin.

Unlike normal skin, actinically damaged skin actually thickens with aging. The main characteristic of such change is the presence of thickened, degraded elastin fibers.[8] This condition is described as "basophilic degeneration" or "elastosis."[9] Mature collagen is decreased, with immature type III collagen becoming dominant at the expense of the usually abundant type I collagen. It is now known that both ultraviolet A and ultraviolet B (UVA and UVB) cause actinic skin damage. Harmful doses of UVA have been recorded in normal sunlight, most fluorescent light, and in sun-tanning booths.[9] UVA alone can induce photoaging changes in skin, but if combined with UVB in normal sunlight, the elastosis occurs much sooner.[10] Superoxide radicals are thought to be involved in ultrastructural damage caused by UV radiation.[11,12] Unfortunately, many commercially available sunscreens that effectively block UVB do not block UVA radiation. In addition, heat intensifies the damage induced by UV radiation.

Certain inherited dermatologic conditions can present as excessive skin laxity or premature aging. Among these conditions are Ehlers-Danlos syndrome, progeria, pseudoxanthoma elasticum, and cutis laxa.[13]

HISTORICAL BACKGROUND

The history of modern soft tissue augmentation dates to the late 1800s when Neuber reported the use of small pieces of fat harvested from the upper arm to reconstruct depressed facial defects from tuberculous osteitis.[14] Gersuny was the first to use low-melting-point paraffin as an injectable material to correct a cosmetic deformity.[15] Over the ensuing years a number of injectable materials, including vegetable oils, mineral oil, lanolin, and beeswax, were tried. It soon became clear that the injection of paraffin and other oils was associated with a high incidence of inflammatory reaction and foreign-body granuloma formation and therefore was unsafe.[16] The use of paraffin in the Western world was abandoned around the time of World War I.

Severe tissue reaction and unpredictability of long-term results with the early materials led investigators in the early

1960s to assess the new highly purified polymers for such applications. Pure injectable liquid silicone, distributed in 1962 by Dow Corning as "medical grade" silicone, was embraced as ideal among these synthetic polymers. Despite the caution suggested in a number of reports, silicone soon became widely used for augmentation of many soft tissue defects by direct injection, in some cases using large volumes of the material.[17,18] Severe complications associated with large-volume implantation of liquid silicone finally led the U.S. Food and Drug Administration (FDA) to declare this material unsuitable for direct injection. However, some controversy remains regarding the efficacy and safety of the so-called microdroplet injection technique popularized by Orentreich, Webster et al.[19–21] Orentreich and Orentreich[19] reported that the record of purified injectable liquid silicone is one of "safety essentially without serious flaw in approximately 1400 patients under continuous study." Many of untoward outcomes of silicone injections were the result of unknown, sometimes adulterated, preparations of silicone, and not the Dow Corning product. However, the use of this product has not received FDA approval. This reflects the inherent lack of safety in implanting millions of microparticles into tissue with no effective way to remove them should complications occur.

Over the next three decades, further investigations have provided many alternative materials, both tissue-derived and synthetic. Injectable collagen, gelatin, and fat are among the available materials. Polytetrafluoroethylene (Teflon) paste, still used for vocal cord rehabilitation, was utilized for facial augmentation, but technical difficulties in injecting the thick paste were encountered, and an exaggerated inflammatory reaction prevented its widespread use. At present, a number of synthetic substances, including silicone, expanded polytetrafluoroethylene (ePTFE) and polyester, and polyamide meshes, constitute the bulk of accepted alloplastic materials[3,22] (Fig. 22–1).

CONTEMPORARY BIOLOGICALLY DERIVED FILLER MATERIALS

Currently in the United States the use of biologic materials derived from human or animal tissues is a more commonplace practice than the use of synthetic biomaterials. The two most commonly used materials for soft tissue augmentation are autologous fat and bovine collagen. With advancement of laboratory techniques in tissue culturing, injection of pooled human collagen and cultured fibroblasts has been added to present options.

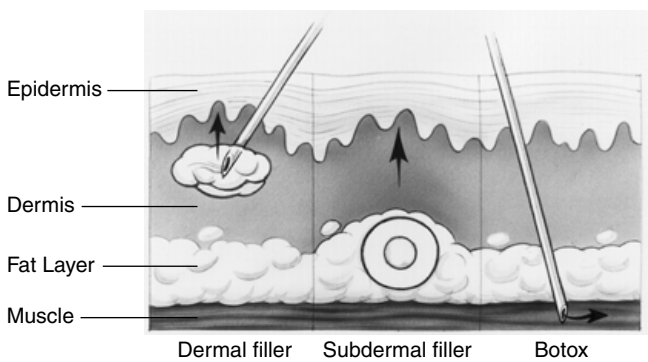

Figure 22–1 Methods of wrinkle management can be divided into two basic categories: (1) filler materials—intradermal (e.g., collagen) and subdermal (e.g., SoftForm); (2) neuromuscular agents (e.g., Botox).

Materials Derived from Autologous Human Tissue

Autologous Fat Injection

The unpredictable results with using free-fat autografts were soon realized and were mostly due to local absorption of the transplanted fat. Two decades after Neuber's report of successful free-fat autografting technique,[14] Bruning reported the first technique of fat injection.[23] He placed small pieces of fat into a syringe and used fat transfer to correct post-rhinoplasty deformities. Peer in 1950 reported an average loss of 45% in the weight of the free-fat implant by 1 year.[24] He proposed the cell survival theory, postulating that the living fat becomes ischemic after harvest, some fat cells die, and the tissue is resorbed and replaced by cystic structures and fibrous tissue. Other reports indicate that fat grafts that were harvested surgically maintained volume better than suctioned fat grafts.[25–26] With the advent of liposuction, as described by Illouz in the late 1970s, large amounts of fat were readily available for implantation.[27]

The method of microlipoinjection involves harvesting, storage, and reimplantation of fat. Fat is harvested aseptically into a sterile container, using local anesthesia and tumescent technique with a blunt-tipped microcannula or a syringe. The harvested fat can also be frozen in liquid nitrogen for future use. Lateral thigh, hips, buttocks, and abdomen can serve as potential donor sites. Serosanguinous material is separated from the fat, which is then washed with sterile saline. The fat graft is then injected into the subcutaneous tissue with a large-bore needle (Fig. 22–2). After injection, the area is massaged so that the fat fills the injected field smoothly. Indications for microlipoinjection include treatment of nasolabial and melolabial folds, glabellar furrows, lips, and hemifacial atrophy. Because of the expected absorption, overcorrection of 30 to 50% is usually recommended. Recipient sites with more mobility show a higher rate of resorption, and multiple treatments may be required for long-lasting results.[28,29]

In addition to donor site morbidity, potential complications of microlipoinjection include mild swelling and slight ecchymosis at the treatment site, which is usually resolved within 72 hours. There is one reported case of unilateral blindness following autologous fat injection to the glabella.[30] Resorption of the fat graft requiring repeated injections and replacement of the graft by fibrotic tissue have been the major problems with this technique.

Lipocytic Dermal Augmentation

In 1989, Fournier developed a modification of autologous fat injection.[31] He hypothesized that if adipocytes were ruptured and the triglyceride contents removed, the remaining cell walls and intracellular fibrous septae could be used as a fibrous tissue filler for correction of dermal abnormalities. He referred to this tissue as *autologous collagen*, assuming it was rich in collagen.

Coleman and colleagues have reported excellent clinical results with good patient acceptance.[32] The longevity of this material in their experience appeared to be comparable to

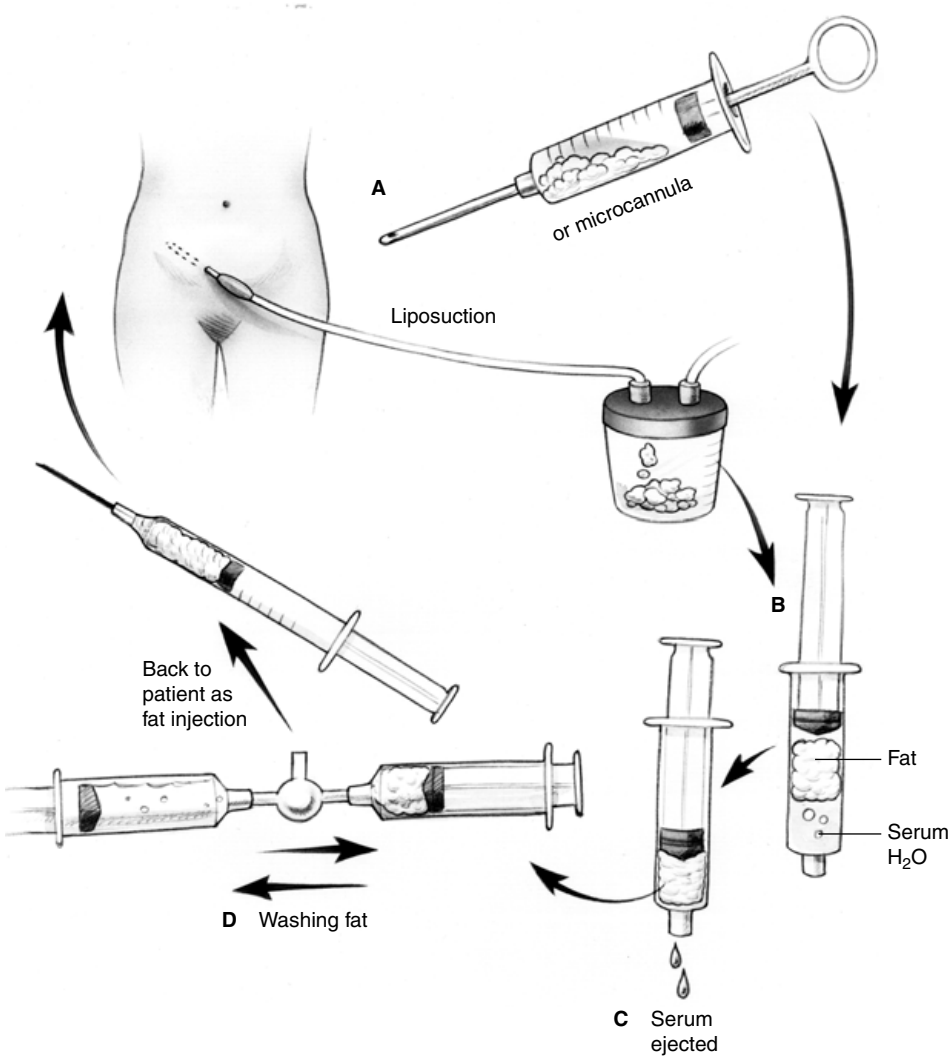

Figure 22–2 Harvest and preparation of autologous fat for injection.

that of Zyplast (processed from bovine collagen) or Fibrel (collagen from porcine source), especially if a second refining procedure is repeated 2 to 4 weeks later. Early biopsies revealed no intact adipocytes but a significant inflammatory infiltrate. Subsequent biopsies showed expansion of the dermis and replacement of the inflammatory cells with cellular fibrosis. Interestingly, they demonstrated that the refined graft material itself contained very little collagen. Instead, the injection promoted collagen deposition by the host.

Although technically more difficult and time consuming than use of Zyplast or Fibrel, this method of dermal augmentation appears to be safe and has produced acceptable clinical outcomes. It can be beneficial in management of perioral atrophy and correction of cutaneous scars. It can also be combined with other techniques, such as microlipoinjection, laser, or botulinum exotoxin A (Botox). The procedure often has to be repeated. However, because of abundance of donor material, it can be cost-effective, particularly for larger defects.

Fat is harvested as in the microlipoinjection approach. The fat is allowed to sit in syringes for a few minutes so that it can be separated from the liquid portion of the aspirate. The harvested fat is then transferred to small syringes, adding 1 cm^3 of sterile distilled water to each 2 cm^3 of fat, and the syringes are frozen in liquid nitrogen. The syringes are immediately thawed in warm water. This process separates the injectable supernate from the oily residue, which is discarded. By centrifuging the syringes for 1 minute at 1000 rpm, the triglycerides further separate from the injectable material. The processed fat can then be injected intradermally using a 23- or 25-gauge needle.

The longevity of augmentation from lipocytic dermal augmentation has been shown to be similar to that of Zyplast collagen.[33] Because of the anticipated resorption, slight overcorrection or repeat treatments should be considered. Side effects and complications of this procedure are the same as those of microlipoinjection.

Autologous Dermal Grafting

Dermal grafting constitutes dissection, harvest, and reimplantation of small, solid pieces of autologous dermis as a means of soft tissue augmentation. Initially used in ophthalmologic procedures and voice rehabilitation, dermal grafts have been used for the treatment of depressed scars, facial lines and wrinkles, and deep, broad, soft-tissue defects.[34–36] It is not as effective in the treatment of fine wrinkles or small, fibrotic acne scars. Large acne scars, at least 4 to 5 mm in diameter, tend to respond to this treatment best.

Undermining of scars alone has been shown to improve the appearance of these defects by separation of the anchoring fibrous bands from the overlying skin and formation of new collagen and granulation tissue, thus augmenting the defect.[37] However, after this technique, called *subcision*, the undermined scars in a number of instances eventually reattach to the underlying fibrous bands. The insertion of the dermal graft after subcision can theoretically prevent the reattachment of these bands and lead to longer lasting results. Subcision is first performed using an 18-gauge NoKor (Beckton-Dickinson and Co., Franklin Lakes, NJ) in the middermal plane. There is a gritty resistance to the needle as the fibrous bands are incised. Dermal grafting is performed 2 to 6 weeks after the initial undermining.[38]

The postauricular area can serve as a good donor site. The advantages of this area include its relative avascularity and scarcity of hair follicles or other skin appendages, and the fact that the scar will be hidden. The skin is dermabraded with a coarse diamond under local anesthesia to the level of deep dermis. Dermabrasion technique offers speed and precision in depth; however, the epidermis can also be removed with a scalpel or laser. The dermis can then be harvested using a scalpel to the level of the retroauricular fascia and is immediately placed in cold sterile saline. The donor site is closed with an absorbable suture material. The dermal graft with the attached fatty tissue is then dissected into appropriate pieces. Smaller grafts, 4 to 6 mm, can be used for smaller acne scars, whereas larger strips can be used for augmentation of larger defects, glabellar lines, or nasolabial folds. The recipient sites are then undermined with an 18-gauge NoKor needle in the middermis and the graft is then inserted through the needle hole and placed in the desired position. For larger or longer recipient sites, such as the nasolabial folds or the lip, one can pull the graft through underneath the undermined area by tying a suture to one end of the graft and passing it through the undermined tunnel. The two ends of the subcutaneous tunnel are then closed with a fine, absorbable suture, including the graft with the stitch.

Side effects and complications of this procedure include local bruising, hematoma, discoloration, edema, crusting, and pain. Wound infection is uncommon but possible. Development of epidermal inclusion cysts is possible if the epidermis is not completely removed from the graft. Acute cystic lesions can be painful but can be easily resolved with incision and drainage. Migration of the graft is not common and may necessitate insertion of an additional graft. Scarring at the incision sites may occur, but that can also be treated by resurfacing.

A correction of 40 to 70% after one session and 50 to 100% after two sessions has been reported. There is some settling of effects between 1 month and 6 months after the treatment; therefore, slight overcorrection at the time of grafting is recommended.[39,40]

Cultured Human Fibroblasts (Isolagen)

With the advent of new tissue culture techniques, large quantities of fibroblasts can be grown easily.[41] Tissue-cultured fibroblasts can then serve as potential dynamic, living filler material in correction of scars. Isolagen (Isolagen Technologies, Inc., Paramus, NJ) is the product of such a process.[42] The company processes 3-mm biopsies of autologous retroauricular skin and within 4 to 6 weeks prepares 1- to 1.5-cm^3 syringes of injectable autologous fibroblasts in biocompatible media. The product is then injected into the superficial, middle, and deep dermis with a tuberculin syringe and a 30-gauge needle (Fig. 22–3). The material must be injected within 24 hours of shipping to obtain

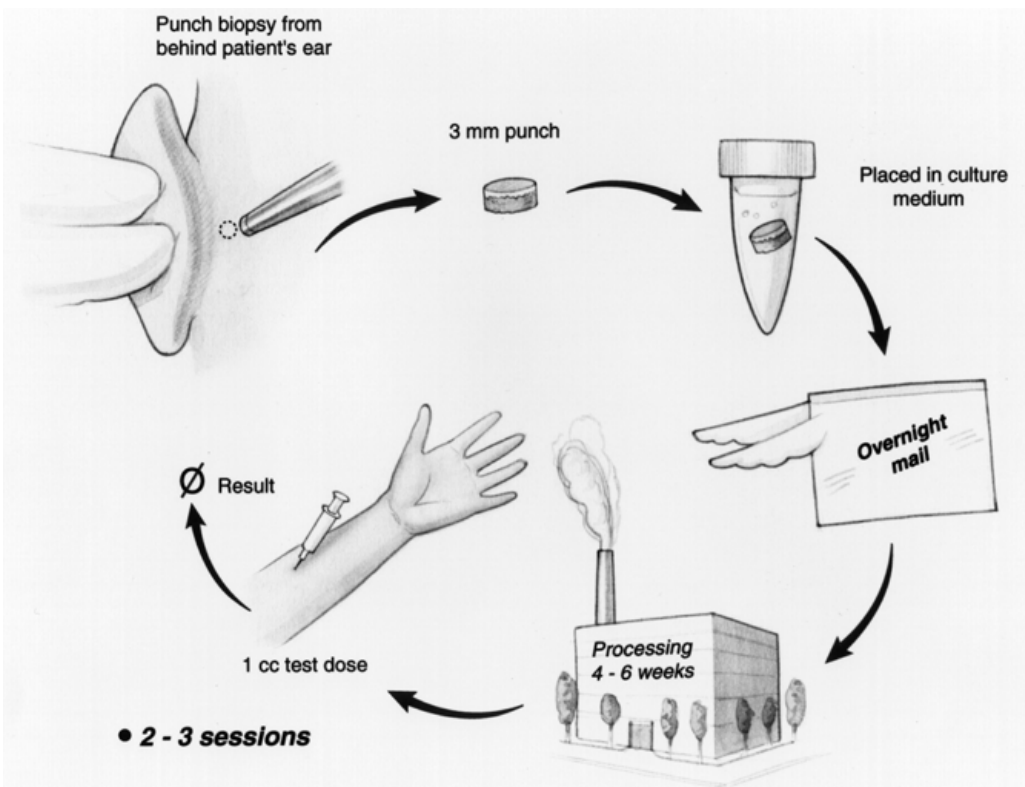

Figure 22–3 Manufacturing of Isolagen from autologous retroauricular skin.

95% viability of the fibroblasts. Viability drops to 85% and 65% at 48 hours and 72 hours, respectively.[43] It has been advocated for the treatment of facial rhytids, nasolabial folds, glabellar furrows, scars, and hypoplastic lips. The recommended treatment includes three to four injection sessions over a 3- to 6-month period. In a study of more than 100 patients with 18- to 30-month follow-up, patient satisfaction and patient-perceived degree of correction have been about 80%, with no report of major complications or hypersensitivity reactions. Isolagen can be combined with other resurfacing procedures or with bovine collagen injection for a more dramatic effect. Though the product and its concept appear promising, long-term results are yet to be determined.[43] This product is currently under investigation for FDA approval.

Autologous Injectable Collagen (Autologen)

Autologen (Collagenesis Inc., Beverly, MA) is composed of intact autologous collagen fibers dispersed into an injectable form derived from autologous dermis. The collagen fibers are suspended in a sterile, neutral pH phosphate buffer. This product is typically offered in a standard 4% solution (Autologen) or a cross-linked 6% preparation (Autologen XL), but it can also be custom concentrated to suit a patient's needs. Since the material is processed from the patient's own skin, it theoretically avoids allergic or immunologic reactions and the potential for disease transmission.[44,45]

Autologen has been advocated for treatment of facial wrinkles, dermal contour defects, and scars.[46] It is injected into the middermis, using a 27- or 30-gauge needle (Fig. 22–4). Injection at the proper level creates mild blanching of the overlying skin. Most defects require three or four injections at 2- to 4-week intervals. The suspension does not contain a local anesthetic, and injection can be painful.[47] In a retrospective analysis of 25 patients reported by De Vore and colleagues, there was 50 to 75% correction of facial wrinkles after a single injection for up to 3 months and 50% correction up to 6 months.[44] These results have not been repeated by all users.

The main disadvantage of Autologen is that skin must be obtained from the donor-recipient. So far, skin from blepharoplasty, facelift, browlift, abdominoplasty, scar revision, and other cosmetic procedures has been processed. Once tissue is collected, it can be frozen for up to 2 weeks or shipped to the company's laboratory immediately. The yield is approximately 1 mL per 2 in.^{2} of donor skin. Limited histopathologic studies show no significant inflammatory reaction to Autologen.[47] Additional clinical studies of Autologen are required to assess its long-term effects.

Materials Derived from Homologous Human Tissue

Acellular Human Dermal Matrix (AlloDerm)

Soft-tissue augmentation using human-derived tissues has historically produced variable results. Although autologous grafts are generally preferred, donor site morbidity is an obvious limitation in their use. AlloDerm (LifeCell Corp., The Woodlands, TX) is an acellular dermal matrix processed from human allograft skin, obtained from U.S. tissue banks. The structural and biochemical integrity of dermis and the basement membrane is maintained and the graft is freeze-dried without damage to the extracellular matrix.[48] Cell removal is accomplished by uncoupling cell matrix adhesion through manipulation of calcium concentration, ionic strength, and acidity together with the use of low molecular weight buffered detergents. The process renders the graft nonimmunogenic. It is stable for 2 years under refrigeration and is rehydrated for 10 to 20 minutes in normal saline or lactated Ringer's solution immediately prior to use (Fig. 22–5).

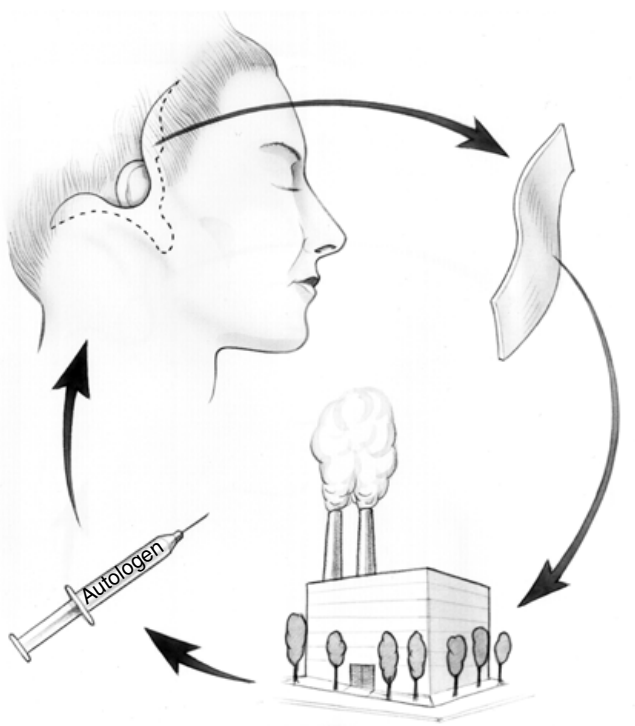

Figure 22–4 Preparation of Autologen from autologous skin.

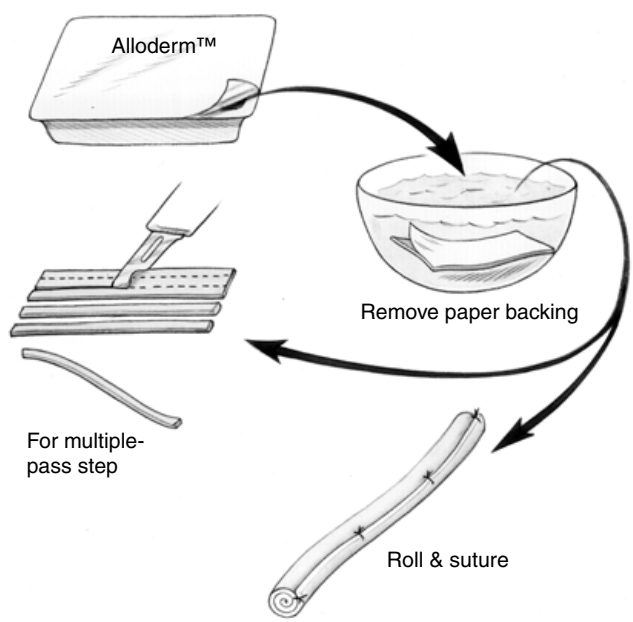

Figure 22–5 After rehydration, AlloDerm is designed in appropriate rolls or strips prior to implantation. These rolls are generally placed by retrograde tunneling.

AlloDerm was first used clinically in the treatment of full-thickness burns.[49] Since its first use, it has been applied in a variety of reconstructive and cosmetic procedures as a soft-tissue augmentation material. Experience with AlloDerm in lip augmentation[50,51] and treatment of nasolabial and melolabial folds[52,53] and glabellar frown lines has been satisfactory. It has also been used as a dermal implant in small pieces to elevate depressed scars.

For nasolabial folds, a 3 × 7 cm piece of AlloDerm is cut diagonally into two triangular segments.[52,53] Each segment is rolled along its long axis after rehydration. Some surgeons use an absorbable suture material to secure the free edges of the graft. In these instances, however, minimal suture should be used to prevent inflammation. Incisions are made at the corner of the lip and in the alar groove at the base of the nostril, and a subdermal tunnel is created with an elevator. The graft is then pulled through and is gently massaged and positioned properly along the tunnel. The incision sites are closed with sutures, and oral and topical antibiotics are administered for several days.

Perioral atrophic wrinkles can be treated with lip augmentation using AlloDerm.[50,51] Generally, a 3 × 7 cm piece of the graft is hydrated and rolled on itself. The graft can also be trimmed to obtain a specific contour and thickness. The use of sutures to secure the shape of the graft should be minimized. Some surgeons place the graft without any sutures, allowing the graft to conform to the insertion tunnel. Small incisions in the oral mucosa, slightly lateral to the oral commissure, are made and a submucosal tunnel is created just inferior to the vermilion border using blunt dissection. Care is taken to prevent injury to the orbicularis muscle. The graft is then pulled through the tunnel and positioned evenly by massaging the lip. The excess material is then trimmed and the incision sites are closed with suture. Maximal swelling of the operative site will occur 3 days post operatively. Topical and oral systemic antibiotics are used for several days. The use of prophylactic acyclovir for patients with a history of herpes simplex is advisable.

Hypersensitivity reactions and infection requiring removal of the graft have been rare. Volume diminution of 30 to 50% at the operative site after 1 year has been reported.[54] There are also reports of 65 to 70% graft retention after 18 months in mobile areas and 100% volume retention in fixed places for up to 2 years.[54] These early reports of longevity have generally been refuted in clinical practice. Most surgeons employing this material report 6–18 months of persistance.

Homologous Injectable Collagen (Dermalogen)

Dermalogen (Collagenesis Inc., Beverly, MA) consists of injectable human collagen fibers in an aseptically processed suspension prepared from human donor tissue obtained from U.S. tissue banks. It may be regulated by the FDA as a human tissue transplant. As with Autologen, the suspension is rendered acellular, with collagen fibers remaining intact. The donor material is screened and processed extensively to prevent any potential transmission of disease vectors. The indication and use of Dermalogen are identical to those of Autologen, but without the necessity of harvesting autologous skin. It is available in 3%, 4%, and 5% concentrations and is injected with a 30-gauge needle. The product is shipped along with a skin test, to be performed 72 hours before treatment. Preliminary data suggest persistence of correction for 6 to 12 weeks.[47] However, further clinical studies of Dermalogen and its long-term outcomes are under way.

Materials Derived from Nonhuman Sources

Injectable Bovine Collagen

Knapp and colleagues were the first to report the development of a highly purified preparation of bovine dermal collagen in 1977.[55,56] They injected purified collagen from both human and bovine skin into 42 patients over 20 months. The preparation had been purified, filtered, and dialyzed in physiologic phosphate-buffered saline with 0.5% lidocaine. All subjects were tested with 0.1 mL of material before treatment. Complications included cellulitis, urticaria, and hyperpigmentation of the skin. No difference was seen between bovine and human collagen.

Following an ensuing collaborative effort, the injectable collagen Zyderm I Collagen Implant (Collagen Corp., Palo Alto, CA) received FDA approval for general marketing in 1981.[57,58] This became the first legally approved nonautologous agent in the United Sates for soft-tissue augmentation. Zyderm collagen is derived from cowhide and is a purified suspension of bovine dermal collagen. The processing of this material includes purification, enzymatic degradation, and sterilization. After purification, bovine collagen is digested with pepsin and reconstituted in physiologic saline containing 0.3% lidocaine at a final concentration of 35 mg/mL.[57] During this process, the majority of antigenic potential is removed from the telopeptide regions of the molecule, without disruption of the natural helical structure, making it more immunologically compatible with human tissue. The intact and nearly species-nonspecific helical portion of the byproducts was composed of 95% to 98% type I collagen, with the remaining 2% to 5% composed of type III collagen.

The primary limitation of Zyderm was its short-lived corrective effect as a result of rapid resorption of the implant.[57–60] To circumvent this problem, more concentrated preparations, Zyderm II and Zyplast, were introduced for general use.[61] Zyplast is collagen cross-linked with glutaraldehyde, which tends to increase the survival time after implantation and decrease antigenicity. Unlike Zyderm I and Zyderm II, Zyplast was developed primarily for deep dermal injection. In a comparative study of Zyplast and Zyderm, Kligman and Armstrong found Zyplast to be more stable.[58] However, it did produce a greater inflammatory response with fibroblastic infiltration and collagen deposition, whereas Zyderm was mainly absorbed by 3 months without a fibroblastic reaction. Even with Zyplast, despite its longer durability, repeated treatments were necessary.

Patients are tested with 0.1 mL of the material injected subdermally in the volar forearm area. The site is inspected after 48 to 72 hours and at 1 month. Development of erythema, induration, or both after 6 hours indicates a positive result and thus is a contraindication to use of the implant. There is a reported positive skin test rate of 3 to 3.5% and 1.3 to 6.2% false-negative rate among individuals.[62] Therefore, a repeat test is recommended after 2 to 4 weeks. Treatment may begin 2 to 4 weeks after a negative second skin test.

Complications and adverse reactions associated with collagen use include transient erythema, edema, ecchymosis, local skin necrosis, local granulomatous reaction, and abscess formation. Mild and transient erythema may be expected soon after treatment. Hanke and colleagues demonstrated an incidence of 0.09% for skin flap necrosis, which was thought to be secondary to compromised arterial supply when Zyplast was injected deep into dermis.[55,57,61,63] Abscess formation has been believed to be due to hypersensitivity. Treatment of the painful, swollen cysts involves incision and drainage. This complication, though rare (4 in 10,000), can persist for more than 2 years. In several reports, some patients demonstrated elevated levels of circulating anti-Zyderm antibody after single or multiple treatments.[64] These circulating anti-bovine collagen antibodies have been found to cross-react with human collagen.[65,66] Sensitization may be from earlier implant exposure or previously ingested beef. Certain individuals with human leukocyte antigen (HLA) DR4 may be genetically more prone to hypersensitivity.

Gelatin Matrix Implant

Spangler reported the first use of fibrin foam as injectable filler for facial scars and wrinkles in the 1950s.[67,68] Fibrin foam was a fractionation product of plasma containing fibrinogen and prothrombin. After implantation under depressed scars, it resulted in the deposition of fibrin, followed by the infiltration of fibroblasts and production of new collagen. Based on this concept, Gottlieb refined the technique by developing the gelatin, aminocaproic acid, and plasma (GAP) repair technique.[69,70] The gelatin serves to elevate the depression and allows clot formation; aminocaproic acid stabilizes the fibrin by inhibiting fibrinolysis, and the patient's plasma provides the clotting factors. Gelatin matrix implant (Fibrel, Mentor Corp., Goleta, CA) is an evolution of the GAP repair system and was approved by the FDA for general marketing in 1987. It is sold as a kit, which contains the lyophilized mixture of 100 mg of absorbable gelatin powder and 125 mg of ε-aminocaproic acid. The gelatin is porcine-derived, and a skin test is required, which should be evaluated after a month. Several patients with allergic reaction to Zyderm have been treated with Fibrel without hypersensitivity. Fibrel has gained acceptance primarily for intradermal injection as a treatment for depressed scars. The more fibrotic scars do not elevate well with Fibrel. Fine creases on eyelids, lips, and photoaging rhytids on facial skin do not respond well to Fibrel injections because of the viscosity of the implant and the associated inflammatory response.

A study of 321 patients treated for scar and wrinkle correction over a 5-year period showed 80% maintenance in correction at 2 years and 50% at 5 years after treatment.[71] The reported adverse reactions include local erythema, edema, pruritus, contusion, and pain. No major adverse systemic reactions have been reported in the original 288 patients treated with Fibrel.[72] Although Fibrel has been reported to be less allergenic and less immunogenic than the bovine products, it does require more preparation time and plasma acquisition. Coupled with greater discomfort than that associated with collagen injections, these factors have placed limitations in its use and acceptance.

Hylan B Gel (Hylaform)

The biocompatibility of the hyaluronic acid molecule, along with its water insolubility and resistance to degradation and migration, make it an attractive candidate for dermal augmentation.[73,74] The molecule exhibits no species or tissue specificity because the chemical structure of this polysaccharide is the same among all species. Hylaform (Biomatrix Inc., Ridgefield, NJ) is a purified, animal-based hyaluronic acid compound, processed from rooster's comb. This product has been used to treat depressed cutaneous scars, wrinkles, and folds. Hylaform gel is available in 5.5% concentrations. A series of injections is usually needed for maximal correction. Reported complications include transient erythema at the site, bruising, and papule formation. Hylaform is available in Europe, Canada, and other continents but has not yet received FDA approval.[75]

Restylane

Restylane (Q-Med, Uppsala, Sweden) is a cross-linked, stabilized, high molecular weight (20 mg/mL), nonanimal, third-generation hyaluronic acid gel, produced from bacteria through fermentation. It in available in sterile syringes containing 0.7 mL of the material. It is injected in middermis using a 27- or 30-gauge needle. It has been used in Europe for the treatment of the glabella, nasolabial folds, oral commissures, depressed acne scars, and lip augmentation. A 50 to 80% persistence of correction has been reported after 6 months.[76] The main reported complications are erythema and edema at the injection site. Like Hylaform, this product resorbs over time. Restylane is not available in the United States.

Resoplast

Resoplast (Rofil Medical International BV, Bredia, The Netherlands) is the first European-made injectable collagen implant. Composed of a bovine monomolecular collagen solution, Resoplast comes in 3.5% and 6.5% concentrations and requires a skin test. The indications, injection technique, and results are comparable to those for Zyderm or Zyplast. This product in not currently available in the United States.

SYNTHETICALLY DERIVED FILLER MATERIALS

Though the majority of injectable and implant materials used for soft tissue augmentation are biologically derived, a number of synthetic materials have been in use with varying degrees of success. Some recently developed materials are promising in terms of their persistence and stability.

Liquid Silicone

A derivative of silica and based on the element silicon, silicone is a polymer of dimethylsiloxanes. Liquid silicone is a clear, colorless, and relatively inert fluid. It was initially used as injection material in Asia, Europe, and Latin America before it came into use in the United States. In 1963, Dow Corning (Midland, MI) produced medical grade 360 liquid silicone and later made a more pure form of silicone, MDX 4-4011.[19–21]

The technique of silicone injection is probably the most crucial element in successful treatment. It should be injected into the dermis and fat in *minute* amounts. Each particle is then encased in a fibrous capsule over the ensuing weeks. Augmentation and tissue filling is the result of the fibroblastic reaction and not the presence of silicone alone. The fibrous reaction and capsule formation develops over several weeks. Because silicone implantation leads to permanent results, extreme caution should be taken in its use and undercorrection is strongly recommended.[77,78]

Major complications have been reported with silicone implants, including inflammation, induration, discoloration, ulceration, migration, and formation of silicone granulomas.[16,18,19,77,78] It is worth mentioning that many of reported complications have not resulted from the use of the purified Dow Corning product (MDX 4-4011) but from silicone implants of unknown purity or even adulterated silicone containing olive oil or other ingredients. Liquid silicone received FDA approval in 1994 for ophthalmologic and podiatric use.[79] However, injectable silicone is not currently approved by the FDA for tissue augmentation and remains dangerous due to lack of reversibility.

Polymethylmethacrylate (Artecoll)

Polymethylmethacrylate (PMMA) microspheres (Artecoll, Rofil Medical International, BV, The Netherlands) has been used in Europe as an injectable filler material. The microspheres are 20 to 40 μm in size—large enough to escape phagocytosis but small enough to be used intradermally.[80,81] PMMA is provided in a 3.5% collagen solution containing 0.3% lidocaine. The microspheres have a smooth surface, and become covered initially by a layer of monocytes after 2 days, by fibroblasts at 2 months, and by a fibrous capsule at 7 months.

The main indication for use of Artecoll has been the naturally occurring folds and wrinkles of the face. Generally, 1 mL is sufficient for the treatment of the glabella, nasolabial folds, sagging corners of the mouth, or for lip augmentation. Artecoll is not suitable for the treatment of crow's feet because they are too superficial.[82]

Erythema, edema, moderate pain, and pruritus are common reactions to Artecoll injection and usually last for several days. Other major complications have been uncommon.[16] However, due to its lack of reversibility, patients who experience misplacement in tissue, inflammatory reactions or infections have no alternative treatment except wide local tissue excision. For cosmetic applications, this makes the material less than desirable, if not dangerous. Experience with this material is limited, and long-term effects are not known. Artercoll has not received FDA approval.

Bioplastique

Bioplastique (Uroplasty, BV, The Netherlands) is a white, heavily textured, biphasic copolymer with a solid phase containing textured vulcanized silicone rubber microparticles and a liquid phase containing a biocompatible plasdone hydrogel. It is also an inert injectable material with the inherent limitations seen with injectable silicone. Because the microparticles are 100 to 400 μm in diameter, they cannot be engulfed by macrophages, as such engulfment is limited to particles smaller than 60 μm.[83–85] Bioplastique should never be injected into the superficial tissue because of its large particle size, but it is ideally placed below the level of dermis. It may be useful in treatment of depressed scars, hollow cheeks, nasal bridge deformities, subcutaneous contour defects, and lip augmentation. Bioplastique is too thick to fill lines, wrinkles, or creases. Undercorrection of the scar defect is recommended because the fibroblastic reaction and collagen deposition take several weeks to complete and the results are permanent. Overcorrection may result in a contour defect.[85,86]

Several studies have demonstrated a foreign-body giant cell reaction to Bioplastique. Histologic analyses show an acute low-grade inflammatory response followed by a low-grade chronic inflammation as the gel carrier is resorbed. The hydrogel is replaced by fibrin and later by fibroblasts. At 7 days, macrophages fuse into giant cells because they are unable to phagocytize the particles. The giant cells remain in a stable form on the surface of the particles.[87,88]

Complications with this material have occurred when the material was injected too superficially into the skin or when too much material had been injected, creating a hard, palpable mass. In such a case, the implant and surrounding tissue can be removed by microliposuction or total excision.[85,86] Concerns regarding its irreversible effects and potential for inducing an inflammatory reaction have limited its acceptance. This product is not available in the United States, nor is there an application pending with the FDA.

ePTFE

Expanded polytetrafluoroethylene (Ultrasoft, Tissue Technologies Inc., San Francisco, CA; Gore-Tex, WL Gore, Flagstaff, AZ) is a highly biocompatible, inert, carbon-based alloplast that has been used as a safe and reliable vascular graft for more than 20 years. After its initial application as vascular graft in 1970s, the usage of ePTFE was expanded to hernia repair and cosmetic and reconstructive procedures.[89,90] The advantages of this prosthetic material have been well documented and established. ePTFE has a multiaxial microstructure consisting of nodules interconnected by thin fibrils and is manufactured with a wide variety in "pore sizes." It is easy to handle, causes minimal tissue reaction, and is nonthrombogenic. The material retains its strength, thickness, size, and pliability after implantation. Its microfibrillar structure allows little cell penetration and ingrowth into the material.[91–93] Comparative studies among different forms of ePTFE have demonstrated the superiority of the tubular form (SoftForm) in terms of tissue ingrowth and stability.[92] Longitudinal tissue ingrowth into the implant lumen serves to better anchor the implant and minimize the risk of migration. Meanwhile, the relatively small amount of fibroblast migration into the walls of the implant renders it easily removable.

SoftForm was available in a kit, including the implant material and a cutting trocar placed in an outer cannula (Fig. 22–6). The implant is available in 5-, 7-, and 9-cm lengths and 2.4-, 3.2-, and 4.0-mm diameters. It has been used for the treatment of the nasolabial folds and perioral area, facial scars, soft tissue defects, and lip augmentation (Fig. 22–7). The procedure is performed in the office setting under local anesthesia after careful marking of the patient's soft tissue defect, wrinkle, or fold has been done in the upright position.

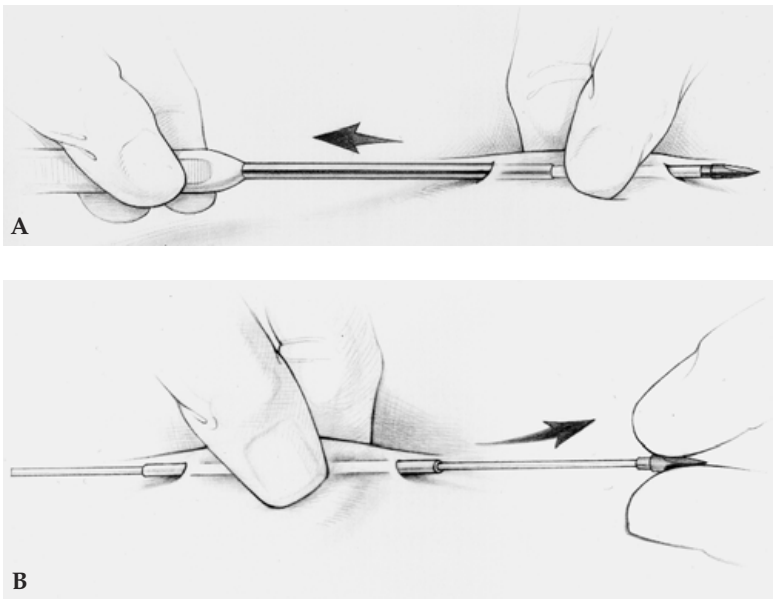

Figure 22–6 Ultrasoft delivery device. **(A)** After tunneling the device under the desired area of augmentation, the cannula is withdrawn, leaving the trocar-implant in place. **(B)** Gentle pinching of the skin surface is performed as the tip of the trocar is grasped and advanced.

Precise tunneling of the trocar cannula in the subcutaneous tissue beneath the defect is essential for proper correction.[94]

Softform experienced two unacceptable late-term complications. The material was seen to become firmer (more palpable) after several weeks. This is presumed to be due to ingrowth into the interstites of the material wall—eg. the wall of the tubes. In addition, shortening in the longitudinal access was seen in many patients, particularly the lips. This was due to an "accordion" effect in the thick walled tubes. Ultrasoft was developed with thinner walls (softer before and after implantation) and more length for single implant placement in the lips. The early data shows this implant to have dramatically improved the shortcoming seen whit Softform.

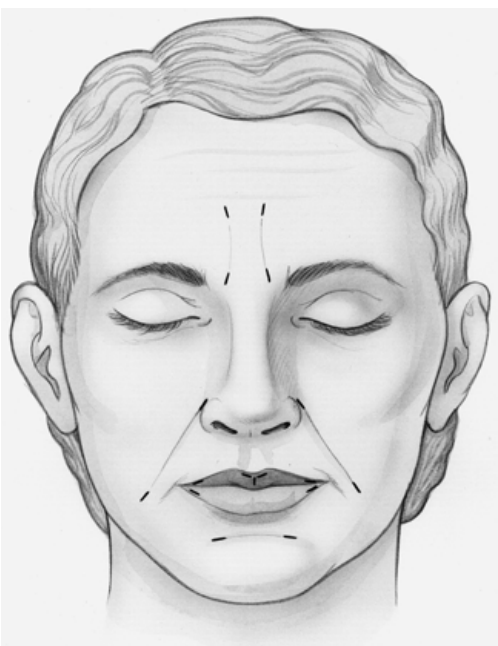

Figure 22–7 Sites amenable to augmentation with Ultrasoft. The entry and exit site incisions for the implantation are marked.

For nasolabial fold augmentation, small stab incisions in the fold, approximately at the level of the oral commissure and in the alar groove, are created. Tunneling in the subcutaneous tissue is performed with the trocar tip. Excessive resistance to the trocar tip is an indication of incorrect depth, and the trocar should be withdrawn and repositioned into an often slightly deeper plane. When the implant is visible at both entry and exit sites, the cannula and the trocar are removed. The tissue is then draped and massaged over the implant and the excess implant trimmed. With both luminal ends of the implant remaining open (for ingrowth of fibrous tissue), the ends of the implant are buried in the wound and the incision is closed using a nonabsorbable monofilament suture (Fig. 22–8). Topical and oral antibiotics are used for several days. In most cases, the entry and exit sites are not visible after a short healing period, but a light resurfacing may be required if the closure is not precise.

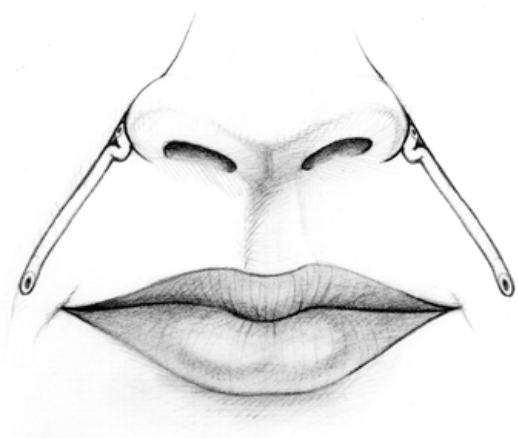

Figure 22–8 Ultrasoft implanted in nasolabial groove, ensuring that both ends of the tube are open for tissue ingrowth. Note the S-shaped redundancy created by trimming the implant to leave 4 to 5 mm extra length for augmentation at the superior end of the nasolabial triangle.

Lip augmentation follows the same principles as in the nasolabial fold augmentation. For the upper lip, augmentation of the vermilion border in two segments, sparing the cupid's bow, appears to produce better results (Fig. 22–9). The implant is centered just below the vermilion border in the upper lip. Placement of a third implant 3 months after the initial vermilion enhancement can produce a "rolling effect" and thus a more pronounced augmentation (Fig. 22–10). This "A-frame" technique increases the vertical height of the lip. The lower lip is usually augmented using a single, long

Figure 22–9 Pictorial description of Ultrasoft technique.

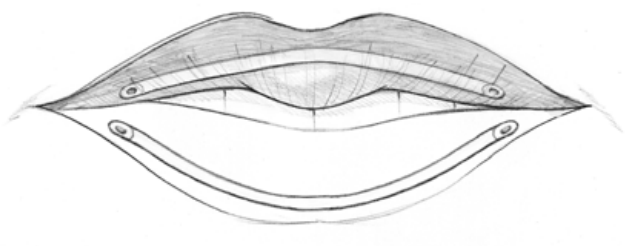

Figure 22–10 In addition to augmentation of the lip at the vermillion border, a third implant spanning the entire upper lip provides increased vertical lip height.

(9-cm) implant, spanning the entire lip, centering the implant just above the vermilion border (Fig. 22–11).

Complications, including extrusion, have been uncommon and in most cases related to precision of technique and placement. Transient, mild erythema and edema at the implant site is expected. Ultrasoft has received FDA approval and is currently available in the United States.

Physiologically Active Agents

Botulinum Exotoxin

The applications of botulinum toxin have recently expanded to include cosmetic procedures. Its introduction to cosmetic applications was based on observations that facial wrinkles were significantly reduced in patients treated with botulinum A exotoxin (BTX-A) for essential blepharospasm.[95] The effects of BTX-A on facial lines and wrinkles are due to the fact that many wrinkles are the result of underlying muscular contractions. By weakening or paralyzing the relevant muscle groups, BTX-A can result in a smoother skin appearance.

Several features of BTX-A therapy make it an attractive choice for treatment of facial wrinkles, as an alternative to certain types of surgery and tissue augmentation techniques. It is safe, easy to administer, and locally effective. In addition, the toxin acts selectively and in a reversible manner; therefore, it enjoys a relatively low side effect profile.

Botulinum neurotoxin (BTX) is produced by *Clostridium botulinum*, an anaerobic bacterium. It is produced in seven serologic serotypes, A to G, of which BTX-A is the most potent in producing muscle paralysis in humans.[96] Although other serotypes (i.e., BTX-B and BTX-F) are currently being investigated, only BTX-A is commercially available.

BTX-A produces muscle paralysis by binding to the presynaptic cholinergic terminals and blocking the release of acetylcholine at the neuromuscular junction (NMJ).[97] The unique mechanism of action of BTX-A makes it very specific, allowing a very small amount of the toxin to produce a significant effect. This allows production of clinical results with small therapeutic doses, thereby making systemic side effects unlikely.

In therapeutic doses, the initial affects of BTX-A are observed 2 to 3 days after injection. Maximal weakness occurs at approximately 1 to 2 weeks post injection, when the muscle fibers begin to atrophy and continue to do so for 4 weeks. Although BTX-A results in permanent inactivation of the blocked cholinergic terminals, the return of normal muscle function occurs through turnover and repair, absorption of inactive terminals, axonal sprouting, and production of new NMJ. The effects are reversed after 3 to 6 months when the enzymatic activity is returned to NMJ, thus resulting in the long duration of action of BTX-A. However, the histologic changes of BTX-A injection may last for as long as 3 years. Despite these observed changes, the muscle fibers are normal in their activity and power.[98]

There are currently three commercially available BTX products: Botox (Allergan, Inc., Irvine, CA), Dysport (Ipsen, Ltd., UK), and Mysbloc BTX-B (Elan Pharmaceutical, San Diego, CA). Clinically, Botox is three to four times more potent (in mouse units) than Dysport, and its dose must be adjusted accordingly. Botox is available in a vial and must be reconstituted with sterile, nonpreserved saline prior to intramuscular injection. Each vial contains 100 units of *C. botulinum* toxin type A, 0.5 mg of human albumin, and 0.9 mg of sodium chloride in a sterile, lyophilized form with no preservative. The 100 units of Botox is significantly below the calculated median lethal dose (LD_{50}) in an average person weighing 70 kg (2500 to 3000 units).

BTX-A has been successfully used for the treatment of glabellar frown lines, crow's feet, horizontal forehead lines, mental creases, horizontal neck lines, and smile lines[98] (Fig. 22–12). It has also been used in cases of facial asymmetry or paralysis to reduce expressivity on the unaffected side. BTX-A is injected intramuscularly along the wrinkle lines. The actions of the toxin can vary from a slight weakening to complete paralysis of the injected muscle, mainly based on the injection dose. The clinician has to determine the location and

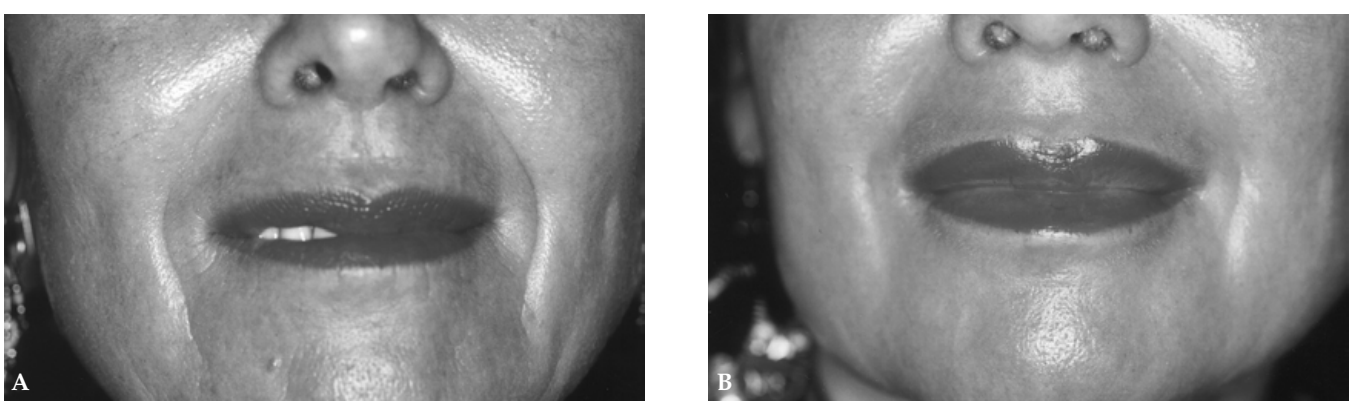

Figure 22–11 Preoperative **(A)** and 3-month postoperative **(B)** views after upper and lower lip augmentation with Ultrasoft and laser resurfacing of facial skin.

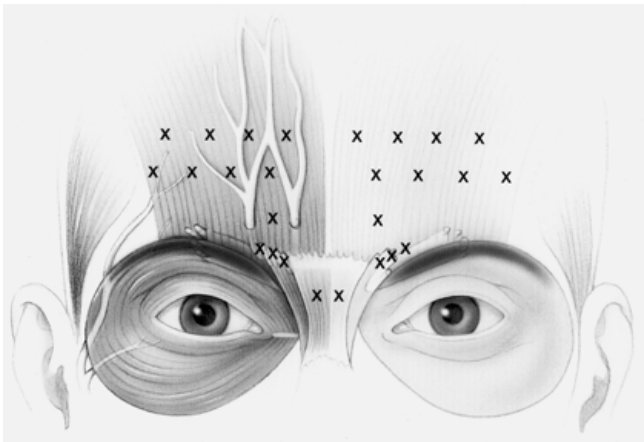

Figure 22–12 Injection sites for Botox treatment of forehead wrinkles.

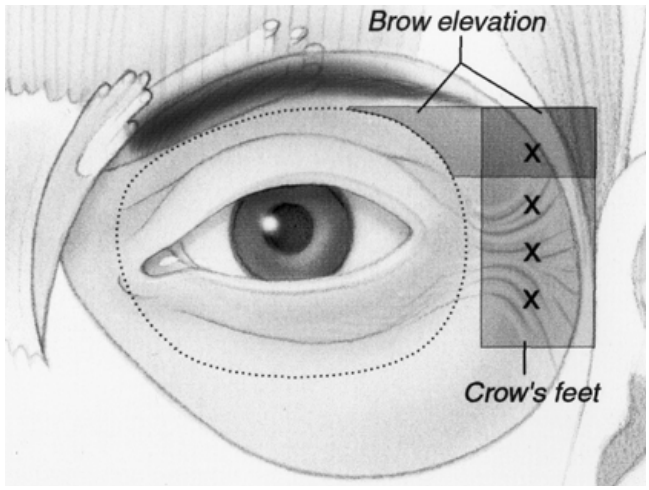

Figure 22–13 Areas of Botox injection for temporal brow elevation and crow's feet. Note that injection sites are lateral or superior to the orbital rim to avoid collateral muscle weakness (ptosis or strabismus).

number of injection sites and the desired effect after paralysis. Clearly, individual differences in the underlying anatomy and muscular function should be carefully considered.

BTX-A has recently been used as a minimally invasive measure for temporal browlift with good success.[99] In this procedure, 8 to 10 units of Botox is injected intramuscularly into the lateral and superolateral fibers of the orbicularis oculi, beneath the lateral one third to one half of the brow (Fig. 22–13). This injection weakens the most superolateral portion of the orbicularis muscle, leaving the elevating action of the frontalis muscle on the brow unopposed, resulting in a moderate lateral brow elevation. Treatment usually continues by injection of the crow's feet in the same session.

There are very few complications associated with BTX-A therapy, and the effects are reversible. Reported complications include ptosis after treatment of the glabellar region as a result of migration of the toxin through the orbital septum to the levator muscle, and a temporary droop in the lower eyelid after treatment of crow's feet. There are also reported cases of drooping of the eyebrows after treatment of the forehead lines.[98,100,101] Furthermore, BTX-A has immunogenic properties, though there are no reported cases of the development of antibodies as a result of usage of BTX-A in therapeutic doses for cosmetic applications.[98]

A newer form of BTX, bitulinum toxin type B has demonstrated promising results in clinical trials. This BTX has a more rapid onset, is stable virtually indefinitely in solution (it can be stored), and has received FDA approval for neurologic applications. The longevity of action of this product has yet to be determined.

CONCLUSION

There have been significant advancements in minimally invasive techniques for management of facial wrinkles and soft tissue augmentation. Although there is no single material or method that can be applied in all clinical scenarios, a number of excellent options are currently available to the clinician. Meanwhile, there is ongoing research for development of new materials as experience with current techniques becomes more refined. Injectable and implantable materials as part of the clinician's armamentarium in facial rejuvenation have received a favorable welcome from the medical community and the general population. As many of the current techniques are recently developed, further experience and long-term follow-up are necessary to ensure the desired outcome.

ACKNOWLEDGMENT

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Chapter 23

Botulinum Exotoxin A (Botox) for Facial Wrinkles

Andrew Blitzer, William J. Binder, and Mitchell F. Brin

Botulinum exotoxin A (Botox), produced by the bacterium *Clostridia botulinum*, is a potent neurotoxin that exerts its effect at the neuromuscular junction, inhibiting the release of acetylcholine. The effect of the toxin is a muscular weakness or flaccid paralysis.[1] Botox has been safely and effectively used in the treatment of patients with facial dystonia, hemifacial spasms, or facial tics. In treating these patients we noticed a cosmetic benefit. Often patients who were receiving unilateral Botox injections for dystonia or hemifacial spasm would return asking to have their contralateral side injected to give them a more youthful appearance.[2]

Botox improves the cosmetic appearance by decreasing or eliminating the hyperfunctional facial lines caused by skin pleating due to the contraction of the underlying muscles.[3] The loss of facial hyperfunctional lines with resultant smooth skin surface is seen in conditions that cause facial muscle weakness, such as facial nerve injury, Bell's palsy, or stroke. Botox does not address skin lines unrelated to muscular hyperfunction, such as actinic damage, loss of dermal elastic fibers, or skin atrophy. These may be best managed with chemical peels, laser resurfacing, or injection of filler materials.

In 1989, Botox was approved by the FDA as safe and effective therapy for blepharospasm, strabismus, and hemifacial spasm. Spasticity was added to the label in 1998. The National Institutes of Health (NIH) Consensus Conference of 1990 also included a number of "off-label" indications, including adductor spasmodic dysphonia, oromandibular dystonia, and torticollis. Many other off-label uses are becoming the standard of therapy. We have used Botox for more than 12 years and reported it for the correction of hyperfunctional lines of the face, including glabellar lines, horizontal forehead lines, lateral orbital lines ("crow's feet"), platysmal bands, and hyperactive mentalis muscles.[4] Carruthers and Carruthers[5] simultaneously reported similar results of Botox injections for the correction of hyperfunctional facial lines.

Botox treatments require use of a standard freezer that will keep toxin at −15°C to −20°C, sterile nonpreserved saline, syringes, and small-gauge or hollow-bore monopolar electromyography (EMG) needles. Botox (Allergan, Inc., Irvine, CA) is shipped on dry ice, and each vial contains 100 units of freeze-dried, lyophilized botulinum toxin A. The frozen toxin is reconstituted with nonpreserved saline before treatment. We usually add 4 cm^3 of saline yielding 25 units/cm^3 (2.5 units in 0.1 cm^3); 2.5 cm^3 of saline yielding 40 units/cm^3 (4 units in 0.1 cm^3); or 2 cm^3 of saline yielding 50 units/cm^3 (5 units in 0.1 cm^3).

The patient's facial lines are photographed for medical-legal reasons and for the purpose of comparison after treatment (Figs. 23–1 to 23–3). The photographs should show the patient's face at rest and with the activity that exaggerates the facial lines. A detailed analysis of the facial lines should decipher which lines are functional, which are caused by changes in the properties of the skin (e.g., actinic or age-related changes), which are the result of underlying structural deformity, and which are scar-related. A careful medical history is taken, with particular attention to prior cosmetic surgery and facial treatments, prior trauma, bleeding tendency, current medications, sensitivity to drugs, propensity to scarring, or hypo- or hyperpigmentation. We use a pre- and posttreatment rating scale of the functional lines that is used at rest and during activity. The rating is performed both by the patient and by the physician during each visit. A 0–3 rating scale has been developed for evaluation (0 = no facial lines; 1 = mild facial lines; 2 = moderate facial lines; 3 = severe facial lines).[3,6]

Despite the paucity of data, patients who are pregnant or lactating should not be injected because the effects of the toxin

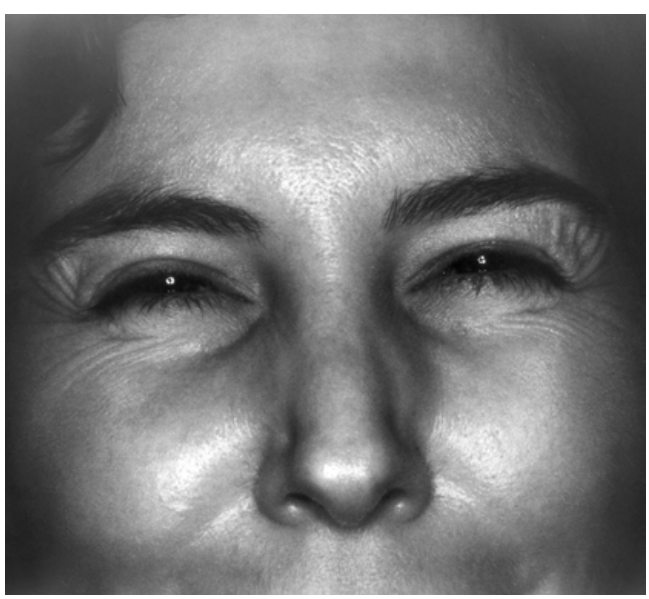

Figure 23–1 Patient before injection with excessive squint lines (crow's feet) around the lateral and inferior orbital area.

Figure 23–2 Lateral view of the excessive squint lines prior to injection.

on the fetus are unknown. We recommend treating with caution patients with underlying neuromuscular disease, such as Eaton-Lambert syndrome, myasthenia gravis, and motor neuron disease. Aminoglycoside antibiotics may interfere with neuromuscular transmission and potentiate the effect of a given dose of Botox; therefore, we do not recommend prescribing Botox for a patient undergoing aminoglycoside treatment.[6]

TECHNIQUE

An informed consent should be obtained from each patient following explanation of the injection procedure, the reason for injection, and the potential complications. The patient should be informed that Botox injections were approved by the FDA in 1989 as safe and effective therapy on label for blepharospasm, strabismus, and hemifacial spasm. In 1990, the NIH Consensus Conference on the Clinical Uses of Botulinum Toxin included the treatment of spasmodic dysphonia, oromandibular dystonia, facial dystonia, occupational writer's cramp, and torticollis. In 1998, spasticity was added to the on-label use. Other off-label uses included management of tremor, juvenile cerebral palsy, hyperhidrosis, sphincter dysfunction, and hyperfunctional facial lines.[7]

After consent is obtained, ratings performed, and pictures taken, the patient's face is marked with a pen for all of the areas of maximum muscle pull causing the bothersome hyperfunctional lines. The site of each injection is marked to

Figure 23–3 Patient demonstrating hyperfunctional frontal lines prior to injection.

treat each of the muscles causing hyperfunction. Circles are drawn around each injection, allowing 1 to 1.5 cm for diffusion of the toxin from each injection point. The confluence of circles should totally cover the area of excess muscle function without infringing on other adjacent muscles (see Figs. 23–4 to 23–6). A photograph or diagram of the injection sites and the dose at each site should be made and kept as part of the patient record to allow for postinjection assessment of the efficacy of a given treatment session and provide a "road map" for future injections. Depending on the patient's response, the placement of injections and the dose can be adjusted and recorded for future injections.

When the marking is complete, the area to be injected can be iced or treated with EMLA to decrease the discomfort associated with skin penetration by needle. The toxin is then drawn up in a tuberculin syringe with a 27-gauge, hollow-bore, Teflon-coated monopolar EMG needle. This needle is hooked up to the EMG machine, and ground and reference leads are placed on the face. The needle is placed through the overlying skin to impale the muscle previously marked for injection. The patient is instructed to accentuate the specific facial expression, such as frowning, squinting, or elevating the brow. If the needle is in an active part of the muscle, a loud burst of activity will be heard on the speaker of the EMG machine. If a distant signal is obtained, the needle should be moved until it is in a maximal position and then the toxin is injected. This is repeated at each mark for injection. The EMG technique increases the accuracy of the delivery and therefore decreases the doses necessary for a given desired response. If a larger dose is needed in a given area, either a larger volume or an increased concentration in the same volume can be given. Increasing the volume may lead to diffusion of toxin to adjacent muscles, causing unwanted weakness. To avoid this, increase the concentration of toxin in the same volume that will increase the degree of weakness without increasing the area of diffusion. Injections around the eye for orbicularis oculi weakening can be done with a tuberculin syringe and a 30-gauge 0.5-in. needle. Similarly, patients with very prominent muscles, or those who have been previously

Figure 23–4 We mark all patients for location of injection sites. To maximize the effect and minimize the unwanted areas of weakness that can occur in forehead injections, I put one mark between the medial aspect of the brows. Marks are then made 1 cm above the brow at the midpupillary line. A triangle is then drawn. The toxin injections are all given above these lines, allowing for elevation of the lateral brow, continued mimetic function of the lateral brow, and no migration of the toxin to the levator muscle. Marks are then made about 1.5 cm apart across the forehead lines to encompass all of the area within the triangle.

Figure 23–5 The crow's feet lines are marked while the patient is smiling. The first mark is made 1 cm lateral to the lateral canthal ligment and on the plane of the lateral canthus. If there are lines above this area, a second mark is made above. A third or fourth mark is made over the inferior wrinkles following the orbital rim. These are marked bilaterally and then injected.

Figure 23–6 A lateral view showing the crow's feet marks for injection.

injected, where the muscles have been well identified can be injected without EMG using a 30-gauge 0.5-in. needle. We are currently developing a 30-gauge coated 1-in. needle that can be used with a portable EMG monitor to allow for very accurate toxin placement without the discomfort of the larger 27-gauge needle. After the injection is performed, gentle pressure can be applied to the needle site to avoid ecchymosis. Carruthers has developed a technique of gentle pressure away from the eye or important adjacent muscle to aid in the diffusion to areas of desired weakness. The patient is asked not to rub or massage the injected area for about 6 hours so as to avoid excess diffusion to adjacent muscles, and thereby decrease the chance of excess weakness of adjacent facial muscles.

Glabellar Injections[4,9–11]

Glabellar injections control the hyperactivity of the corrugator and procerus muscles, which is responsible for producing "scowl" lines. In our series, we have injected 7.5 to 25 units in this area to control the muscle contractions producing the glabellar lines. We usually start with 2.5 to 5 units per 0.1 cm^3 in each corrugator muscle and 2.5 units per 0.1 cm^3 into the procerus. The dose depends on the preinjection assessment of the size of the muscle. Men generally have larger muscles and require larger doses. The corrugator muscle can be injected

with several individual needle sticks or the muscle can be "skewered" on the EMG needle and injected on needle withdrawal. The injection of the corrugator muscle should extend laterally enough to encompass the length of the muscle without passing the midpupillary line. Too much lateral extension too close to the brow may lead to weakness of the levator muscles of the upper lid and produce ptosis.

If ptosis is produced, the patients can be treated with apraclonidine 0.5% eyedrops (Iopidine, Alcon, Inc., Fort Worth, Texas). This drop stimulates Müller's muscle (adrenergic muscle), which is below the levator muscle. Treatment usually produces a 1- to 2-mm elevation of the lid margin.

Frontalis Injections[4,9–11]

The frontalis muscle pulls in a vertical direction, creating horizontal pleats in the forehead skin. Toxin should not be injected close to the brow as this may cause brow ptosis or even levator ptosis. We like to raise the injection site progressively away from the brow as you proceed laterally to leave some functional frontalis, thereby leaving some expressive function to the lateral brow while eliminating most of the forehead wrinkles. Most of our patients prefer to have some residual mimetic function of the brow. If there are a number of rows of horizontal forehead lines, several rows of injections can be made to encompass the lines. Again, circles of 1 to 1. 5 cm^3 are drawn to ensure that all desired areas of weakness are included in the toxin injection plan. After the plan is drawn, the forehead is treated with ice or EMLA. The underlying frontalis muscle is then injected with EMG guidance to assure needle placement within the hyperfunctional muscle (Fig. 23–7). We generally inject 2.5 units per 0.1 cm^3 at each mark over the forehead. Our dose range is 10 to 30 units. If there is a particularly hyperactive area near the brow, we will use a more concentrated solution (5 units per 0.1 cm^3) in that area of the frontalis muscle to avoid excess diffusion to adjacent muscles.

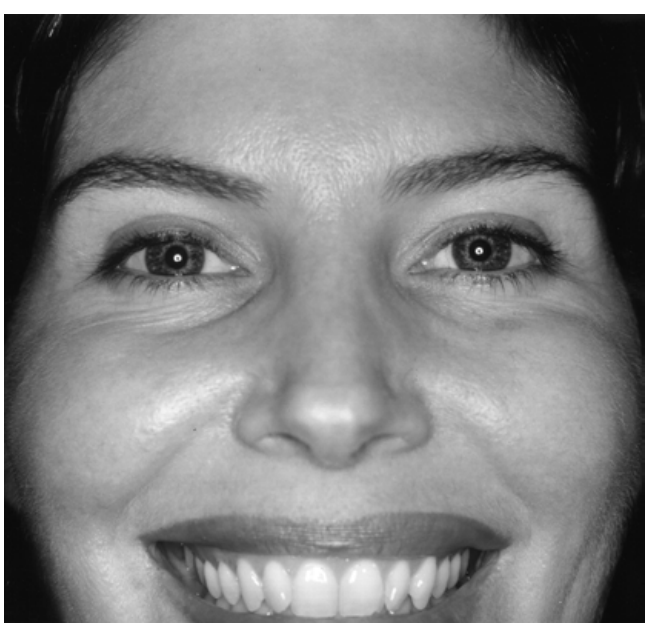

Figure 23–7 Patient 2 weeks post Botox injection of hyperfunctional facial lines. Note the loss of lines in the forehead area and a diminution of the crow's feet lines.

Brow Adjustment[12]

Often, weakening the glabellar or frontalis muscles causes an arching of the lateral brow upward if the lateral frontalis was not treated. Lateral frontalis weakening often causes brow ptosis. If too much arching is produced, a small amount of toxin (1 unit per 0.1 cm^3) can be injected into the lateral frontalis to drop the brow slightly. If not enough brow elevation was achieved, 1 unit per 0.1 cm^3 injected at the orbital rim laterally will weaken the attachment of the orbicularis oculi and allow for more pull by the frontalis to elevate the brow laterally.

"Crow's Feet" Injections[4,8–11,13]

Lateral orbital lines, or "crow's feet" lines, result from hyperactivity of the lateral portion of the orbicularis oculi muscle. This muscle functions in the closing of the eye, blinking, and squinting, but excessive lateral activity will excessively pleat the lateral orbital facial skin, creating crow's feet. Small amounts of Botox can weaken the lateral aspect of this muscle and thereby decrease the wrinkling of the skin without interfering with eye blink or eye closure. To accomplish the desired weakening, pen marks are drawn 1 cm from the lateral canthi. The patient is asked to squint, and if there are hyperfunctional lines above the mark, a second mark is made in this superior area. The squint lines below the first lateral mark are then addressed with another mark made in the inferior area to encompass the lower wrinkles (Figs. 23–1, 23–2, 23–5, 23–6, 23–9, 23–10). Marks are made bilaterally. Do not make injections too close to the eyelids or orbit, as this may cause delayed eye closure, decreased blink, epiphora, mild ectropian, or possible diplopia.

The skin is then treated with ice or EMLA. Patients are generally injected around the eyes with a 30-gauge, 0.5-in. needle for comfort. If there has been difficulty in obtaining a desired result, the EMG needle is used to improve the accuracy of needle placement. Our starting dose is generally 2.5 units per 0.1 cm^3 in each of the previously drawn marks. Our usual dose is 7.5 to 15 units per side.

Nasolabial Folds[6,9]

These hyperactive lines can be softened with injection at the connection between the orbicularis oris and the levator muscles (zyngomaticus major and minor and levator anguli oris). However, weakening of these muscles changes the character of the patient's smile and is unacceptable to most people. Use of filler materials and other approaches often produce better results.

Nasal Flare

Some patients have excessive and bothersome flaring of the nasal alae. This flaring is the result of excessive contraction of the nasalis muscle. We have utilized a technique described by Carruthers in which 5 units per 0.1 cm^3 is injected into the nasalis bilaterally. This has produced excellent results if used in small volumes to avoid diffusion to the lip elevator muscles.

Mentalis Injections[4,6,10]

Patients with excessive lip pursing have hyperactive mentalis and orbicularis muscles. This phenomenon occurs especially after chin implants or orthognathic surgery, and the activity may produce abnormal lip postures with a "peau d'orange" skin appearance. We have found that small amounts of Botox (2.5 to 5.0 units) on each side may be used to prevent this overactivity and improve the skin's appearance. The injection is given at a point halfway between the vermilion border of the lower lip and the edge of the mentum, and 0.5 to 1 cm medial to the oral commissure. The EMG technique is used and the patient is asked to pucker his or her lips. When the needle is in a most active place within the mentalis muscle, the toxin is injected. The toxin should not be injected too close to the lip to avoid excessive weakness of the orbicularis oris muscle and consequent change in smile or drooling.

Platysmal Band Injections[14,15]

Patients who have prominent platysmal bands before or after facelift may have benefit from Botox injections without a submental incision for muscle plication. We perform these injection by first marking the anterior and posterior edges of the muscle bilaterally. The region of the excessive platysmal banding is marked and horizontal lines spaced about 2 cm apart are drawn. Generally three horizontal lines is sufficient. The EMG monopolar needle is used to skewer the muscle starting from a skin stick medially at the edge of the band. The needle is passed perpendicularly to the muscle fibers. The patient can activate the platysma while the injection is given by depressing the lower lip. Once the muscle is skewered, the toxin is injected on withdrawal of the needle. The muscle is generally injected with 2.5 to 5.0 units per 0.1 cm^3 per site with two or three sites per side. The dose range in our series is 7.5 to 20 units per side. One needs to keep the volume and dose small to prevent diffusion to the strap muscles of the anterior neck, which can cause dysphonia or dysphagia if weakened.

Adjunctive Botox Injections[16]

Relaxation of the underlying facial musculature has been found to be extremely beneficial to enhancing the results of laser resurfacing or with the use of fillers such as collagen. The best results are staged, starting with Botox injections and having the patient return after a week for the second procedure. If the patient is having laser resurfacing, relaxing the skin folds around wrinkles allows proper orientation of the collagen fibers to give the best and longest lasting results. With the continued underlying weakness, the skin heals without the fold, until the muscular strength returns at 4 to 5 months, at which time Botox injections may be repeated.

Botox can relax the skin lines and therefore minimize the amount of collagen or other filler needed to enhance the cosmetic result. Once the persistent furrow is filled, the material seems to last much longer without the constant muscle squeezing effect. Therefore, less material is needed to correct the line, and the material lasts longer when used in conjunction with Botox.

FOLLOW-UP

After the injections are complete, the patients are asked to return to our office at two weeks postinjection to reevaluate the facial lines and the results of the toxin. New photographs are taken, and once again the ratings are made by the physician and the patient. If the hyperfunctional lines are still bothersome to the patient, additional toxin may be injected. The dose and the location of the additional toxin should be determined based on the amount and location of excessive function. The dose and location of the additional toxin are mapped for future reference. When the muscles are adequately weakened and a pleasing facial skin contour is achieved, the patient is instructed to come back when the facial lines again become prominent and bothersome. In general, this is about 4 to 6 months. In some patients who have been treated a number of times, the Botox effect seems to last for longer and longer periods, perhaps related to a behavior modification (Figs. 23–7 to 23–10).

COMPLICATIONS[17,18]

Complications of Botox injections include mild bruising or local pain at the site of injection. There also may be transient weakness of adjacent muscles related to diffusion of the toxin.

Figure 23–8 Patient 2 weeks post Botox injection. Note the flat forehead with no wrinkles, but elevation of the lateral brow and only lateral brow expressivity upon gesturing or attempts at brow elevation.

Figure 23–9 Patient 2 weeks post Botox injection. Note the loss of crow's feet lines and the pleasing contour of the periorbital skin.

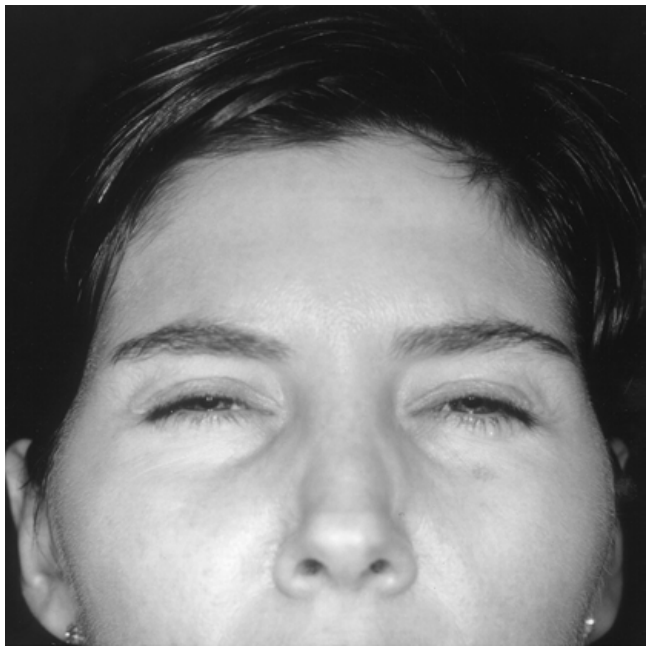

Figure 23–10 Patient 2 weeks post Botox injection. Note the minimal number of lateral orbital lines with squinting.

This effect on adjacent muscles is technique- and dose-related. To minimize this side effect, one should use the smallest volume and dose possible. We have used EMG guidance to allow very accurate placement of the needle in the most active part of the muscle. EMG guidance has allowed us to maximize the effect with a minimal dose. Careful placement of small amounts of toxin will eliminate or minimize unintended adjacent muscle weakness. If local adjacent muscle weakness, such as ptosis, occurs, it will be self-limited. There have been no long-term complications or hazards of Botox use. Muscle biopsies taken from patients after repetitive Botox injections have not shown any permanent atrophy or degeneration. Some patients receiving high doses (300 units or more, such as for torticollis) may develop antibody to toxin. These antibodies have not produced hypersensitivity reactions or anaphylaxis. However, the antibodies do block the effect of the toxin, making the patient resistant to further therapy.

Over the past 15 years, we have found botulinum toxin injections for hyperfunctional facial lines to be extremely safe and useful. The injections may be used alone or in combination with peels, resurfacing or filling techniques. Patient satisfaction is extremely high.

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Chapter 24

Aesthetic Mandibular Implants

Harry Mittelman and James Newman

Augmentation of the central mentum with alloplastic implants has been an established procedure for more than 40 years. The popularity of this procedure has dramatically increased in the past 10 years as our understanding of the anatomy and aging process of the mandible has increased and as the alloplastic implants have been more artistically designed to fit, form and function. An appreciation for the indications for augmentation of the central mentum and midlateral mandible is rooted in an understanding of the aesthetic facial proportions and the anatomy of both the young and the aging mandible.

One need only look at the models of beauty in fashion magazines to realize that one of the prerequisites for beauty as we know it in the Western World is a balanced proportion of the chin in its central mentum, and a straight, youthful, full jawline as the central mentum transitions into the midlateral mandible. The beauty of a strong jaw bone is depicted by some of the great artists of the past as well. Although a variance exists between the "strong" chin of a man and of a woman, both give the illusion of power, strength, confidence, assertiveness, aesthetic balance, and beauty. A receding chin often conveys an illusion of negative attributes, such as weak character, combined with a lack of proper facial proportions, resulting in a lack of optimal beauty.

At first glance, one might consider chin augmentation to be a minor procedure. When one understands the anatomy of the balanced optimal mandible as well as the genetic differences in mandibles, and particularly the aging process of the mandible, the actual surgical procedure can be straightforward. However, the quality of the result is based on the proper selection of the implant to be used. That selection process is difficult unless the surgeon is aware of the different options and how to choose among them. The number of alloplastic, Silastic (Dow Corning, Midland, Michigan), and elastomer implants as well as mandibular implants made of other materials can sometimes be confusing. It is possible, however, to fulfill 98% of the needs of the facial aesthetic surgeon using a relatively small armamentarium of alloplastic mandibular implants. When the surgeon understands the anatomy and the aging process of the mandible that he or she is augmenting, the procedure can be properly performed to optimize surgical results in proportions exceeding the degree of difficulty of the procedure. While using different alloplastic implants it is important to understand that essentially the same procedure can be used to treat the genetically imperfect mandible, the traumatized mandible, and the aging process of the mandible that participates in classic signs of aging. No aesthetic surgical procedure in the authors' armamentarium yields as much aesthetic benefit for as little time and effort as is involved in augmenting the mandible with properly chosen alloplastic, Silastic, elastomer rubber implants.

ANALYSIS OF THE LOWER JAW

The presence of a hypoplastic mentum is the most common indication for chin augmentation. The basic tenets of facial aesthetic proportions have been summarized by Powell and Humphreys and include both a frontal and lateral assessment.[1] The frontal view of the face may be divided into thirds, with the lower boundary extending from the subnasale to the menton. This lower third can be subdivided so that the upper third is occurring from the subnasale to the stomion superiorus, whereas the lower two thirds occurs from the stomion inferiorus to the menton. With age, there is loss of the vertical height and anterior projection of the mandible, and the ideal proportion is lost. On lateral view, the method of Gonzales-Ulloa[2] may be applied to define a hypoplastic mentum. This technique defines aesthetic chin projection when the anterior soft tissue point of the chin, the pogonion, just touches a vertical line dropped from the nasion at a 90-degree relationship to the Frankfort plane. When the chin is posterior to this line and class I occlusion is present, a hypoplastic mentum is present. A hypoplastic mentum may be a result of microgenia, which is a small chin that results from underdevelopment of the mandibular symphysis, or from micrognathia, which is a result of hypoplasia of various parts of the jaw. Mandibular augmentation is generally done for microgenia or mild cases of micrognathia. Most important is an evaluation of the patient's dental occlusion. Augmentation is most appropriate for patients with microgenia who have normal or near-normal occlusion.

Although congenital factors contribute to the presence of a hypoplastic mentum, the development of a prejowl sulcus is due primarily to the aging process. Loss of elasticity of the skin of the eyes, face, neck, and submental wattles are the most obvious and commonly observed effects of aging. A subtle change also occurs in the configuration of the area just anterior to the jowl, which can have an important effect on facial appearance. As a result of progressive atrophy of soft tissue in the area between the chin and jowl, and the gradual bone reduction of the mandible in this same area, a patient may develop a groove between the chin and the remainder of the body of the mandible, an area known as the prejowl sulcus[3] (Fig. 24–1).

Figure 24–1 Example of the prejowl sulcus (*arrows*) due to aging of the underlying mandible and soft tissues in an adult woman.

During aging, there are two major contributing factors to the formation of the prejowl sulcus. One is bony resorption of the mandible at the junction of the central mandible (mentum) and the midlateral mentum. This area, below the mental foramen, has been shown in anatomy books to develop bony resorption and a concavity.[4] This area may be referred to as the *anterior mandibular groove*. The anterior mandibular groove of the bony surface can be reflected on the external surface of the soft tissue jawline as an indentation between the jowl and the chin, and is referred to as the *prejowl sulcus*. The other major contributing factor to the formation of the prejowl sulcus can be soft tissue atrophy during aging between the chin and the jowl. With time, this can become part of the commissure mandibular "marionette line" or "drool line." In most individuals who form a prejowl sulcus with aging, it is frequently due to a combination of soft tissue atrophy and bony resorption at the area of the prejowl sulcus.

RELEVANT ANATOMY OF THE MENTUM

Although the basic anatomy of the mandible is familiar to the aesthetic surgeon, some points are worth emphasizing. The position of the mental foramina is somewhat variable but is usually found below the second premolar tooth. An anatomic study has been described showing that in 50% of cases the mental foramen is at the level of the second premolar, in 25% it is found between the first and second premolars, and in the remaining 25% it is posterior to the second premolar.[5] In the young adult mandible, the mental foramina generally lies midway between the alveolar ridge and the inferior border of the mandible and approximately 25 mm lateral to the midline, though the distance may vary from 20 to 30 mm. In children, it is lower on the mandible and more anterior, whereas during the aging process, because of the atrophy of the alveolar ridge, the mental foramen is closer to the alveolar ridge while maintaining a fairly constant distance from the inferior border of the mandible. Thus, its relative position is higher. Even in the aging mandible, there seems to be a distance of more than 8 mm between the mental foramen and the inferior border of the mandible at the site of the muscle attachments. The neurovascular bundle exits the mental foramen in a superior direction and has a tough sheath surrounding it.

The importance of the anatomy of the mental foramina in the aging mandible relates directly to the comfort level that the aesthetic surgeon has in the technique used for placement of extended mandibular implants. This anatomy clearly indicates that the surgeon must dissect carefully in creating a pocket for the implant that is below the mental foramen yet above and down to the level of the insertion of the muscles in the inferior border of the mandible. Generally, one has 10 mm of space in that area. Properly designed implants should have a height in this area of around 6 to 8 mm. Because of the upward direction and durable sheath of the neurovascular bundle of the mental foramen, the use of an elevator in this 8- to 10-mm space may touch the sheath and even stretch it to some degree, but it would be very difficult to transect it. Although the surgeon has a greater safety factor because of the nature of this anatomy, at the same time he or she must use caution in the technique of elevating this pocket.

IMPLANT SELECTION

Implant selection involves the type of material from which the implant is made, as well as the selection of the particular shape of implant that meets the needs of the patient's aesthetic imperfection. The ideal material for mandibular or malar implants should have the right consistency, flexibility, firmness, nonreactivity, resistance to infection, stability, removability, changeability, ease of manufacture, and be harmless to surrounding tissue.[6] The only alloplastic implant that meets almost all of these criteria is solid silicone elastomer rubber (Silastic).

Silastic is made of a polymer that can be varied to provide the proper consistency in terms of softness as well as flexibility. The body accepts the material, forming a fibrous capsule around the implant without distorting the implant itself. Fenestrated Silastic implants can be further stabilized with fibrous tissue ingrowth. The material can be commercially machined to different sizes and shapes with the help of computer-aided design technology. These preformed implants can be customized by trimming with conventional instruments and blades in the operating room as indicated.

Selection of one of the many commercially available Silastic mandibular implants can be confusing. The first decision must be the use of an extended mandibular implant rather than a central chin implant. The three best researched and most commonly used extended mandibular implants are the extended anatomical mandibular implant (four sizes), the variety of Flowers chin implants (standard, vertical, anterior tilt, and posterior tilt), and the Mittelman prejowl–chin implants (four sizes) (Fig. 24–2). All three of these implant types provide a slightly different configuration and philosophy but give very good results. The extended anatomical mandibular implant provides varying chin augmentation

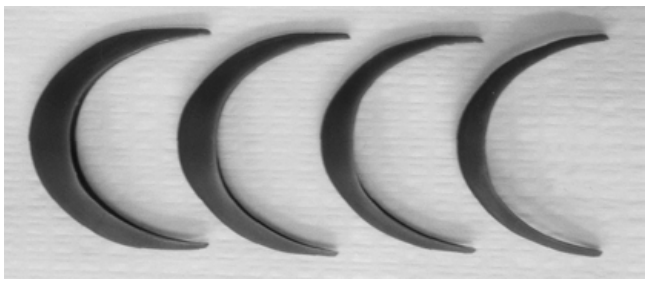

Figure 24–2 Complete set of sizers for chin–jowl implants (XL, L, M, S).

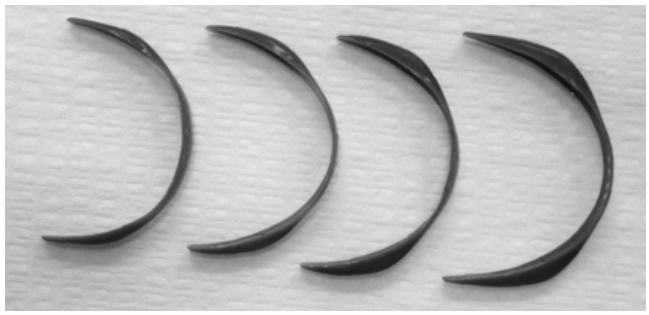

Figure 24–3 Complete set of sizers for prejowl implants (S, M, L, XL).

depending on the need of the patient, but the extension of the implant beneath the mental foramen is of approximately the same size no matter what size augmentation is in the area of the mentum itself. In other words, augmentation in the area of the prejowl sulcus stays the same regardless of the size of the augmentation in the area of the mentum. The Flowers mandibular implant provides for a variation in the tilt of the Silastic implant at the central mentum with a tapered extension along the mandible beneath the mental foramen.

The Mittelman prejowl–chin implant provides four variations in augmentation of the mentum combined with a comparable four variations of the extension of those implants into the area of the prejowl sulcus. It is intended to provide four different sizes of augmentation in the prejowl sulcus at the same time that the surgeon is providing four different sizes of augmentation of the mentum. In addition to this, there is an extended mandibular implant that provides no augmentation in the chin itself, providing augmentation only of the prejowl sulcus (Fig. 24–3). This implant becomes an extremely important adjunct for the facelift patient who has adequate chin augmentation but who so frequently has a prejowl sulcus. There has been another modification of the extended chin implant by Terino[7] whereby a more squared anterior projection has been designed that is particularly helpful in achieving a more prominent anterior projection.

The Silastic implants described here can be of varying durometers or firmness. The softer solid implants are more flexible and can be more easily placed through smaller incisions. They are also more conforming to the mandible and may cause less bony resorption. We utilize Silastic implants manufactured with a durometer of 10 for mandible augmentation. Most of the extended mandibular implants and all of the prejowl implants have multiple fenestrations, which can help with fixation of the implant to the periosteum or soft tissue of the mentum. The surgeon can also create fenestrations with a skin-punch biopsy device or add more fenestrations if desired. There is no standardization of the implant sizes (e.g., the medium size of one manufacturer versus that of another). However, there is some consistency among different designed implants of the same manufacturer. Physician judgment is made easier by the availability of "sizers" by the established manufacturers. The sizers can be inserted until the surgeon feels satisfied with the result. Then the sizer is removed and the actual implant of that size placed into the pocket.

SURGICAL TECHNIQUE

The chin implants described here can be placed either intraorally or through a submental incision. The essential setup includes a Bernstein nasal retractor, narrow but blunt dissectors, straight clamps, and a gentamicin saline solution to bathe the implant prior to insertion (Fig. 24–4). The submental incision is placed anterior to the submental crease and the soft tissue, muscle, and periosteum are divided, exposing the central mentum (Fig. 24–5). Dissection is then performed in the subperiosteal plane with one hand on the dissector and the second "smart" hand guiding the instrument externally, thus protecting from any excursions above the intended dissection pocket (Fig. 24–6). The lateral pockets should be dissected approximately 6 cm from the midline and remain below the level of the mental foramen for proper positioning. After the pockets are developed, the implant is removed from the gentamicin solution and placed in the pocket with a clamp. After one half of the implant is placed, it is guided with clamps and a retractor into the opposite pocket by folding it acutely onto itself (Figs. 24–7 to 24–9). Then the implant is checked for smoothness against the mandible and absence of curls from the implant's lateral extensions (Fig. 24–10). The implant has multiple fenestrations and a central blue marking that designates the middle of the implant. The fenestrations within the implant allow for tissue ingrowth and stability of

Figure 24–4 Instruments used for aesthetic chin augmentation. Note the basin of gentamicin saline solution.

Figure 24–5 Exposure of the central mentum after skin, subcutaneous tissue, and periosteum have been divided.

Figure 24–6 Dissection of the lateral pocket for insertion of the Silastic implant. Note the noninstrument hand guiding the path of dissection along the inferior border of the mandible.

Figure 24–7 Placement of the Silastic implant into half of the dissected pocket with guidance using straight clamps.

Figure 24–8 Folding of the Silastic implant acutely to facilitate passing into the opposite dissection pocket.

Figure 24–9 Introducing the folded Silastic implant into the contralateral dissection pocket.

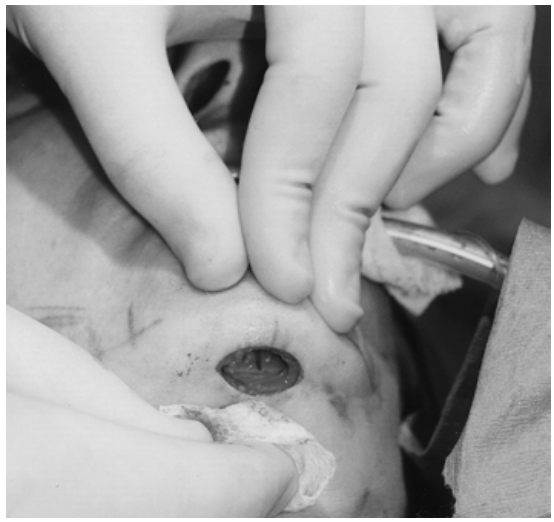

Figure 24–10 Implant has been placed and is checked for alignment. Note the midline blue mark of the implant.

the implant. The blue mark in the implant assists the surgeon in placing the implant symmetrically. Prolene sutures secure the implant to the periosteum, and the overlying soft tissue and muscle are then closed over the implant (Figs. 24–11 and 24–12). A meticulous closure of the muscle and subcutaneous tissue is then performed, followed by a separate skin closure. The results of chin augmentation can be appreciated on both lateral (Fig. 24–13) and oblique views (Fig. 24–14).

POSTOPERATIVE CONSIDERATIONS

Although a long list of complications can be listed with any procedure, the incidence of these problems in the case of mandibular augmentation is often low and almost always temporary. When complications occur, they are easily treatable, and in the case of proper implant selection or patient

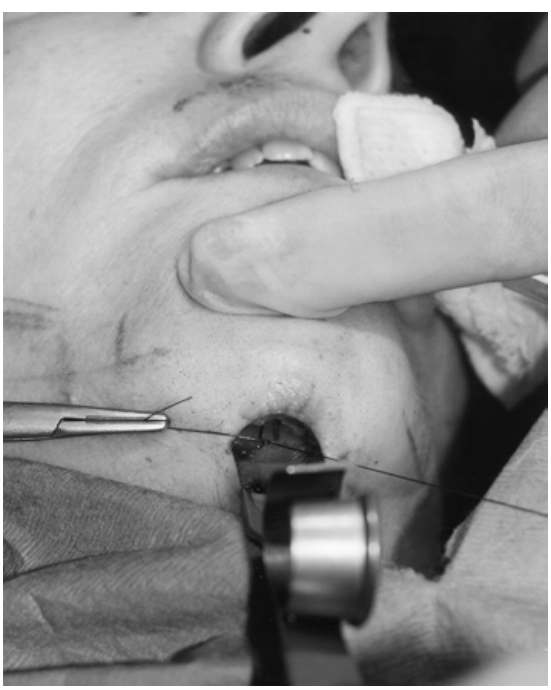

Figure 24–11 Securing the implant with a fixation suture through the periosteum, soft tissues, and fenestration of the implant.

Figure 24–12 Closure of the periosteum and soft tissue over the implant with Prolene suture.

Figure 24–13 **(A)** Preoperative lateral view of adolescent woman with a hypoplastic mentum. **(B)** Postoperative lateral view of the same patient after aesthetic chin augmentation.

Figure 24–14 **(A)** Preoperative oblique view of adult man with a hypoplastic mentum. **(B)** Postoperative oblique view of the same patient after aesthetic chin augmentation.

preference, the procedure is reversible and changeable to suit the postoperative desires of the patient or the surgeon.

The literature suggests that infection with the use of alloplastic implants occurs in about 4 to 5% of procedures. However, this incidence is lowered by the use of intraoperative gentamicin solution to soak the implant and irrigate the surgically created pockets. Hematoma is very uncommon. Asymmetry does not occur with extended anterior mandibular implants unless one or both of the pockets are placed above the mental foremen.

However, sensory alterations occur in 20 to 30% of patients with chin implants, though on a temporary basis. This hypesthesia should be expected and discussed preoperatively. This occurs far more often than with central mandibular implants but should not dissuade the aesthetic surgeon from using extended mandibular implants. Migration or extrusion of the implant has not been experienced with extended mandibular implants. Skin necrosis for the external approach is equally rare.

Bone resorption under chin implants has been reported since the 1960s, but without significant clinical effects.[8] Implants placed too high over the suprapogonion erode through the thin cortex more easily. The absorption over the thicker cortical bone of the mental protuberance and the pogonion is less and clinically less significant. The extended mandibular implants that by virtue of the mental foramen keep it from riding up higher, and the muscle attachments that keep it from riding inferiorly, provide ideal stability at the proper level of the chin. The softer solid Silastic implants tend to resorb less bone than the harder implants. The larger implants may cause greater resorption due to a greater degree of tension between the periosteum, muscle, and bony cortex. Absorption seems to occur in the first 6 to 12 months, and is self-limiting if the implant is properly positioned. It is possible that a small portion of the resorption actually stabilizes the implant over the following years. The soft tissue profile of the chin seems to remain stable despite this process. No pain or dental erosion occurs as a result of this. If the implant is removed, the bony resorption area may regenerate.

Visual or palpable projections of the lateralmost portion of the extended implants do occasionally occur, possibly as the result of the capsular formation buckling the feathered edges upon themselves. This is especially true with the extremely thin, very pliable edges of the extended anatomical chin implants. Frequently, palpation and massaging of these edges expand the capsule in that area and eliminate this palpable projection, making it clinically insignificant. Rarely, the implant has to be removed, the pocket expanded, and the implant repositioned. A pocket that is initially too small will also cause a buckling of the feathered edges, creating this type of imperfection within the first few weeks after surgery. The projection that is due to capsular contraction frequently occurs after 6 weeks.

The smile may be altered as a result of muscle injury or swelling of the lower lip that can only be evidenced on smiling but not in the resting position. A portion of one lower lip may appear to be weaker by not retracting inferiorly as much as the lateral portion of the lip due to a temporary injury of the depressor muscles. This occurs more often with the intraoral approach.

Although asymmetry secondary to proper placement of an implant may not occur, poor preoperative planning for a preoperative asymmetrical mandible may be evident postoperatively. Any preoperative asymmetry must be discussed with patients so that they understand that any postoperative asymmetry is a result of the preoperative status and not caused by the implant or implantation technique. A very small percentage of patients exhibit a temporary speech impediment, usually lisping, secondary to the effects of swelling or dissection on the depressor muscles of the lip. Enough of an effect on the depressor muscles or the mentalis combined with hypesthesia can occasionally cause temporary drooling and slight slurring of speech. Motor damage to the branches of the marginal mandibular nerve is rare and temporary if it occurs. Preoperative chin clefts or dimples may change to some degree postoperatively. Although the list of potential problems listed above is long, actual experiences with problems other than hypesthesia and bony resorption have been uncommon and temporary.

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Chapter 25

Aesthetic Facial Implants

William J. Binder, Brent Moelleken, and Geoffrey W. Tobias

Over the past decade, the marked improvement in biomaterial and the design of facial implants have expanded their use in aesthetic surgery and offered ready-made solutions for replacement needs, avoiding donor morbidity and reducing operative complexity. Facial implants are currently used to augment skeletal dimension, to restore facial contour by expanding areas where facial volume loss occurs, or to work in combination with rhytidectomy or other procedures as part of the more current multimodality approach to facial rejuvenation surgery. Common implant procedures include cheek augmentation to balance the effects of malar hypoplasia; mandibular augmentation to create a stronger mandibular profile and better nose–chin relationship; mandibular body and angle implantation to create a stronger lateral dimension to the mandible; submalar and midfacial implantation to fill out the hollowness and augment the flatness that occurs to the midface during the normal process of aging; nasal implantation in the form of dorsal or dorsal-columella shapes; or premaxillary (peripyriform) implantation to augment a retrusive midface. Computer-assisted custom-designed implants now provide solutions for more complex facial defects due to trauma, congenital causes, or acquired immunodeficiency diseases. Long-term HIV-positive patients become victim to an accelerated form of lipodystrophy, with complete loss of facial fat brought about by antiretroviral therapy and other factors related to the HIV virus itself that are not completely understood.[1,2]

Critical to the successful use of facial implants is the accurate assessment of facial anatomy. Distinguishing relationships between different bony promontories and determining the volume and thickness of surrounding soft tissue and skin will dictate the subtleties of choosing implant shape, type of material, and ultimate placement to attain both the patient's and the surgeon's vision of the end result.

CONCEPT OF FACIAL CONTOURING

The individual configuration of nose, malar-midface area, and mandible-jawline determines the fundamental architectural proportions and contour of the face. Balance between these structures and the even distribution of the overlying soft tissue structures determines facial beauty and harmony. Modern hallmarks of beauty are distinguished by bold facial contours that are accentuated by youthful malar-midface configurations and a sharp, well-defined jawline. Any of these promontories being too small or too large affects the aesthetic importance of the others. For example, reducing the nasal prominence causes both the malar-midface and the mandibular-jawline volume and projection to appear more distinct, whereas accentuating the malar-midface or enhancing the mandibular or malar-midface volume makes the nose appear smaller and less imposing.

The concept of facial contouring implies a change in the shape of the face. Only by judiciously altering mass and volume in different anatomic regions and redistributing the overlying soft tissues can the surgeon produce substantive contour changes. Typically, when augmentation is the desired goal, it is accomplished through selection of implants with the proper shape and design, and controlling their position over the facial skeleton.

IMPLANTS AND BIOMATERIALS

Deciding which biomaterial to use for implantation requires an understanding of the histopathology of the individual implant material–tissue interface and the host response. All implant materials induce the formation of fibroconnective tissue encapsulation, which creates a barrier between the host and the implant.[3,4] Adverse reactions are a consequence of an unresolved inflammatory response to implant materials. The behavior is also a function of configuration characteristics of the site of implantation, such as thickness of overlying skin, scarring of the tissue bed, and underlying bone architecture that would tend to create a condition for implant instability. For example, implants that are more deeply placed with thicker overlying soft tissue rarely become exposed or extrude. Other important factors, such as prevention of hematoma, seroma and infection both during surgery and in the postoperative stage, contribute to the prevention of host–implant interaction and to increasing implant survivability.

The Ideal Implant

The ideal implant material should be cost-effective, nontoxic, nonantigenic, noncarcinogenic, host-acceptable, and resistant to infection. It should be inert, easily shaped, easily conformable, easily insertable, and capable of permanently maintaining its original form. The implant should be easy to modify and customize to the needs of the recipient area during the surgical procedure without compromising the integrity of the

implant and should be easy to team-autoclave without degradation of the implant.

The presence of favorable surface characteristics is important for implant placement and stabilization; paradoxically, it is just as important to facilitate easy removal and exchangeability without causing injury to surrounding tissues. Implant immobilization implies that the implant will be fixed in place for the lifetime of the patient. Implant materials such as silicone elastomer induce the formation of a surrounding capsule that maintains implant position, whereas expanded polytetrafluorethylene (ePTFE), which encapsulates to a lesser degree, provides fixation with minimal tissue ingrowth. Each type of material–host interaction provides certain advantages in different clinical settings. Materials that cause significant tissue ingrowth and permanent fixation are often undesirable, particularly if the patient desires to change augmentation characteristics in later years. The natural encapsulation process of silicone and the minimal surface ingrowth into ePTFE products insures immobility yet provides exchangeability without damage to surrounding soft tissue.

The ideal implant design should include tapered margins that blend with the adjacent bony surface to create a nonpalpable, imperceptible transition to the surrounding recipient area. An implant that is malleable and conforms readily to the underlying structures further reduces mobility, while the anterior surface shape should imitate the desired natural anatomic configuration. The new silicone implant Conform (Implantech Associates, Inc., Ventura, CA) is currently being engineered for enhanced conformability to the underlying bony surface. For example, implants with a new type of grid backing reduce the memory of the silicone elastomer and improve flexibility. Greater adaptability to irregular bony surfaces reduces the chance of movement and prevents posterior dead space from occurring between the implant and underlying bone (Fig. 25–1). Renewed interest in research and development in biomaterial engineering has led to development of a composite implant (using both silicone and ePTFE) that promises to combine the advantages of two biomaterials for future use in facial implants (Personal Communication. Implantech Associates, Inc. and W.H. Gore, Inc., January, 1999).

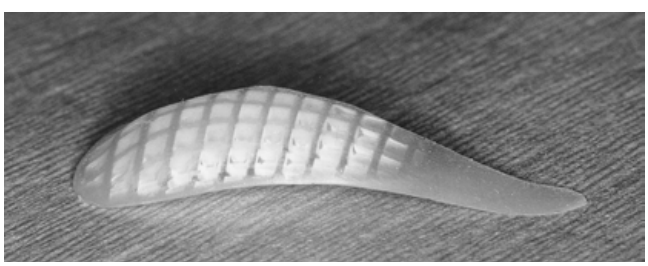


Figure 25–1 The Conform implant is made from a softer silicone material and has a grid design on the posterior surface of the implant that reduces its memory to more easily adapt to the underlying bone surface. The grid feature also reduces the chances of implant slippage and prevents displacement.

Implant Biomaterials

Polymeric Materials/Solid Polymers

Silicone Polymers

Beginning in the 1950s, silicone has had a long history of widespread clinical use with a continued, excellent safety–efficacy profile. The chemical name for silicone is polysiloxane. Currently, only silicone elastomer can be customized by the use of three-dimensional computer imaging and CAD/CAM technology. Differences in manufacture have significance in the purity and stability of the product. For example, the harder the implant the more stable it is. An implant that has a hardness (durometer) of less than 10 will approach the characteristics of a gel and over time potentially "leach" or leak some of its internal molecular substances. However, the most recent studies on breast implant gel silicone have shown no objective cause and effect for silicone in producing scleroderma, systemic lupus erythematosus, collagen vascular disease, or other autoimmune diseases.[5,6] Solid silicone elastomer has a high degree of chemical inertness, is hydrophobic, and is extremely stable, with no toxicity or allergic reactions.[7] Tissue reaction to solid silicone implants is characterized by a fibrous tissue capsule without tissue ingrowth. When unstable or placed without adequate soft tissue coverage, the implants are subject to moderate ongoing inflammation and possible seroma formation. Capsular contracture and implant deformity rarely occur unless the implant is placed too superficially or migrates to the overlying skin.

Polymethacrylate (Acrylic) Polymer

Polymethacrylate polymer is supplied as a powdered mixture and catalyzed to produce a very hard material. The rigidity and hardness of the acrylic implants is a problem in many applications that involve inserting large implants through small openings. In the preformed state, there is difficulty in conforming the implant to the underlying bony contour.

Polyethylene

Polyethylene can be produced in a variety of consistencies, with the current most popular form being porous. Porous polyethylene, also known as Medpore (W. L. Gore, Flagstaff, Arizona), suggests stability with minimal inflammatory cell reaction. However, the material is hard and difficult to sculpt. The porosity of polyethylene permits extensive fibrous tissue ingrowth, which provides an advantage for enhanced implant stability. However, it is extremely difficult to remove secondarily, creating a condition for potential damage to surrounding soft tissue, particularly if placed in areas of thin soft tissue covering.

Polytetrafluoroethylene

Polytetrafluoroethylene comprises a group of materials that has had a defined history of clinical application. The known brand name was Proplast, which is no longer made in the United States because of complications related to its use in temporomandibular joints. Under excessive mechanical

stress, this implant material was subject to breakdown, intense inflammation, thick-capsule formation, infection, and, ultimately, extrusion or explantation.

Expanded Polytetrafluorethylene (ePTFE) (Gore-Tex, W. L. Gore, Inc.)

This material was originally produced for cardiovascular applications.[8,9] Animal studies showed the material to elicit limited fibrous tissue ingrowth without capsule formation and minimal inflammatory cell reaction. The reaction seen over time compared favorably with many of the materials in use for facial augmentation. The material has found acceptable results in subcutaneous tissue augmentation and for use in preformed implants. Due to lack of significant tissue ingrowth, ePTFE offers advantages in subcutaneous tissue augmentation because it can be modified secondarily and removed in the event of infection.

Mesh Polymers

The mesh polymers, which include Marlex (Davol Corp., Providence, RI), Dacron (Dow Corning, Midland, MI), and Mersilene (Dow Corning, Midland, MI), have similar advantages of being easily folded, sutured, and shaped; however, they also promote fibrous tissue ingrowth, causing difficulty with secondary removal. Polyamide mesh (Supramid) is a derivative of nylon that is hydroscopic and unstable in vivo. It elicits a mild foreign body reaction with multinucleated giant cells and over time causes implant degradation and resorption.[10]

Metals

Metals consist essentially of stainless steel, vitallium, gold, and titanium. Except for use of gold in some indications, such as upper eyelid springs or in dentistry, titanium has become the metal of choice for long-term implantation. Reasons include high biocompatibility, high corrosion resistance, strength, and minimal x-ray attenuation during computer tomographic scanning or magnetic imaging.

Calcium Phosphate

Calcium phosphate or hypdroxyapatite materials are not osteoconductive but do provide a substrate into which bone from adjacent areas can be deposited.[11] The granule form of hydroxyapatite crystals is used in oral and maxillofacial surgery for augmenting alveolar ridge. The block form has been used as an interpositional graft material in osteotomies.[12] However, it has been shown to be of less value as an augmentation or onlay material due to its brittleness, difficulty in shaping or contouring, and inability to adapt to bone surface irregularities and mobility.

Autografts, Homografts, and Xenografts

Autografts, available as autogenous bone, cartilage, and fat, are limited by donor site morbidity and limitation of available donor material. Processed homograft cartilage has been used in nasal reconstruction but eventually succumbs to resorption and fibrosis. Other forms of materials and injectables are commercially available (Table 25–1).

TABLE 25–1 Subdermal and Subcutaneous Injectable Filler Materials

Zyderm and Zyplast
Dermalogen
Autologen
Isolagen
AlloDerm
Autogenous dermal grafts
Autogenous fat
Human placental collagen
Hylaform gel
Restylane
Artecol
Liquid silicone

Tissue Engineering and Formation of Biocompatible Implants

During the past several years, tissue engineering has emerged as an interdisciplinary field. Properties of synthetic compounds are manipulated to enable delivery of an aggregate of dissociated cells into a host by a method that results in the formation of functional new tissue. The field of tissue engineering has evolved by combining scientific advances in multiple fields including material science, tissue culture, and transplantation. These techniques facilitate the seeding of cells into a suspension that provides a three-dimensional environment that promotes matrix formation. This structure anchors cells and permits nutrition and gas exchange, with the ultimate formation of new tissue in the shape of a gelatinous material.[13] A number of tissue-engineered cartilage implants have previously been generated based on these new principles. This includes joint articular cartilage, tracheal rings, and auricular constructs. For in vivo cartilage formation, alginate has been successfully employed with the injection by syringe for the treatment of vesiculoureteral reflux. This results in the formation of irregularly shaped beads of cartilage, which are capable of obstructing the regurgitating urinary flow found in urethral incompetence. Tissue engineering offers the potential to grow cartilage in a precisely predetermined shape and presently is in the developmental stage of generating various types of contoured facial implants consisting of immunocompatible cells and matrix.[14] Once employed on a commercial basis, these techniques would require minimal donor site morbidity and, like alloplastic implants, reduce operative time.

PATHOPHYSIOLOGIC FACTORS IN AGING

It is generally acknowledged that patients endowed with strong, well-balanced skeletal features will best endure the ravages of age.[15] Analysis of the faces of teens reveals an abundance of soft tissue that provides the underlying framework for the harmonious composite of youthful facial form.

Full cheeks and smooth, symmetrical contours free of sharp, irregular projections, indentations or skin wrinkling, or dyschromias commonly characterize these youthful faces.[16] Facial structures, like the rest of the body, are in a state of constant flux and are influenced by many factors, such as sun exposure, weight loss, trauma, or disease. Even excessive exercise contributes to the development of certain consistent and identifiable facial contour defects. The development of lines and wrinkles is a result of genetic factors, sun exposure and other environmental exposures, smoking, underlying diseases, gravity, and the effects of muscular action.[17]

Depending on the underlying skeletal structure, involutional soft tissue changes associated with the aging process bring about different but definable configurations of the face that appear progressively more obvious and pronounced with time. Recognition of these various defects and configurations caused by aging is an integral part of the successful use of facial contouring procedures. These include the development of a generalized flattening of the midface, thinning of the vermilion border of the lips, formation of jowls, areas of deep cavitary depressions of the cheek, the formation of deep folds of the skin and rhytides.[18] Other specific soft tissue configurations include the prominence of the nasolabial folds, flattening of the soft tissue button of the chin, and formation of the prejowl sulcus[19,20] (Fig. 25–2).

Figure 25–2 Resorption of bone within the anterior mandibular groove, coupled with relaxation of the soft tissue causing progressive encroachment of the jowl, creates the prejowl sulcus and contributes to the development of the marionette lines (*arrow*). In these conditions, the prejowl implant is used to augment and correct this specific deficiency and assist the rhytidectomy to achieve the desired straight mandibular line and prevent recurrence of the jowl. (From Binder WJ. A comprehensive approach for aesthetic contouring of the midface in rhytidectomy. *Fac Plast Surg Clin North Am* 1993;1:231–255. With permission.)

Among many techniques evolving in facial rejuvenation surgery, the missing link still remains the ability to permanently replace soft tissue volume in sufficient quantity and with lasting effect. The recent popularity of fat transplantation has reemphasized tissue replacement as a key component of the rejuvenation process. However, if autogenous fat is not available in the presence of an atrophic soft tissue component of the face that will not benefit from repositioning, then the options are limited to simulating its replacement with the use of alloplastic implants. Alloplastic augmentation techniques can volumetrically address these problems by softening sharp angles or depressions, reexpanding the underlying surface to smooth out wrinkles as well as enhance inadequate skeletal structure.[21–23]

Surgical Considerations in Nasal Augmentation

The relatively thin skin overlying the nasal dorsum often fails to provide adequate camouflage for poorly contoured replacement tissue. Nasal augmentation has been performed using many different materials. Currently, the most commonly used implants consist of silicone, ePTFE, and polyethylene. Silicone eventually produces some overlying skin atrophy and must be anchored to prevent movement. Both ePTFE and silicone have the potential to cause infection but are easily removed and replaced. Polyethylene (Medpore) implants, as with any other implant that promotes significant tissue ingrowth, invites the potential for major soft tissue damage to the overlying skin if removal becomes necessary. Homograft cartilage has a high percentage of resorption and autogneous bone has an additonal problem of warping.

Because human hyaline cartilage has a limited capacity to regenerate, effective long-term dorsal nasal reconstruction has remained problematic despite extensive efforts to use a wide variety of autografts, allografts, and alloplastic materials. A suitable replacement implant intended to reconstruct the original nasal profile must possess a number of unique characteristics. It must be of adequate length and have consistent curves, thickness, and tapered edges so as to fit well over the nasal bridge and blend in with the surrounding soft tissues and bone. In addition, it must possess a high degree of malleability, flexibility, and compliance so as to endure despite long-term stresses and trauma.

The use of autogenous tissue avoids the problem of bioincompatibility but sometimes fails to provide necessary volume to provide the size and shape. A more ideal substitute to replace deficient skeletal structure, particularly over the nasal dorsum, would be a neocartilage graft reproduced from one's own cells that closely mimics the original skeletal contour. This cartilage implant has been synthesized through tissue engineering.[24] The concept involves use of donor septal cartilaginous tissue that is harvested and broken down to its cellular components. The cells are cultured in vitro, thus permitting them to multiply. A synthetic alginate scaffold is created in the shape of a dorsal nasal implant through a molding process. The cells are impregnated into the gelatin scaffold, which is placed subcutaneously into mice and permitted to evolve, in vivo, into a final shape. It is during this phase that the alginate scaffold slowly dissolves and is replaced by viable hyaline cartilage. The cartilage is then

harvested as an autogenous implant. This process promises to be a valuable addition to the field of nasal and facial augmentation in the near future (Personal Communication, G. Tobias, September, 1999.)

Surgical Considerations in Midfacial Enhancement

Refinements in aesthetic contouring and lifting of the midface have increased patient expectations. Our ability to rejuvenate the midface and correct midface volume problems has improved dramatically. Rhytidectomy has become just one component of facial rejuvenation options. Now, browlift, midfacial augmentation procedures, cheeklift, midface lift, and resurfacing techniques all must be considered when customizing a surgical plan for a patient. If possible, the ultimate goal for midfacial enhancement is to combine the two key components of rejuvenation and augmentation. If, however, either surgical option by itself is insufficient to relocate ptotic soft tissue or augment volume loss, then the alternative solution must individually be combined with other procedures to provide the maximum multimodality approach to remedy the problem.

Specific criteria are available for determining regions of aesthetic deficits and their corresponding alloplastic solutions.[25,26] In addition, other distinguishing considerations in midfacial aging and imbalance must also be identified. They are periorbital aging, midfacial descent and volume loss, and facial bony maldevelopment with accompanying soft tissue imbalance, ptosis, and asymmetry.

Periorbital aging. With age, there is a weakening of the orbital septum and herniation of the periorbital fat, causing infraorbital bulges. The orbicularis muscle becomes ptotic, especially in its most inferior aspect. Use of conventional blepharoplasty tends to exacerbate laxity of the lower canthal ligament, which contributes to the formation of the "tear-trough" deformity or, in severe cases, causes senile ectropion.[27,28] Attendant with aging is subcutaneous tissue atrophy, which has more damaging affects on the very thin infraorbital skin accounting for the hollowness of the eyes with advanced aging.

Skeletal insufficiency and imbalances are usually caused primarily by the hypoplastic development and inherent bony imbalances of the facial skeleton, which are exacerbated by the aging process.

Midfacial descent and volume loss. Midfacial descent involves ptosis of the infraorbital subcutaneous tissues, the malar fat pad, the suborbicularis oculi fat (SOOF),[1] and the orbicularis muscle. As the cheek falls and collects on the upper nasolabial fold, the thicker tissues of the malar fat pad descend and leave the infraorbital region exposed to thin soft tissue covering. Thus, the nasojugal/tear trough region becomes prominent, the lower eyes appear hollow, and the infraorbital rim becomes more prominent. The loss of subcutaneous tissues occurs everywhere in the body but affects midfacial tissues more severely, including the buccal fat pad, the malar fat pad, and the SOOF. As these tissues continue to lose volume and descend, different patterns of midfacial aging develop in the infraorbital and cheek regions.

In the midface, most soft tissue deficiencies are found within the recess described as the "submalar triangle."[29] This inverted triangular area of midfacial depression is bordered above by the prominence of the zygoma, medially by the nasolabial fold, and laterally by the body of the masseter muscle (Fig. 25–3). In patients, in whom the severe degenerative changes of the skin and the loss of underlying soft tissue and fat associated with deficient underlying bone structure are combined, the gravitational effects of aging will be exaggerated and cause further deepening of depressions, folds, and wrinkles. In other individuals who have exceptionally prominent cheek bone structure combined with thin skin lacking in subcutaneous or deep supporting fat, facial depressions will be further emphasized. This type of pattern causes a gaunt or haggard appearance in an otherwise healthy person. The severe form of this midfacial pattern can be seen in anorexia nervosa, starvation, or in a newly identified group of HIV-positive patients who have been on protease inhibitors for

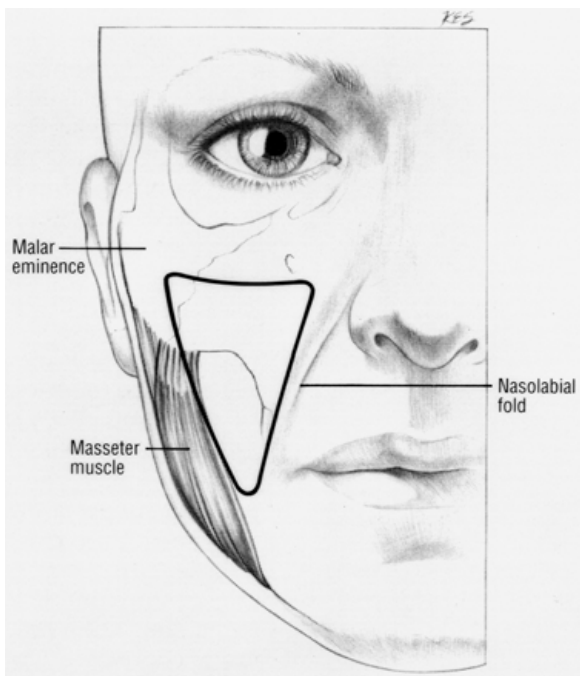


Figure 25–3 The inverted submalar triangle is an area of midfacial depression bordered medially by the nasolabial fold, superiorly by the malar eminence, and laterally by the main body of the masseter muscle.

[1]SOOF is the transition tissue between the orbital septum and the malar fat pad. This is a thin layer of granular fat present under the lower orbicularis fibers. It is *not* connected to the periorbital fat, which remains separated from the SOOF by the orbital septum and its insertion onto the inferior orbital rim at the arcus marginalis.

prolonged periods. In combination with the primary disease process, the protease inhibitors and other newer generation HIV therapies have a predilection for erosion of the midfacial fat and the buccal fat pad.[1,2] (Fig. 25–4). These conditions of volume loss that are also associated with the aging process often preclude use of rhytidectomy alone for complete facial rejuvenation and are currently being successfully treated with the use of computer-assisted custom-designed facial implants.[30]

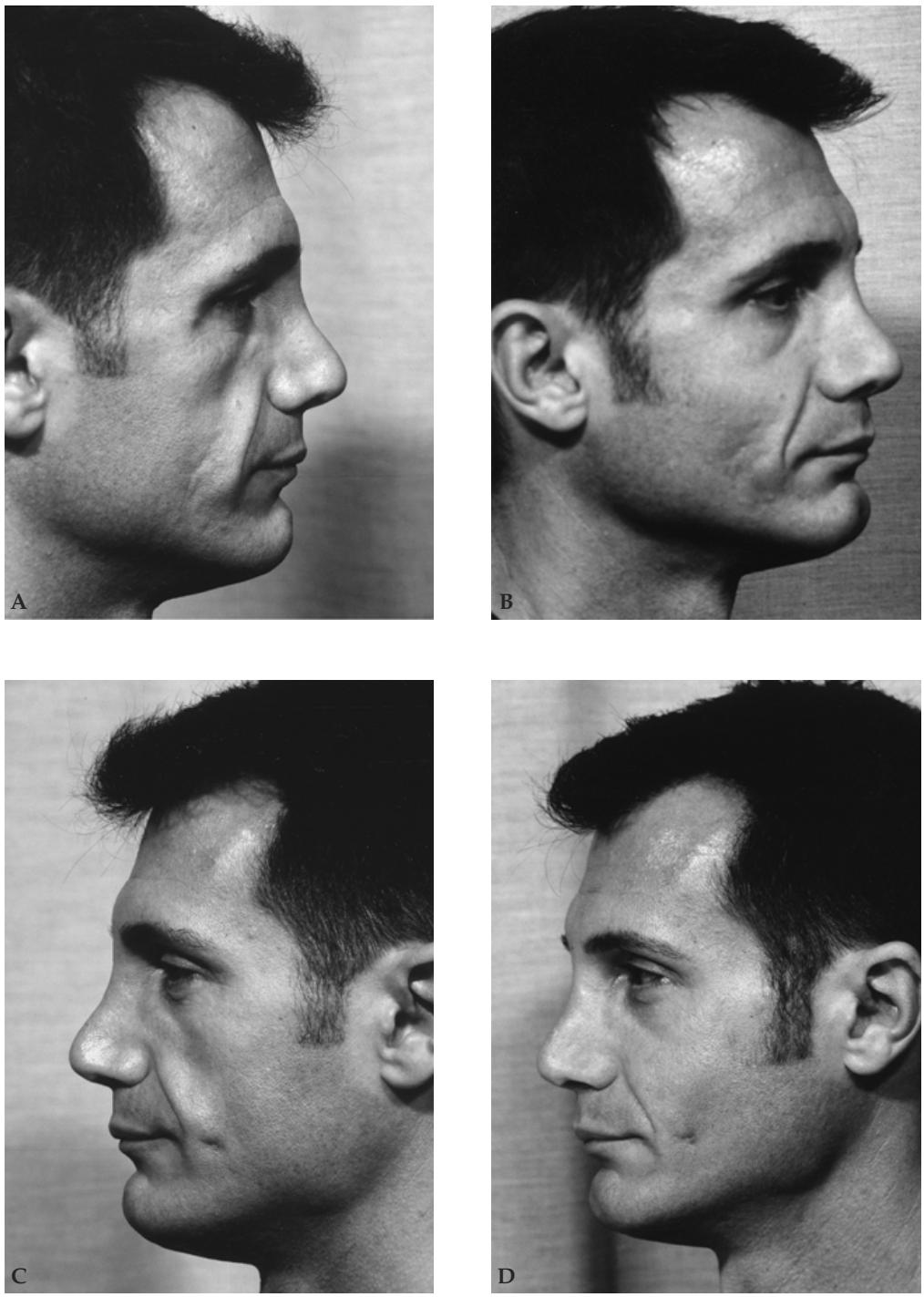


Figure 25–4 **(A, C)** This preoperative photograph represents a patient who has been treated with protease inhibitors for a prolonged period. Many patients eventually develop complete erosion of the midfacial fat and the buccal fat pad leaving a particularly deep cavitary depression in the midface. **(B, D)** At 1 year post surgery, the condition was successfully treated with computer-assisted custom-designed midfacial implants.

Midfacial Procedures: (A Mulimodality, "Multilevel" Approach)

For successful rejuvenation of the midface, this descent and volume loss must be camouflaged, corrected, or replaced. This now entails a multilevel as well as a multimodality approach to the pathophysiologic events of aging. *Camouflage techniques*, such as arcus marginalis blepharoplasty, cause blunting of the nasojugal groove/tear trough region by securing the infraorbital fat bulge past the arcus marginalis.[31] *Midlevel cheeklift techniques* reverse midfacial descent by lifting the midfacial tissues and anchoring them in a more superior-lateral direction.[32] Alloplastic or autogenous augmentation techniques reverse the effects of midfacial descent by replacing midfacial volume and providing soft tissue support at the deepest plane. Because there are many elements of structural deficiency and phenomena of aging, along with rhytidectomy, laser resurfacing, and many other adjunctive techniques, facial implants are used collectively as a necessary part of the framework to restore and extend the optimum aesthetic qualities of the youthful face. Imperfections related to the superficial, soft tissue component of the face, whether it be epidermis, dermis, subcutaneous fat, or, in some cases, muscle, have been corrected with the use of autogenous tissue and synthetic implants. Autogenous fat, homografts, and xenografts such as AlloDerm (Life Cell Corp., The Woodlands, TX), and collagen, as well as alloplastic materials such as ePTFE, are just a few of the materials that have been used. The myriad of soft tissue fillers currently on the worldwide market are testimony to the fact that the ideal soft tissue substitute to replace the superficial soft tissue component is still not available (Table 25–1).

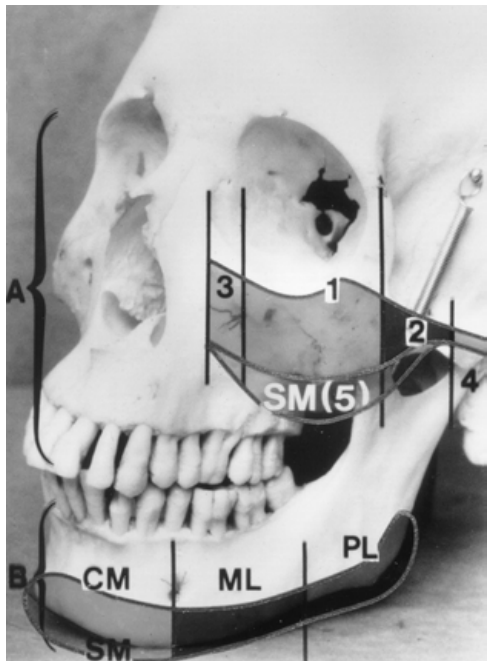


Figure 25–5 Alloplastic facial contouring by zonal principles of skeletal anatomy. The zones of mandibular augmentation: central mentum (CM), midlateral (ML), and posterolateral (PL); the zones of malar anatomy: submalar (SM), submalar zone 5 [SM(5)]. (From Binder WJ, et al. Augmentation of the malar-submalar/midface. *Fac Plast Surg Clin North Am* 1994;2: 265–283. With permission.)

PREOPERATIVE ANALYSIS FOR FACIAL CONTOURING

Considering the infinite variations of facial form that exist, most analytical measurements used in the determination of aesthetic guidelines have been unreliable. Recent analysis and angle guidelines have been helpful as a first step in decifering contour. However, facial augmentation is a three-dimensional procedure that exponentially increases the variabilities of structural diagnosis and ultimate treatment. Having a good understanding of skeletal anatomy and being able to identify specific types of topographic patterns guides the surgeon in making the final determination for optimal implant selection and placement.

Augmentation of the facial skeleton with alloplastic implants changes the deepest skeletal plane of the face with a three-dimensional modality. Evaluation of the face for contouring procedures starts with an understanding of specific zones of skeletal anatomy and identification of distinctive and recognizable configurations of facial deficiency. Correlating these elements of structural and topographic variations is essential for choosing the optimal implant shape, size, and position to obtain the best results in facial contouring.

Evaluation of Mandibular Contour Defects

Delineation of zonal principles of anatomy within the premandible space allows the surgeon to create specific chin and jaw line contour[25] (Fig. 25–5). Traditionally, chin implants were placed over the area between the mental foramina. This familiar location constitutes only one segment or zone of the mandible that can be successfully altered. Implants placed in the central segment alone and without lateral extension often produce abnormal round protuberances that are unattractive. A midlateral zone within the premandibular space can be defined as the region extending from the mental foramen posteriorly to the oblique line of the horizontal body of the mandible. When this zone is augmented in addition to the central mentum a widening of the anterior jaw line contour results. This is the basis for the development of the extended anatomical and prejowl chin implant (Fig. 25–6). The posterior lateral zone is the third zone of the premandibular space, which encompasses the posterior half of the horizontal body including the angle of the mandible and the first 2 to 4 cm of the ascending ramus. This zone can be modified with a mandibular angle implant that will widen or elongate the posterior mandibular angle to produce a stronger posterior jaw line contour.

Zonal principals of skeletal anatomy are useful for conceptualizing the malar midfacial region into distinct anatomical zones (Fig. 25–5). Zone 1, the largest area, includes the major portion of the malar bone and the first third of the zygomatic arch. Augmentation within this zone maximizes the projection of the malar eminence. It produces a high, sharp angular appearance. Zone 2 overlies the middle third of the zygomatic arch. Enhancement of this zone along with zone 1 accentuates the cheek bone laterally, producing a

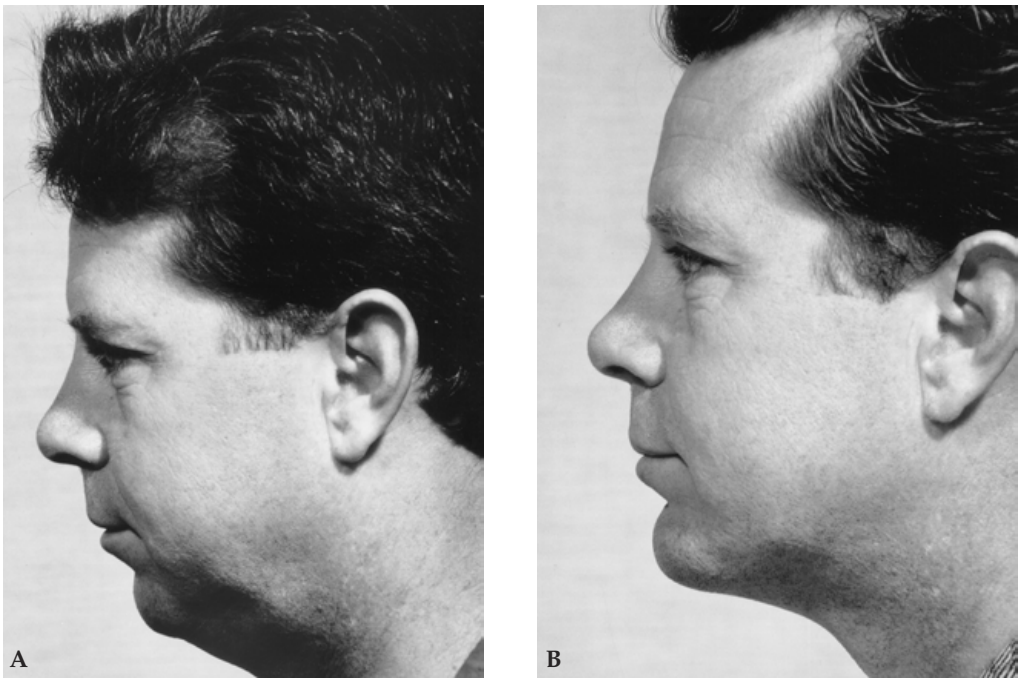


Figure 25–6 **(A)** Preoperative and **(B)** postoperative examples of use of an extended mandibular implant in addition to submental liposuction to create a significantly improved jaw- and neckline.

broader dimension to the upper third of the face. Zone 3, the paranasal area, lies midway between the infraorbital foramen and the nasal bone. A vertical line drawn from the intraorbital foramen marks the lateral border of zone 3, which is the medial extent of the dissection usually done for malar augmentation. Augmentation of zone 3 gives medial fullness to the infraorbital region. Zone 4 overlies the posterior third of the zygomatic arch. Augmentation in this area produces an unnatural appearance and in most cases is not indicated. The tissues overlying this zone are adherent to the bone, and dissection must be performed cautiously because the zygomaticotemporal division of the facial nerve passes superficially within the temporoparietal fascia over the zygomatic arch and would be prone to injury. Zone 5 is the submalar triangle.

Midfacial Contour Defects

A topographic classification of midfacial contour deficiencies has proven to be extremely useful as a basic reference guideline to correlate distinctive anatomic patterns of deformity to specific implants.[26] (Table 25–2; Fig. 25–7) Type I deformity occurs in a patient who has good midfacial fullness, but insufficient malar skeletal development. In this case, a malar shell implant to augment the zygoma and create a higher arch to the cheekbone would be desirable. The larger surface area of the implant imparts greater stability and helps reduce rotation or displacement. Inferior extension into the submalar space establishes a more natural transition from the localized area of maximal augmentation to contiguous areas of relative recession (Fig. 25–8). Type II deformity occurs in a patient who has atrophy or ptosis of the midfacial soft tissues in the submalar area with adequate malar development. In this case, submalar implants are used to augment or fill these depressions or provide anterior projection (Figs. 25–9). Type II deficiency is the most common, found most in the aging patient where the submalar implant is used effectively as an adjunct to the facelift surgery (Fig. 25–10). Type III deformity occurs in a patient who has thin skin and exceptionally prominent malar eminences. These characteristics combine to cause an abrupt transition from the cheek bone superiorly to an extreme area of hollowness found within the submalar region, producing an exceptionally gaunt or skeletonized facial appearance. In this group of patients, a second-generation submalar transition implant is used to fill the abrupt midfacial hollow. Type IV deformity is the result of malar hypoplasia and submalar soft tissue deficiency, which is described as the "volume-deficient" face. In this situation, a single combined malar-submalar implant must serve two purposes: it must proportionately augment a deficient skeletal structure over the malar area and fill the void created by absent midfacial soft tissue within the submalar area. Because this condition is also associated with premature aging of the skin in terms of excessive midfacial wrinkling and deep folds, these patients are often classified as suboptimal candidates for rhytidectomy. As seen in Fig. 25–11, total midfacial restoration and lateral mandibular augmentation, using a combined malar-submalar implant and prejowl implant, provide the structural basis for this patient to derive greater benefit from the concurrently performed rhytidectomy procedure and successfully eliminate the deep folds that were present in

TABLE 25–2 Patterns of Midfacial Deformities Correlated with Type of Implant

Deformity type	Midfacial deformity	Type of augmentation required	Type of implant predominantly used
I	Primary malar hypoplasia; adequate submalar soft-tissue development	Requires projection over the malar eminence	Malar implant: "shell-type" implant extends inferiorly into submalar space for more natural result
II	Submalar deficiency; adequate malar development	Requires anterior projection. Implant placed over face of maxilla and/or masseter tendon in submalar space. Also provides for midfacial fill	Submalar implant (New Conform type or Generation I submalar implant)
III	Extreme malar-zygomatic prominence; thin skin; with abrupt transition to a severe submalar recess	Requires normal anatomic transition between malar and submalar regions; plus moderate augmentation around inferior aspect of zygoma	Submalar implant (Generation II): "U"-shaped to fit w/in submalar space and around inferior border of prominent zygoma
IV	Both malar hypoplasia and submalar deficiency	Requires anterior and lateral projection; "volume replacement implant" for entire midface restructuring	"Combined" submalar-shell implant; lateral (malar), and anterior (submalar) projection. Fills large midfacial void
V	Tear-trough deformity (Infraorbital rim depression or recess)	Requires site-specific augmentation along infraorbital rim	"Tear-trough implant"; to fit site-specific suborbital groove

the medial middle third of the face. The tear trough (type V) deformity is specifically limited to a deep groove that commonly occurs at the junction of the thin eyelid and thicker cheek skin. In this deformity, a pronounced fold extends downward and laterally from the inner canthus of the eye across the infraorbital rim and the suborbital component of the malar bone. A tear trough silicone elastomer implant, ePTFE, and fat have been used in attempts to correct this deformity.[28,33]

One specific approach to the hollow infraorbital and nasojugal region is an infraorbital/midfacial elevation technique, the superficial cheeklift.[32] This addresses the vector component of midfacial aging. The superficial cheeklift enables an elevation in the thicker cheekpad skin and subcutaneous tissue to cover the inferior orbital rim. This also reduces heaviness of the upper nasolabial fold (Fig. 25–12). The lateral and midpupillary region are most effectively treated. For a more severe tear trough deformity medially, a concomitant arcus marginalis use of infraorbital fat or tear trough implant can also be used concurrently if additional augmentation is necessary. The superficial dissection plane offers advantages in ease of performance, direct access to the pliable cheekpad, and lower complication rates over subperiosteal dissection techniques. Caution and experience in midfacial anatomy are still necessary before any midface elevation procedure can be undertaken. If excessive midfacial elevation (or overresection of seemingly loose infraorbital skin) is attempted, downward traction from the mouth can result in traction on the lower eyelid. Cheeklift techniques are new and are still undergoing modification as their role in midfacial rejuvenation increases.

PROCEDURE

An implant of a particular shape or size that is used for a wide face may need to have its overall dimension or thickness reduced for a narrow face, or in the presence of thin skin. As all faces are different, it should be the rule that implants require modification. Therefore, the surgeon must

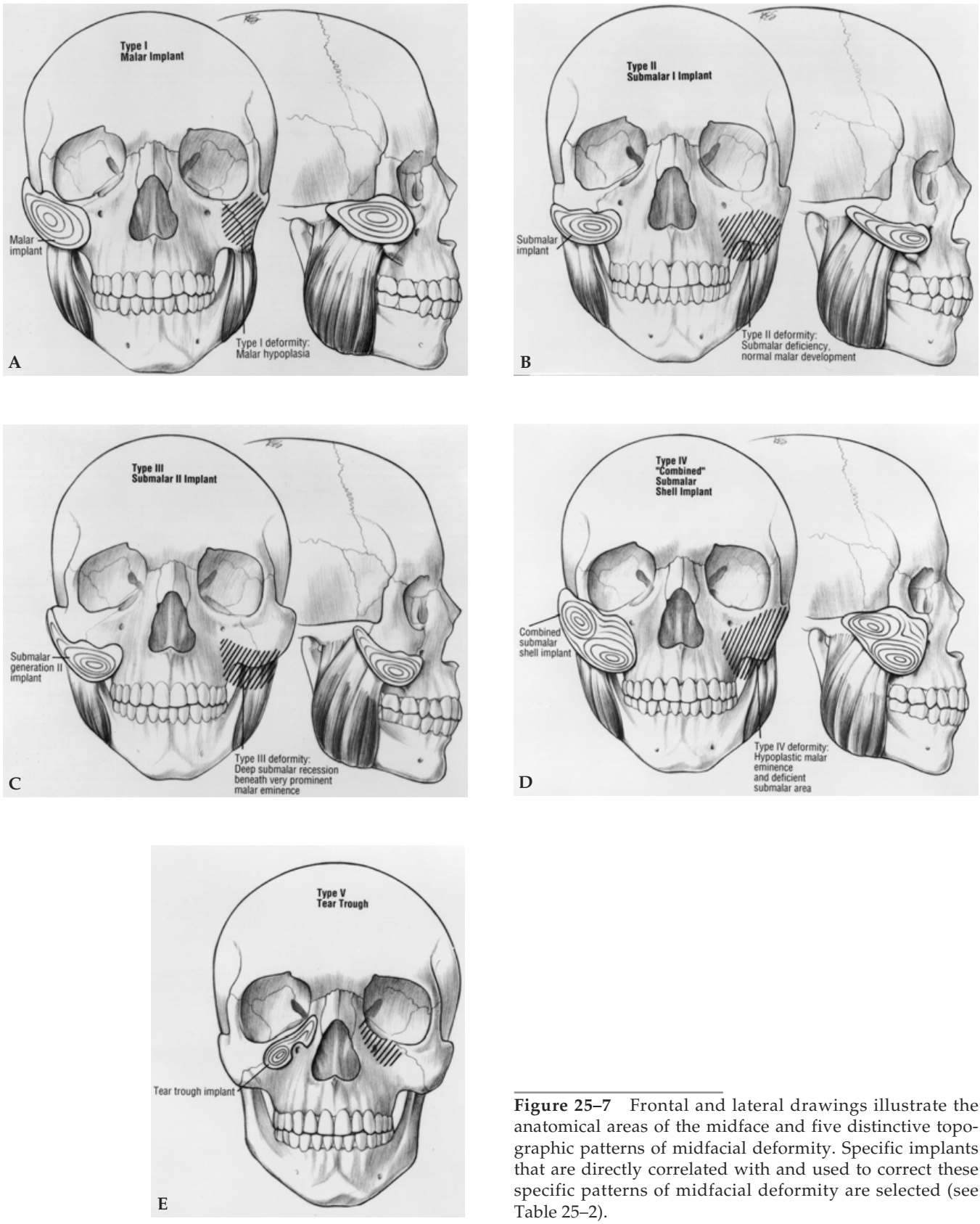


Figure 25–7 Frontal and lateral drawings illustrate the anatomical areas of the midface and five distinctive topographic patterns of midfacial deformity. Specific implants that are directly correlated with and used to correct these specific patterns of midfacial deformity are selected (see Table 25–2).

Figure 25–8 (*left*) Preoperative example of malar hypoplasia (type I deficiency). (*right*) Eight months after malarplasty using a Malar-Shell implant. Augmentation of a greater surface area and extension inferiorly into the submalar space produces a more natural high cheekbone effect.

Figure 25–9 **(A)** Preoperatively, this patient has a relatively good malar bone structure but was complaining of early flatness to the midface (type II deformity) in addition to a mandibular parasymphyseal depression caused by an earlier performed genioplasty. **(B)** Submalar augmentation restored the anterior projection to the middle third of the face, providing a more youthful expression as well as reducing the depth of the nasolabial folds. A custom implant was used to fill in the parasymphyseal depression.

Figure 25–10 **(A, C)** Preoperative. **(B, D)** Six months postoperative. In conjunction with rhytidectomy, lower blepharoplasty, and browlift, a conform submalar implant was used as adjunctively to help restore volume and structure, and to establish the basis for a greater longevity to the facelift operation.

be prepared to have all anticipated designs, shapes, or materials available and be prepared to modify the implant on an impromptu basis. Failure to have the right implant for a particular patient can only yield a suboptimal result.

On the day prior to surgery, the patient is started on a broad-spectrum antibiotic regimen that will continue for 5 days after surgery. Intravenous antibiotics and dexamethasone are also administered perioperatively. Before starting anesthesia, the patient must be in an upright position while the precise area to be augmented is outlined with a marking pen. This initial outline that is drawn on the skin is then explained to the patient so that a cooperative effort is made to finalize both the surgeon's and patient's perception of implant shape, size, and position to optimize their mutual goals (Fig. 25–13).

General Surgical Technique for Facial Implantation

The basic principles for augmenting the malar, midfacial, premandibular spaces or nasal augmentation are identical. Controlling the shape, size, and positioning of the implant will determine the overall final facial contour.

Surgical Technique for Mandibular Augmentation

Anterior Mandibular Implants

Access to the premandibular space can be accomplished by either an intraoral or an external route. The external route utilizes a 1 to 1.5-cm incision in the submental crease.

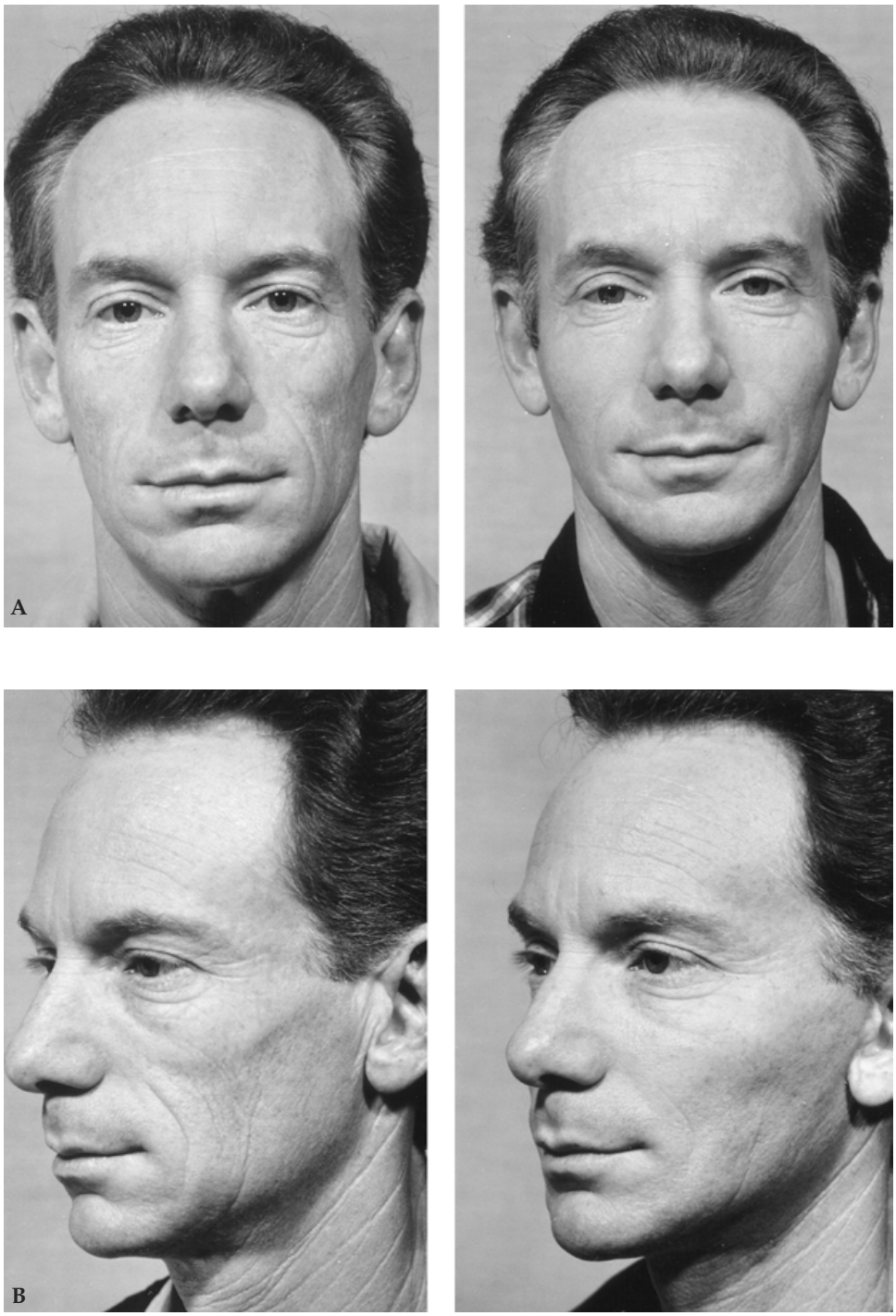


Figure 25–11 **(A)** frontal; **(B)** oblique; *(continues on next page)*

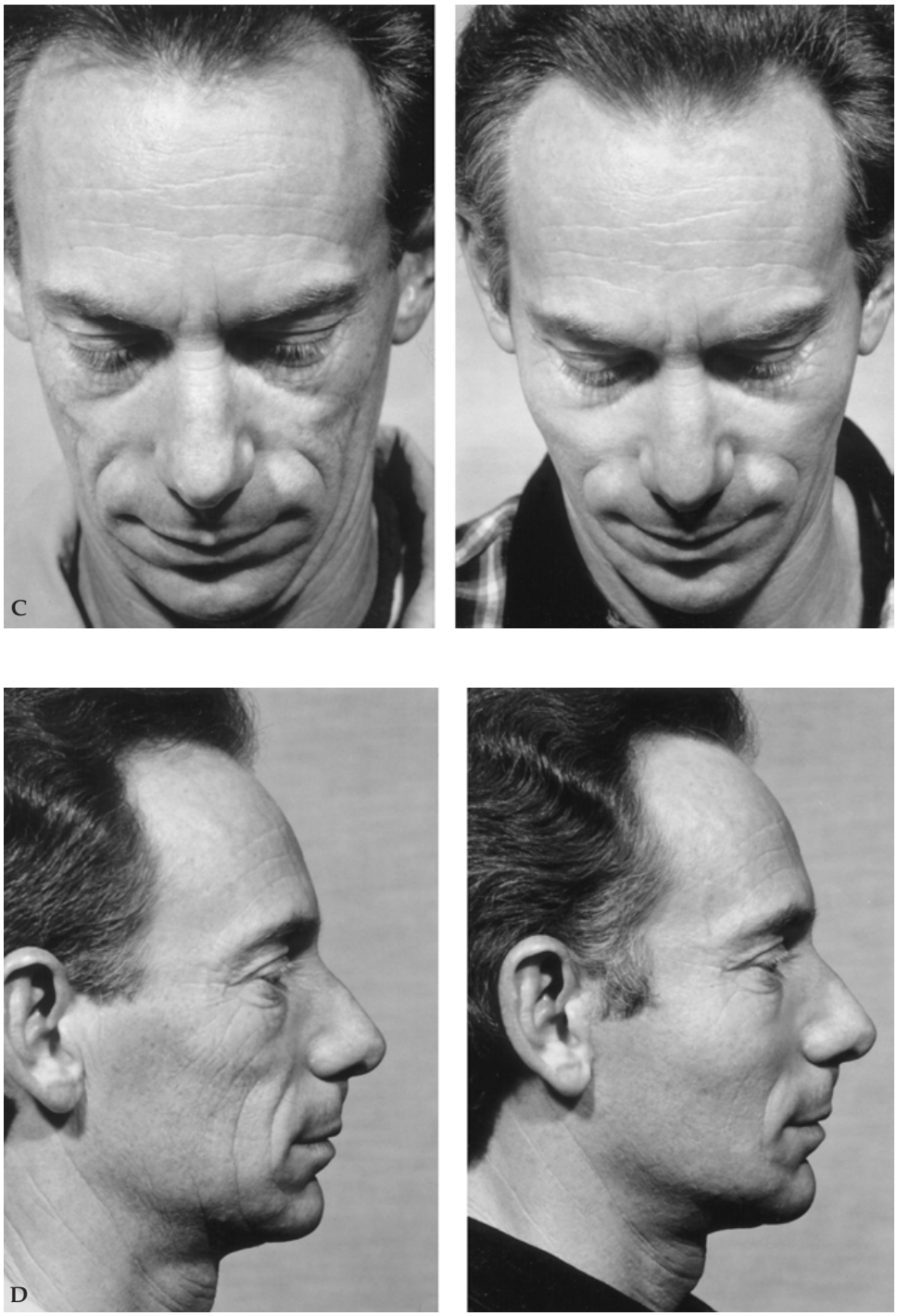


Figure 25–11 *(cont.)* **(C)** head down; **(D)** lateral. *Left* Preoperative analysis of the facial configuration in this 40-year-old patient reveals the presence of severe deficiency in both skeletal structure and soft-tissue volume contributing primarily to the excessive wrinkling of the skin in the area of the midface. *Right* Seven months postoperative; performed concurrently with rhytidectomy, the combined submalar-shell implants were used to restructure the entire midface, and a prejowl implant was used to add width to the mandible. In this patient, these augmentation procedures were essential for the structural and volumetric enhancement required for the facelift procedure to provide meaningful, long-term improvement. (From Binder WJ. A comprehensive approach for aesthetic contouring of the midface in rhytidectomy. *Fac Plast Surg Clin North Am* 1993;1:231–255. With permission.)

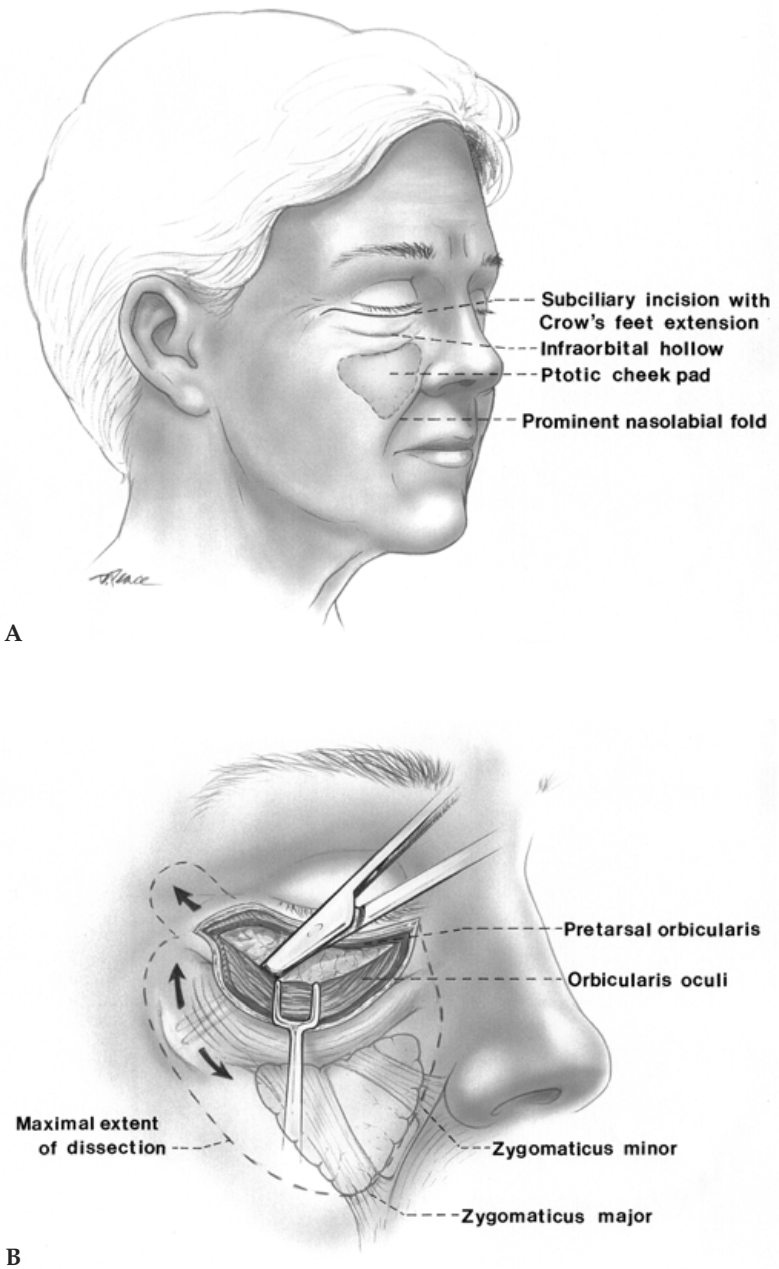
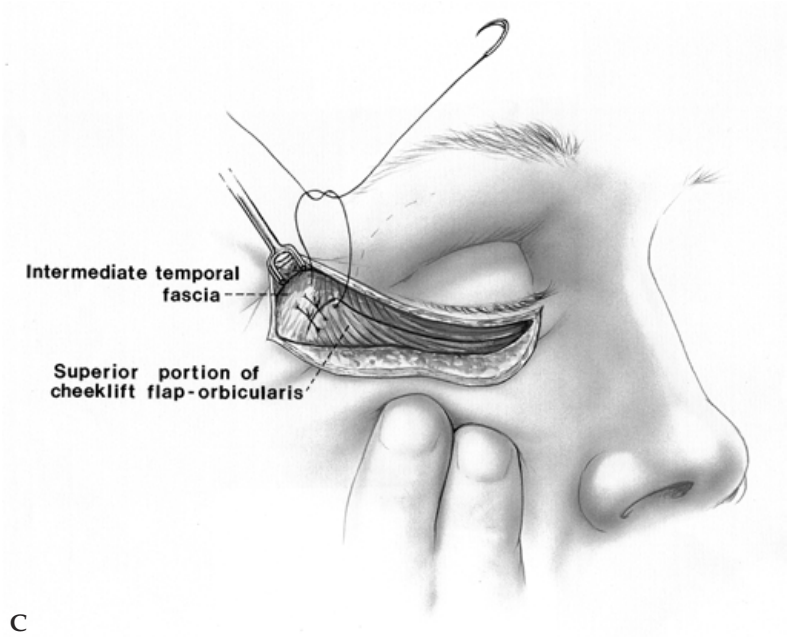


Figure 25–12 **(A)** Preoperative diagram showing infraorbital fat bulge, nasojugal and infraorbital hollowing, and ptotic malar fat pad. **(B)** Intraoperative dissection showing superficial cheeklift dissection in suborbicularis plane. *(continues on next page)*

Advantages of the external route are that it does not involve intraoral bacterial contamination; it has direct access to the inferior mandibular border where cortical bone is present; it does not require significant retraction of the mental nerves; and it allows the implant to be secured to the periosteum along the inferior mandibular border with simple suture fixation. This helps to prevent side-to-side or vertical slippage. The intraoral route provides the obvious advantage of leaving no external scars. The entry wound for the intraoral route is a transverse incision made through the mucosa. The mentalis muscle is divided vertically in the midline raphe to avoid transection of the muscle belly or detachment from the bony origins. This midline incision provides adequate access inferiorly to the bone of the central mentum and eliminates the potential muscle weakness that may occur if transection takes place. Lateral dissection requires identification and retraction of the mental nerves.

Basic technical rules for safe and accurate mandibular augmentation should be followed. (1) Dissection should stay on bone. Placement of implants in the subperiosteal plane creates a firm and secure attachment of the implant to the bony skeleton. Strong adherence of periosteum along the anterior inferior border of the mandible comprises the origins of the anterior mandibular ligament, which defines the pre-



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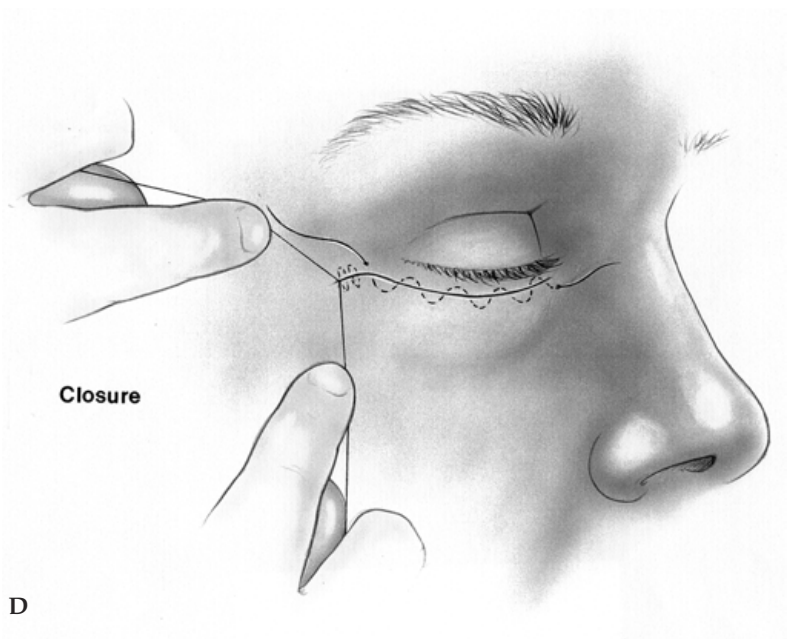


D

Figure 25–12 *(cont.)* **(C)** Anchoring of freed orbicularis oculi flap to intermediate temporal fascia. **(D)** Closure of subciliary incision.
(continues on next page)

jowl sulcus at the inferior aspect of the aging marionette crease. It is often necessary to incise these ligamentous attachments to allow dissection to continue along the inferior segment of the mandible. (2) Dissection of this space must be adequately expanded to accommodate the prosthesis comfortably. A sharp dissecting instrument may be used centrally, but only blunt instruments are used around the nerves and adjacent to soft tissues. (3) The mental nerve should be avoided. This is accomplished by compressing the tissues around the mental foramen with the opposite hand, which helps to direct the elevator away from the nerve and along the inferior border of the mandible. A dry operative field is essential for accurate visualization, precise dissection, proper implant placement, and prevention of postoperative hematoma or seroma.

A Joseph or 4-mm periosteal elevator is used to perform the dissection along the inferior mandibular border. When the pockets are large enough, one side of the implant is inserted into the lateral portion of the pocket on one side and then folded on itself whereby the contralateral portion of the implant is inserted into the other side of the pocket. The implant is then adjusted into position. If the implant material does not allow flexibility, then either the incision must be made larger or the procedure must be performed

Figure 25–12 *(cont.)* **(E)** A 52-year-old woman, preoperative, with hollow infraorbital and nasojugal region. **(F)** Six months postoperative superficial cheeklift. (From Moelleken BRW. The superficial subciliary cheeklift: a technique for rejuvenating the infraorbital region and nasojugal groove—clinical series of 71 patients. *Plast Reconstr Surg* 1999;104(6). With permission.)

Figure 25–13 Prior to infiltration of local anesthetic, the areas requiring augmentation are specifically outlined with the patient sitting in the upright position. In the majority of cases, the medial border of submalar or malar implants is placed lateral to the infraorbital foramen corresponding approximately to the midpupillary line. (From Binder WJ. A comprehensive approach for aesthetic contouring of the midface in rhytidectomy. *Fac Plast Surg Clin North Am* 1993;1: 231–255. With permission.)

through an intraoral incision. Implants expanding into the midlateral or parasymphyseal zone accomplishes anterior widening of the lower third of the facial segment. The necessary average central projection is 6 to 9 mm for men and 4 to 7 mm for women. Occasionally, in a patient with severe microgenia, implants measuring 10 to 12 mm in projection or greater may be necessary to create a normal profile and a broader jawline.

Mandibular Angle Implants

Access to the angle of the mandible is achieved through a 2-to 3-cm mucosal incision at the retromolar trigone. This gives direct access to the angle of the mandible. Dissection is performed on bone and beneath the masseter muscle to elevate the periosteum upward along the ramus and then anteriorly along the body of the mandible. A curved (90 degree) dissector is used to elevate the periosteum around the posterior angle and ramus of the mandible. This permits accurate placement of angle implants that are specifically designed to fit the posterior bony border of the ascending ramus and enhance angle definition. These implants are secured with a titanium screw.

Surgical Techniques for Malar and Midface Contouring

The primary route for entering the malar-midfacial areas is the intraoral approach. Other approaches include the subciliary (via lower blepharoplasty), transconjunctival, rhytidectomy, zygomaticotemporal, and transcoronal routes.

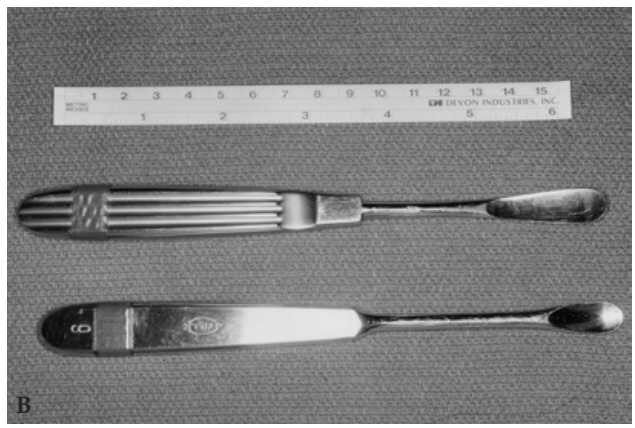
Intraoral Route

The intraoral route is the most common and the preferred route for most midfacial implantations with the exception of the tear trough implantation. After infiltration of the anesthetic solution, a 1-cm incision is made through the mucosa and carried directly down to bone in a vertical oblique direction above the buccal-gingival line and over the lateral buttress (Fig. 25–14). Because the mucosa will stretch and allow complete visual inspection of the midfacial structures, a long incision through adjacent submucosal or muscular layers is not necessary and is discouraged. The incision should be made high enough to leave a minimum of 1 cm of gingival mucosal cuff. If the patient wears dentures, this incision must be placed above the dentures' superior border. Dentures can be left in place after the procedure, which in our experience does not cause extrusion or increase the incidence of complications. A broad Tessier-type elevator (approximately 10 mm wide) is directed through the incision onto the bone in the same orientation as the incision. A broad elevator helps to facilitate the dissection safely and with relative ease within the subperiosteal plane (Fig. 25–14B). While keeping the elevator directly on bone, the soft tissues are elevated obliquely upward off the maxillary buttress and the malar eminence. The elevator is kept on the bone margin along the inferior border of the malar eminence and the zygomatic arch. The external or free hand is used to help guide the elevator over the designated areas. For routine malar-submalar augmentation procedures, no attempt is made to visualize or dissect within the vicinity of the infraorbital nerve unless an implant is intended for this area. If necessary, the infraorbital nerve is easily visualized in a more medial location. The submalar space is created by elevating the soft tissues inferiorly over the masseter muscle below the zygoma (Fig. 25–14C). One can discern the correct plane of dissection by the glistening white fibers of the masseter tendons by direct vision. It is important to note that these masseteric attachments are not cut and are left completely intact to provide a supporting framework on which the implant may rest. As the dissection moves posteriorly along the zygomatic arch, the space becomes tighter and is not as easily enlarged as the medial segment. However, part of this space can be opened by gently advancing and elevating the tissues with a heavy, blunt periosteal elevator. It is of utmost importance that the dissection be extended sufficiently so that the implant fits passively within the pocket. A pocket that is too small will force the implant toward the opposite direction, causing implant displacement or extrusion. Under normal conditions, the pocket is estimated to collapse and obliterate most of the space around the implant within 24 to 48 hours following surgery. Implant selection is aided by observing the actual topographic changes produced by placement of the different implant "sizers" into the pocket (Fig. 25–14D).

Final implant placement must correspond to the external topographic defects outlined on the face preoperatively (Fig. 25–14E). In submalar augmentation, the implant may reside below the zygoma and zygomatic arch, over the masseter tendon, or it may overlap both bone and tendon. The larger shell-type malar implants reside primarily on bone in a more superior lateral position and may extend partly into the submalar space. The combined implant will occupy both areas. Any implant placed in patients with noticeable facial asymmetry, thin skin, or an extremely prominent bone structure may require modification to reduce the thickness or length and avoid abnormal projections. Among the advantages of silicone elastomer midfacial implants is flexibility enabling large implants to be compressed through small openings, which are then able to reexpand in the larger pocket created beyond the incision.[34] This avoids having to make the larger incisions required for more rigid implants and allows for ease of implant insertion and removal during the selection process.

Facial Asymmetry

The most difficult task in achieving successful results in facial contouring is the management of facial asymmetry. During the preoperative consultation, a thorough discussion regarding this problem is essential because most patients are usually unaware of the qualitative or quantitative presence of their own facial asymmetry.[35] Meticulous attention to detail is required to visualize, perceptually integrate, and then make procedural adjustments to accommodate existing three-dimensional discrepancies. It is not unusual to find adequate malar development and a well suspended soft tissue pad with good external contour on one side of the face, and a hypoplastic malar eminence along with relative atrophy of the soft tissues and greater wrinkling of the skin on



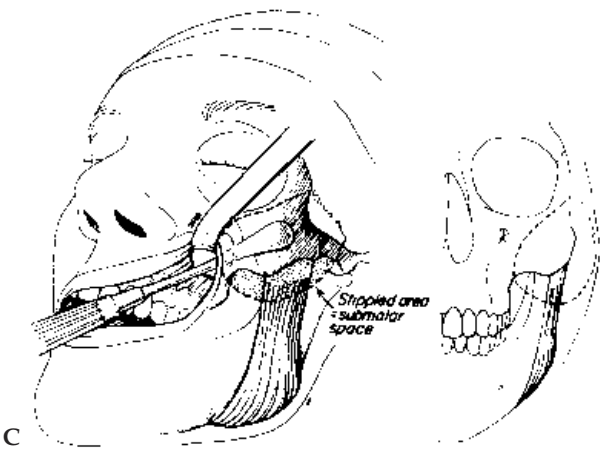


Figure 25–14 **(A)** After injection with local anesthetic, the mucosa is compressed and a single incision is carried through mucosa and periosteum directly onto bone. The incision is small (1 to 1.5 cm) and is placed over the lateral aspect of the canine fossa and lateral buttress at least 1 cm above the buccal-gingival line. **(B)** The 9- and 10-mm curved and straight periosteal elevators used for dissection. **(C)** Demonstrates the general extent of dissection required for most midfacial implants. The dissection must be sufficiently extended posterolaterally over the zygomatic arch and/or expanded inferiorly into the submalar space over the tendinous insertions of the masseter muscle so that the implant can be accommodated passively within the pocket. **(D)** Direct visual inspection of midfacial structure can be obtained through the intraoral route by retracting the overlying tissues. Using sizers or different implants helps to determine optimum size, shape, and position of the final implant selected. (The stippled area represents a sizer that has been placed within the pocket.) **(E)** *Left:* The external drawings made on the skin delineate the malar bone and submalar space below. *Right:* The shape and size of the superimposed implant should roughly coincide with the external topographical defect demarcated prior to surgery. In this case, the inferior aspect of the implant extends downward to occupy the submalar space. (From Binder WJ. A comprehensive approach for aesthetic contouring of the midface in rhytidectomy. *Fac Plast Surg Clin North Am* 1993;1:231–255. With permission.)

the other side. In these cases, it is essential to have an adequate selection of implants available and to anticipate carving or altering the implants to adjust to the differences in contour between the two sides. Unusual asymmetries may also require use of different implants for each side or shims that can be carved from a silicone block that are sutured to the posterior surface of the implant to increase the projection of a particular segment.

Implant Fixation

Once position has been established, it is usually necessary to secure the implant. This can be accomplished by a number of different methods. Internal suture fixation relies on the presence of an adjacent stable segment of periosteum or tendinous structure on which to anchor the implant. Stainless steel or titanium screws can also be used. There are two methods of external fixation used to stabilize midfacial implants. The indirect lateral suspension technique uses 2-0 Ethilon sutures wedged on large Keith needles and placed through the implant tail. These needles are then inserted through the pocket, directed superiorly and posteriorly to exit percutaneously posterior to the temporal hairline. The sutures are then tied over a bolster exerting traction on the tail of the implant. This technique is more suitable for malar implants. The direct method of external fixation is often used in patients with gross asymmetry or when submalar or combined implants are used. In these situations, the direct external method of fixation prevents slippage in the immediate postoperative period. With this method, the implants are positioned to correspond directly with marks on the skin that coincide with the two most medial fenestrations of the implant. Symmetrical placement of both implants is assisted by measuring the distance from the midline to both right and left medial markings (Fig. 25–15A). Then the implants are removed and placed on the skin by lining up the medial fenestration over its corresponding mark. The position of the lateral portion of the implant is then decided by placing a second mark corresponding to the adjacent implant fenestration. A double-armed suture with 1-in. straight needles is then passed through the two medial fenestrations of the implant from a posterior to anterior direction. The needles are advanced through the pocket, passed perpendicularly through the skin, and allowed to exit at the respective external markings (Fig. 25–15B). The implant, following the needles, is guided into the pocket. The implant is then secured in place by tying the sutures over bolsters composed of two cotton rolls (Fig. 25–15C).

Subciliary (Lower Blepharoplasty) Approach

It is more difficult to introduce a large implant through a subciliary approach. However, this is the preferred approach for the insertion of the tear trough implant. In malar augmentation only, when zone 1 or 2 requires a smaller malar implant to achieve high-arch cheek bones, then the blepharoplasty approach may be adequate. The advantages of the subciliary approach are the lack of oral contamination and the soft tissue support inferiorly, which reduces the chances for implant descent. However, this technique can also precipitate an ectropion in the presence of a weak tarsus.

Transconjunctival Approach

The transconjunctival approach has been used for insertion of midfacial implants but may also require disinsertion of the lateral canthal tendon. This necessitates secondary resuspension canthoplasty with the attendant risk of lower eyelid assymmetry.

Rhytidectomy Approach

The malar space may be safely entered through zone 1 of the malar region. Penetration of the subcutaneous musculoaponeurotic system (SMAS) is made medial to the zygomatic eminence and then bluntly carried down to bone. There are no significant facial nerve branches in this area. The malar pocket is then created primarily by retrograde dissection. However, insertion of an implant by this approach can introduce technical difficulties during SMAS dissection and elevation and provides limited access for extended implant positioning.

Zygomatic/Temporal and Coronal Approaches

The cranial facial techniques for subperiosteal facelifts provide ready access to the malar zygomatic region. However, endoscopic approaches for the most part provide reduced exposure or the required visualization necessary for regional augmentation with larger implants.

COMPLICATIONS

Complications of implantation in facial augmentation include bleeding, hematoma, infection, exposure, extrusion, malposition, displacement or slippage, fistula, seroma, persistent edema, abnormal prominence, persistent inflammatory action, pain, and nerve damage.[36] However, in most of the complications listed, very few are due solely to the implant material itself. It is extremely difficult to separate the surgical technique from the surrounding circumstances of the individual operation as well as from individual patient risk factors not associated with the implant.

Extrusion should not occur if the technical rules have been followed. The extended surface area of the larger or extended implants that fit along the midface and mandibular contours minimizes malposition and malrotation. Adequate dissection of the subperiosteal space to a large enough degree to create midlateral and posterolateral tunnels in the mandible and the desired pockets in the midface will maintain the implant in proper position. In mandibular augmentation the mandibular branch of the facial nerve passes just anterior to the midportion of the mandible in the midlateral zone. It is important not to traumatize the tissues that overlay this area. The course of the mental nerve is anatomically directed superiorly into the lower

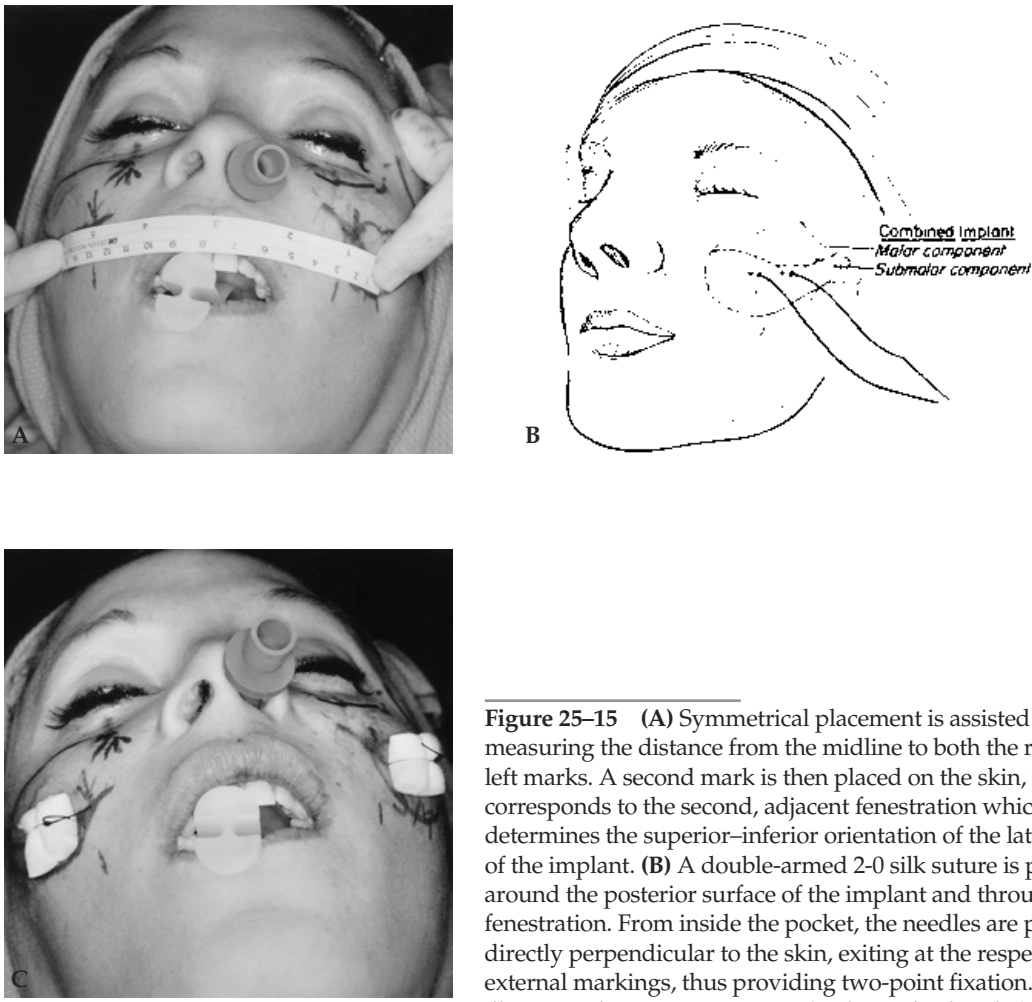


Figure 25–15 **(A)** Symmetrical placement is assisted by measuring the distance from the midline to both the right and left marks. A second mark is then placed on the skin, which corresponds to the second, adjacent fenestration which determines the superior–inferior orientation of the lateral portion of the implant. **(B)** A double-armed 2-0 silk suture is passed around the posterior surface of the implant and through the fenestration. From inside the pocket, the needles are passed directly perpendicular to the skin, exiting at the respective external markings, thus providing two-point fixation. [Figure illustrates the two components (malar and submalar) that form the combined implant.] **(C)** The implant is stabilized by tying of the suture directly over an external bolster (composed of two cotton rolls). The suture and bolster are removed by the third postoperative day. (From Binder WJ. A comprehensive approach for aesthetic contouring of the midface in rhytidectomy. *Fac Plast Surg Clin North Am* 1993;1:231–255. With permission.)

lip, which also helps to protect it from dissection trauma. Temporary hypesthesia of the mental nerve can occur for several days to several weeks after surgery. Permanent nerve damage is extremely rare and in one study represented less than 0.5% of a statistically large numbers of cases.[37] If encroachment on the nerve by the implant is detected due to misplacement or malrotation, then repositioning of the implant below the nerve should be done as early as possible.

The temporal branch of the facial nerve passes posterior to the midaspect of the zygomatic arch, and care must also be exercised when dissecting in this area. Infection can be minimized by irrigation of the pocket at the end of the procedure with either normal saline or with bacitracin, 50,000 units per liter of sterile saline. Soaking the porous implants in antibiotic solution is advised. Drainage techniques are not ordinarily necessary in mandibular augmentation but may be used in midfacial augmentation if there is more than the normal amount of bleeding. We have found that immediate application of pressure over the entire midface by using a full-face compression garment considerably reduces the risk of hematoma, seroma, swelling, and, consequently, the postoperative complications related to fluid accumulation within the pocket (Fig. 25–16).

Bone resorption is more commonly found in mandibular augmentation than in other alloplastic implant procedures. Findings of bone erosion following chin implantation were reported in 1960. However, since these early reports, there have been no clinical reports of significance after surveying large populations of surgeons.[37] As long as the implant is in the correct position over cortical bone, the condition appears to stabilize without the loss of any substantial projection or prior cosmetic enhancement.

Figure 25–16 The immediate application of some pressure over the entire midface by using a full-face compression garment has been found to considerably reduce the risk of hematoma, seroma, and swelling.

DISCUSSION

Understanding the principals of zonal anatomy, observing the types of external facial forms, and paying careful attention to basic techniques result in greater predictability in facial contouring. Critical analysis of the patient's face and precise and focused communication between surgeon and patient lead to optimal patient satisfaction. Many different types of facial implants are available with which the surgeon can create a variety of contours to fulfill most needs. Reconstructing more complex contour defects can be accomplished by using three-dimensional computer imaging and CAD/CAM technology to manufacture custom implants.[25] A recent increase in the number of HIV-positive patients taking protease inhibitors has necessitated the use of this technique to effectively treat this cosmetically disabling condition.

CONCLUSION

Facial implant procedures provide the patient with significant change in his or her facial appearance, and the rewards to the patient in terms of producing increased harmony and proportion to the face are unlimited. Although challenging, few procedures can provide the major rewards that facial contouring procedures can offer.

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Chapter 26

Hair Replacement Techniques

Dow Stough and Jeffrey M. Whitworth

Baldness has afflicted humans for so long that its origins are lost in the mists of prehistory. It is useful to consider the fact that some primates, such as chimpanzees and certain monkeys, also exhibit maturity-related alopecia.[1]

The imaginative remedies for baldness over the course of time are legion, ranging from camel dung to stump water to even less appealing substances. The record of such remedies starts with ancient papyri dating back 5000 years.[2] The Bible sympathized with those who had bald pates but could offer no remedy.

Currently there are delicate and effective surgical techniques for hair transplantation, and they do provide a remedy. These new techniques incorporate the following refinements and advances: the mixing of various sizes of smaller grafts, attention to minute detail in graft preparation and placement, an appreciation of the ramifications dictated by hair quality, and the customizing of procedures to each individual patient.

New techniques have virtually revolutionized hair replacement surgery. As a consequence of advances that have been made, results in males with pattern alopecia have reached a surprising level of excellence, efficacy, and patient acceptance. Today's methodology demands a high degree of expertise in planning and execution.

Other permanent forms of alopecias—female pattern hair loss, scarring because of trauma or surgery, radiation-induced hair loss, localized scleroderma, and the alopecias produced by certain diseases of the scalp—are also being effectively addressed with the expanded armamentarium of techniques available to today's hair replacement surgeon.

Until recently, micrografts were used only in the frontal hairline area. However, extending the use of small grafts to include areas beyond the frontal hairline increases the quality of results significantly. Currently, the trend has been to transplant hairs in "follicular units," a term that refers to hair in its natural groupings of between one and four strands. When transplanted, follicular units are quite natural in appearance and undetectability.

The definition of follicular unit transplantation varies among surgeons. Limmer (personal communication) discusses follicular unit transplantation as follows:

> *Follicular unit transplantation is by definition the redistribution of naturally occurring follicular groupings (follicular units) of 1–4 hairs, rarely more, removed from the donor area by single bladed elliptical excision, careful microscopic dissection beneath the binocular stereoscope, and reimplantation into the bald recipient zone in a needle tunnel or very small slit incision. Donor tissue is carefully trimmed into such follicular units removing "bald" donor tissue. Bald tissue is not removed from the recipient zone to minimize damage to the recipient vascular supply essential to the survival of the grafts. Dense packing during the first session is usual (20–40 grafts per cm^2) to create a cosmetic result that will suffice to stand on its own if no other procedural sessions are ever done.*

Once the donor strip is harvested, the method of strip subsectioning varies from physician to physician. On one extreme of the spectrum, microscopes are used to create one- to four-hair follicular unit grafts. On the other end of the spectrum, automated graft sectioning devices are used to create micrografts.[3]

In this chapter, we will detail our technique for achieving hair restoration using follicular unit implantation. We refer to our technique as the separated needle stick and graft placement method. This broader use of smaller grafts is a major step forward, possibly the most important one in two decades in terms of making possible a truly natural-appearing transplant.

In conjunction with the use of smaller grafts, the placement of smaller grafts into recipient sites without first removing recipient-site tissue constitutes another major advance. This technique, termed *incisional-slit grafting*,[4] maximizes the yield of hairs per graft and the coverage achieved with any given amount of donor hair.

The procedure of incisional-slit grafting, although capable of providing a complete restoration, actually reaches its full potential when used to create a natural appearance with minimum donor hair availability.[5] It also allows effective hair transplantation in patients who have poor-quality donor hair. Incisional-slit grafting is successful because it is not vascularly devastating in the manner of round grafting, and it is extremely efficient and effective in the use of donor hair. Some physicians combine the use of slit grafts and round grafts, and this combination can produce excellent results (Figs. 26–1 and 26–2).

Although difficult to quantify, it has been repeatedly observed that the ultimate yield of growing hairs from grafts placed in incisional-slit recipient sites is greater than that from traditional round grafts, perhaps by as much as a factor of 2.

Even without quantification, it seems obvious that this difference in yield must be related to the difference in degree

Figure 26–1 The combination of round grafts with incisional-slit grafting can be effective. An intermediate stage in this process is shown after round grafts have been placed but before incisional-slit grafting.

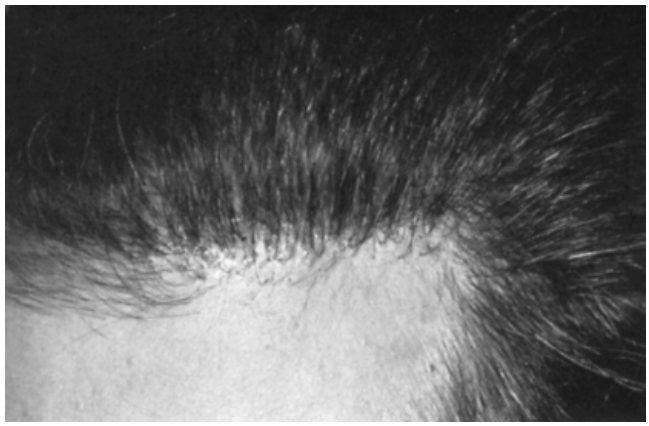

Figure 26–2 The same patient as in Figure 26–1, after incisional-slit grafting refinement and the development of a feathering zone hairline.

of vascular insult posed to the subcutaneous layer. Any disturbance of the interlocking network of arteries, veins, lymphatic vessels, and nerves found there represents a physiologic challenge that tissues must overcome before a new graft can be nourished. The disturbance inherent in the process of removing plugs of tissue enlarges the scope of the physiologic challenge that has to be overcome.

On the other hand, a single-stab incision followed by snug graft placement minimizes the challenge to the tissues and allows graft nourishment to begin immediately. Scarring is also minimized in incisional-slit grafting, and doughnuting is rarely seen. Incisional-slit grafting conserves viable remaining native hair because it does not require the removal of tissue. An argument can be made that increased compression can present a problem in incisional-slit grafting. However, the more natural appearance resulting from the use of this technique outweighs any consideration that would lead to the use of standard round grafts in the creation of a frontal hairline. Round-graft usage should be reserved for more posterior locations (i.e., those beyond the first 1 cm of the hairline zone). In such locations, particularly in areas of total alopecia, the use of small, 1.5- to 1.75-mm punch-prepared sites for the placement of small grafts such as quarter grafts can be quite effective. The pattern of placement of grafts for both techniques is identical. The numbers and sizes of grafts used are also the same.

PATIENT SELECTION

There are many factors and variables to consider when planning for the establishment of a hairline and the reconstruction of hair over the scalp. The following list contains some of the most important considerations:

1. Classification of baldness
2. Classification of hair quality
3. Color similarity between hair and skin
4. Future hair loss expectation
5. Age of patient
6. Motivation, expectations, and desires of patient

CONSULTATION

In the initial consultation, we judge who will be and who will not be a good candidate for hair restoration surgery. In our assessment, we look at five qualities: patient age, a definitive bald area, skin-to-hair color match, hair curl, and density of the donor area.[6] If a patient is felt to be an acceptable candidate, a discussion of risks and benefits of surgery follows, along with arrangements for preoperative lab work and medications. We routinely request hepatitis B and C and HIV tests. This is also the time for discussion of the general medical history of the patient, including current medications and drug allergies.

Classification of Baldness

The Norwood system for the classification of baldness[7] is the most widely used today. It describes and diagrams male pattern baldness stages I through VII, plus the type of variation in those stages. Stage I is the least severe, showing minor to no temporal recession and no crown balding. Stage VII is the most severe, with only the classic horseshoe-shaped band of hair remaining. The system is similar to that devised by Hamilton[8] and yields similar results. A new view of alopecia suggests that these classifications may be useful primarily as a means of defining populations for clinical trials rather than as a determinant of treatment.

Classification of Hair Quality

The term *hair quality* includes considerations of density, texture, curl, and color. Broad criteria have been previously defined for the grading of hair quality.[9] The various grades of hair quality may overlap, and each can be subdivided more specifically.

Hair of coarse texture and above-average density is rated "A" or highest in donor quality, and hair that is fine and sparse in density is rated "D" or lowest in donor quality. There are two intermediate ratings, "B" and "C", that cover the range in between. In general, individuals with hair color

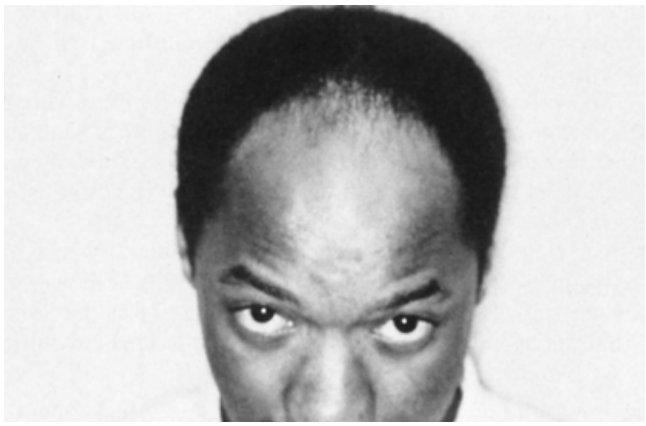

Figure 26–3 Patient shown before transplantation. Good results can be expected with standard round grafts or with incisional-slit grafting because this patient has an excellent match of skin and hair color.

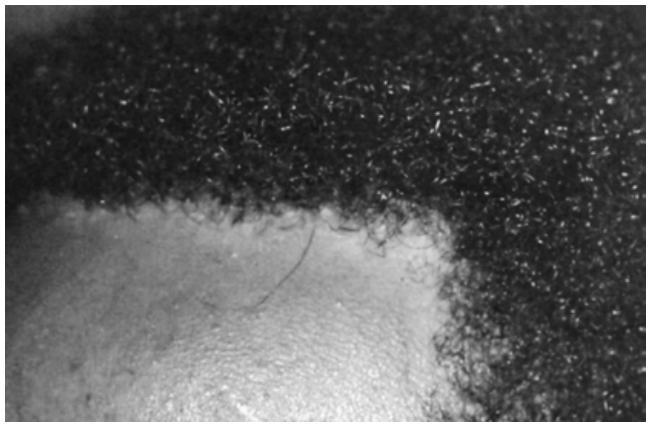

Figure 26–4 The same patient as in Figure 26–3 after hair transplantation. Incisional-slit grafting was used primarily. Some round grafts were placed in the vertex posterior to the hairline area.

that matches the skin color can expect better results than those who have a color contrast between skin and hair. Curliness of hair is also an advantage.

Color Similarity between Hair and Skin

The hair colors that are best suited for transplantation procedures include blonde, red, gray, and the salt-and-pepper combination. The colors of black and dark brown present more of a challenge, especially in individuals with straight hair. Individuals who have dark hair color and light skin may be less suitable candidates for transplantation. The final appearance after transplantation is significantly affected by the degree to which hair color and skin color match. Matching minimizes visual contrast.

The most propitious combination is dark skin combined with dark, curly hair (Figs. 26–3 and 26–4). At the other end of the scale is the combination of light, pale skin and dark, straight hair. In the latter combination, the degree of visual contrast increases the visibility of any transplantation undertaken. There are innumerable combinations on the scale between these two extremes, and hair color differences between the vertex area and the occipital area may occasionally be seen in an individual (Figs. 26–5 and 26–6).

Expected Future Hair Loss

Because androgenetic alopecia is genetically controlled and therefore inherited, expectation of future hair loss can be roughly estimated by referring to a carefully drawn family

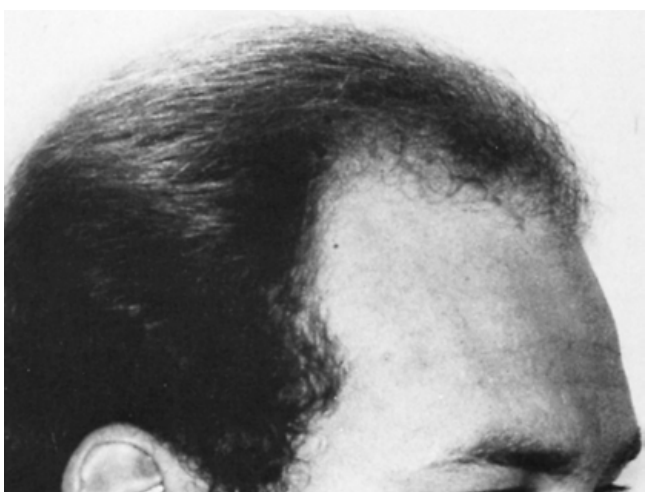

Figure 26–5 This man is shown before transplantation. The hair present in the frontal forelock is of sparse density and light color.

Figure 26–6 The same patient as shown in Figure 26–5 after transplantation. This patient's occipital (donor) hair was darker in color than the original frontocentral hair. Both incisional-slit grafts and standard round grafts were used.

history. Information on close family members should be gathered during initial interviews and used in conjunction with other factors such as age and present stage and pattern of hair loss to arrive at an estimate of expected future hair loss. It is impossible to predict future hair loss with absolute accuracy, and patients should be warned of this uncertainty.

Age of Patient

Androgenetic alopecia is an ongoing process (i.e., it usually occurs over an extended portion of the individual's lifetime). Patient age indicates an individual's place on the alopecia continuum. Knowledge of whether one is at the beginning of the process or the end point allows planning judgments to be made more appropriately. It is true that with today's techniques virtually everyone can experience a satisfying improvement in appearance, but it is also true that those who have unrealistic expectations should be discouraged.

A consideration of patient age also allows an assessment of the appropriate position and contour for the hairline. Patients aged 20 or younger are generally discouraged from undergoing transplantation because it is too difficult to predict what form and course future alopecia will take. Exceptions are made when the patient understands that the extent of future hair loss is an unknown and therefore an accurate prediction of its course impossible and still wishes to proceed.

Motivation

Discussion of the patient's expectations should enlighten the surgeon about the degree of patient motivation present and the patient's perception of the anticipated improvement. The patient should be well informed, must be highly motivated, and should be advised realistically about the expected results of the anticipated procedures. A hairline that complements the facial structures and that represents the surgeon's considered approach to anticipated work should be drawn and discussed with the patient. It is important that each patient have a thorough understanding of the anticipated cosmetic effect before starting procedures, and some believe it is advisable to underrepresent potential benefits. This can serve to guard against unrealistic expectations and avoid future dissatisfactions.

PLACEMENT OF THE HAIRLINE

In determining the placement of the hairline so that it creates balance and compensates for facial inequalities, the surgeon should visualize the face divided by imaginary horizontal planes into three segments of approximately equal vertical depth. The anthropometric demarcations for the three segments are (1) chin to columella; (2) columella to glabella; and (3) glabella to frontal hairline or proposed hairline. The position where the upper boundary of the upper segment falls can serve as a general guide for determining the appropriate height for placement of the hairline.

Caution must be exercised in using this measurement alone because doing so would often result in the hairline being placed too low. As a matter of practice, hairlines are generally placed between 7.5 and 9.5 cm above the midglabellar area. This is a general guide and should not be taken as an absolute or rigid parameter.

The hairline must be placed and designed so that it will indicate an appropriate level of maturity as the years go by, rather than perpetuate a youthful, free-of-recession look that will become inappropriate and possibly even unattractive. In many cases, it will be necessary to place the margin of the future hairline somewhat posterior to the remnant original hairline. This conservative approach will allow an optimum use of donor hair and is more likely to provide adequate coverage. A low, wide hairline will often lead to inadequacies in donor hair, resulting in sparse coverage and poor cosmesis.

All transplanted, recreated hairlines should look natural, but not all natural hairlines are the most aesthetically correct and pleasing in appearance. Because the contours of design will be more or less permanent, their overall effect should be acceptable to the patient throughout a lifetime. It is best to establish a natural but mature hairline. The low hairline of youth may look quite natural at certain ages but could also begin to look inappropriate as years pass. The frontotemporal angle, which constitutes the area in which male pattern baldness begins, is most critical to the design and final appearance.

Over the past 30 years, most transplant surgeons have created sharp symmetric hairlines. There has been a general tendency among surgeons to line up the grafts uniformly along the most anterior portion of the hairline. The results from this symmetric approach can appear artificial. Hairlines in their natural state are not symmetric, nor are they carefully edged like a well-groomed lawn. They exist in an irregular fashion, with hairs scattered up to 1 cm in front of the area where the eye actually begins to perceive the hairline.

Styling preferences particular to certain fashion statements in vogue at any given time should not dictate the design of the hairline as these are fads and sure to change. Of historical interest, it is sometimes possible to gauge the year of previous transplant work by observing the configuration of the hairline. The widow's peak is now rarely employed, and its presence probably indicates a transplant performed in the 1960s.

INCISIONAL-SLIT GRAFTING

Between 1989 and 1998, we utilized a transition zone of single hair grafts, which were placed in an intentionally irregular though not exaggerated pattern. These single hairs were used to construct the transition zone into the more densely transplanted scalp. The results were cosmetically pleasing but still lacked the degree of irregularity of a natural hairline. Observations of our own cases have now led us to conclude that when constructing a hairline a much more exaggerated pattern should be employed to achieve the most undetectable result. We now refer to this as a zig-zag pattern.[10]

The shape of the hairline is drawn into position on the patient prior to making recipient sites. After the general outline has been made, we use marking pens to create an undulating or zig-zag line. With this method, the original marked hairline is used for positioning and then transformed into a waving irregular shape. Recipient sites are placed using the undulated line as the true border. Densities within this zone can be varied. This irregular template has been referred to as a "sawtooth," "snail track," or "zig-zag" pattern. Posterior to this, larger follicular unit grafts of up to four hairs are transplanted to provide a more concentrated density.[10]

Figure 26–7 The donor area is prepared for donor site harvesting. The area is marked, shaved and injected for tumescence. The gauze padding and headband are placed into position prior to harvesting the strip. Afterward they will be pulled over the incision site.

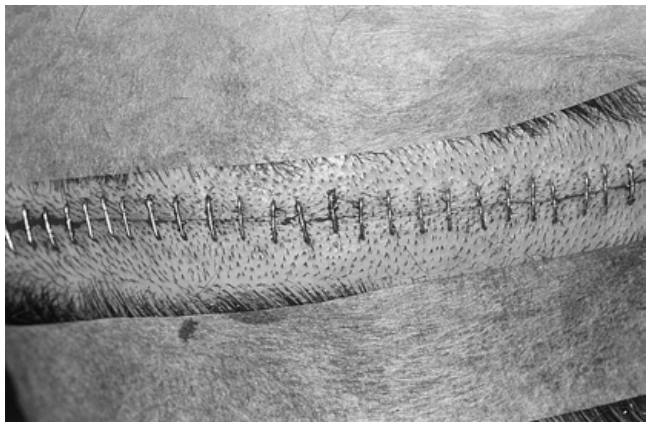

Figure 26–8 Elliptical donor harvesting is employed using a double-bladed knife. The donor site is then closed with staples.

THE SEPARATED NEEDLE STICK AND GRAFT PLACEMENT TECHNIQUE

Donor Strip Harvesting

On the day of surgery, the patient is brought into the surgical suite, a series of standardized preoperative photographs are taken, and the area for donor site harvesting is marked, shaved, and prepared with tumescent anesthesia for excision (Fig. 26–7). An elliptical donor harvest using a double-bladed knife is employed. The donor site is then closed using staples (Fig. 26–8). Immediately after removing the donor strip from the patient, the tissue is given to a team of three or four technicians who subsection it using stereomicroscopic dissection with backlighting (Fig. 26–9). Subsectioning is achieved by initially slivering the donor tissue into thin slivers, one follicular unit in width, then by dissecting individual follicular units from each sliver[6] (Figs. 26–10 and 26–11).

Figure 26–9 Technicians subsectioning donor tissue using stereomicroscopic dissection with back-lighting.

Recipient Site Creation

Following donor strip harvesting, the patient is turned from the prone position to the reclined sitting position. Anesthesia of the area is administered first with blocks of the supraorbital and supratrochlear nerves.[11] Then, immediately anterior to the recipient area we inject lidocaine with epinephrine and then bupivacaine with epinephrine. Epinephrine in a concentration of 1:00,000 is infiltrated throughout the entire recipient area in a superficial dermal location. Following this, recipient sites are made using 18-gauge needles for smaller follicular unit grafts and 19-gauge needles for single-hair grafts at the frontal hairline. Needles are inserted at 30 to 40 degrees from the scalp surface, so that transplanted grafts will be gently angled anterior toward the patient's nose. We find this allows the

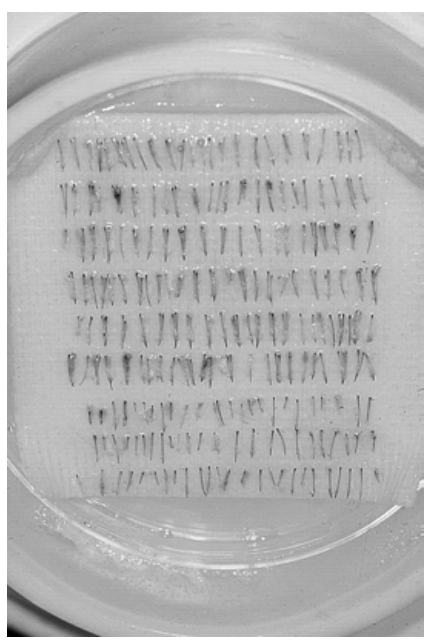

Figure 26–10 Individual follicular units are produced under careful stereomicroscopic dissection.

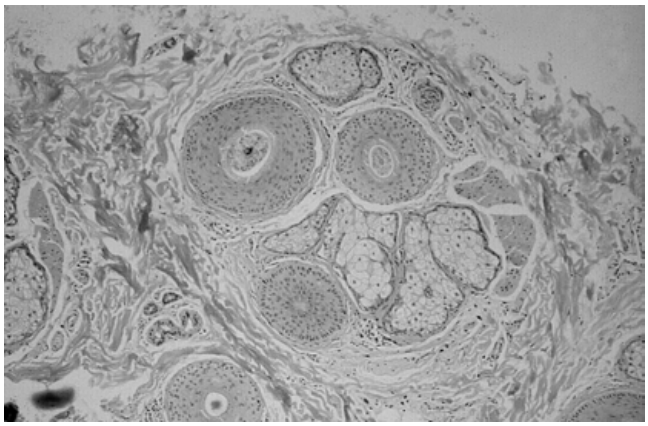

Figure 26–11 The follicular unit anatomy is demonstrated above showing a single unit enveloped by a fibrous stroma enclosing hair shafts, sebaceous glands, and erector pyli muscles.

Figure 26–12 One day after surgical placement of 650 follicular unit grafts.

patient the most versatility in hair styling options. After all recipient sites have been made, our technicians perform the insertion of the follicular unit grafts. Thus, the technique is termed separated needle stick and graft placement because recipient site creation with needles is separated in time from graft insertion. This is an important distinction from the simultaneous needle stick and graft placement techniques. Both methods have their advantages and proponents.[6]

Graft Insertion

Following creation of recipient sites, technicians insert grafts one at a time with jeweler's forceps. Typically, two technicians will work on one patient at the same time to expedite the process. Immediately following the surgery, the transplanted and donor areas are dressed with Polysporin, Telfa, and acrylic gauze. A firmly fitted pressure wrap is left in place for 24 hours. On postop day 1, gentle shampooing is allowed with instructions not to pick any scabbing that has formed in the recipient area (Fig. 26–12). Patients are maintained on a 5-day course of prednisone. Patients are often able to return to work the day after the dressing is removed (postop day 2).

Discussion

The separated needle stick and graft placement technique allows for a 1000-graft procedure to be completed in less than 5 hours on average. Those patients with minimal bleeding and excellent donor tissue characteristics can be completed in considerably less time. The advantages of this technique include the physician having complete control of hairline placement, as well as the positioning and the direction of each graft. The use of stereomicroscopic dissection limits follicular transection, which may contribute to superior quality of transplanted hair. In addition to these benefits, once the physician is finished making recipient sites, he or she is free to engage in other patient care activities. The disadvantages of this technique include the necessity for training in the use of stereomicroscopes for slivering the donor tissue and dissecting the grafts.

Though there are a few proponents of techniques that use larger, standard round grafts or a combination, we do not employ these techniques because we feel the cosmesis of the finished product is less than natural. Follicular unit transplanting does create a result that most closely resembles the natural state. (Figs. 26–13 and 26–14).

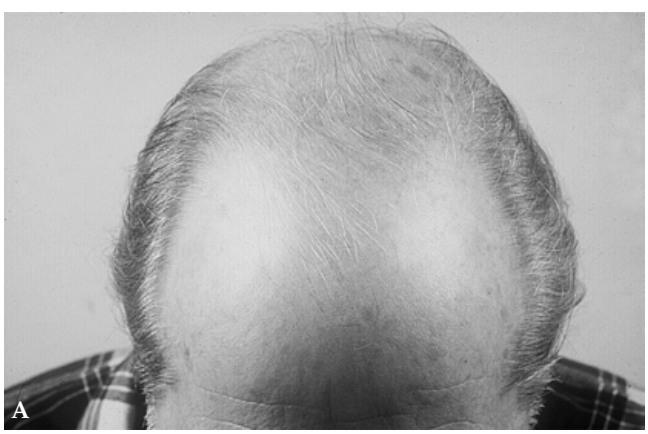

Figure 26–13 **(A)** A 55-year-old white man prior to transplantation. This patient was classified as having Norwood VI male pattern alopecia. **(B)** Same patient after five sessions of transplantation. Each session averaged approximately 600 grafts.

Figure 26–14 **(A)** A 50-year-old white man with Norwood V male pattern alopecia shown prior to transplantation. **(B)** The same patient shown after follicular unit transplantation averaging 500 grafts per session. Note that the density is marginal due to the thin, fine-caliber hair shafts. The final density of a transplant is dependent on the starting caliber of the donor area hair.

SCALP REDUCTIONS

It is not in the scope of this chapter to give a detailed presentation of scalp reduction procedures. However, a simple description of the most salient features of the procedure may provide perspective.

Scalp reductions are usually designed on an individual basis to fit a particular area of baldness. Numerous shapes have been used (e.g., straight, paramedian, mercedes, and double or triple rhomboid). The straight ellipse, the Y, the T, the S, and the crescent have predominated in actual usage. Variations and permutations of these may also be used.

The straight ellipse is the simplest type of reduction. Although technically the easiest of the configurations, it is best to substitute a paramedian approach when possible. The paramedian is less cosmetically obvious and has other inherent benefits when the hair is styled.

The procedure of scalp reduction is performed under local anesthesia (ring block) and clean conditions. The midlines and proposed outer boundaries of the areas intended for excision are marked. The first incisions proceed along an outer margin of a marked area. The use of a Shaw scalpel (hot blade) aids in establishing a dry field and reduces the actual operative time as this instrument has the dual function of excision and cautery (Fig. 26–15).

Undermining is carried out for a distance of approximately 7 to 10 mm on each side of an incision. After undermining has been accomplished, a determination must be made regarding the actual width of the tissue to be excised. Generally, this can be accomplished by manually overlapping one incision edge with another and cutting off the redundant or overlapping segment.

Some judgment must be made regarding the degree of tension that will be placed on the galeal closing. An aggressive approach to reduction would call for removal of a relatively larger amount of scalp, increasing tension on the galeal closure. A conservative approach would dictate a less ambitious excision of tissue, minimizing tension placed on the galeal closure. There are advantages and disadvantages to both approaches.

The aid of intraoperative scalp expanders (Fig. 26–16) to stretch the denser hair–bearing regions of tissue may be employed. Caution is advised in attempting reductions on

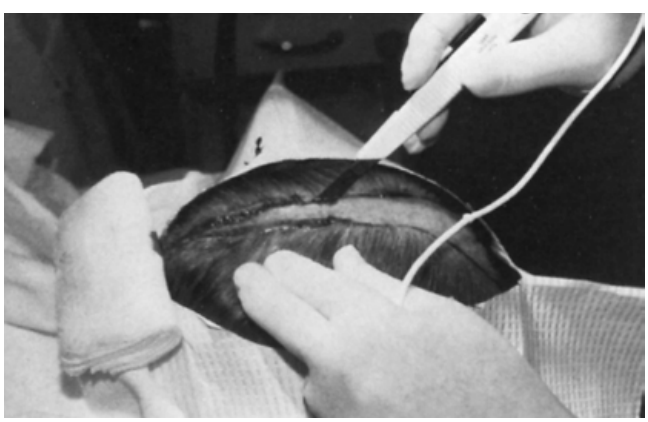

Figure 26–15 Bleeding during a scalp reduction is controlled with the use of a Shaw hot blade.

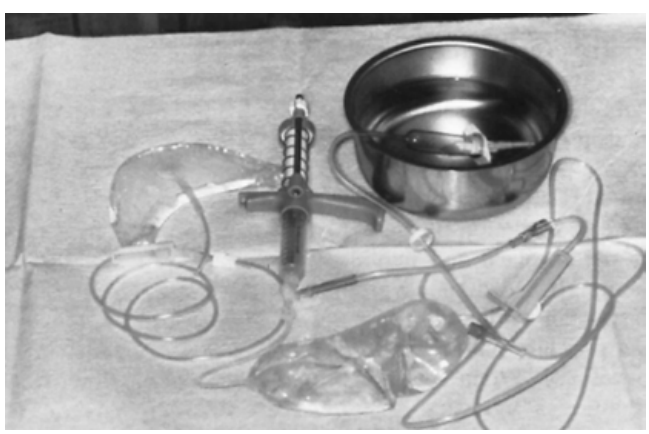

Figure 26–16 The use of intraoperative scalp expanders allows for maximum removal of tissue. These are most useful when dealing with tight scalps.

patients with thin, tight scalps because these patients are less suitable candidates than those with thick, elastic scalps.

After excision of scalp tissue has been completed, the galea is closed first, usually with 2-0 PDS sutures. When closure of the galea has been completed, the skin is closed with staples.

The actual configuration of the patterns used in scalp reduction is frequently modified to avoid leaving scars that are cosmetically apparent. It is often feasible to curve or otherwise adapt various segments of reduction patterns so that the scar can be more easily covered. A Z-plasty procedure should be performed on the posterior segment of scalp reductions to further camouflage this sensitive area.

Scalp reductions are almost always followed by hair transplantation procedures to complete the restoration and to provide cover for the reduction procedure scars.

Crown Balding

For the correction of crown balding, reductions are generally preferred to grafts. Again, patients with thick, loose scalps are much better candidates than those with thin, tight scalps. Small grafts are later placed in the scar area for camouflage. The use of grafts larger than 2 mm in the crown area may lead to the development of a stalked appearance. Only quarter grafts should be used in this area. Also, care must be taken not to place the grafts too close to each other along the edge of the scar because this may produce a zipper effect and thus preclude a natural appearance in the final result.

Exceptions to the rule of treating crown balding with reductions preferentially are made for patients with extremely thin or extremely tight scalps and for those who fear scalp reductions in the belief that the procedure will be too painful. However, most patients are surprised to find that the procedure is comparable with a graft session, and a fair percentage of patients actually prefer a scalp reduction session over a transplant session.

Most patients will require more than one scalp reduction. The limiting factors are scalp thickness and elasticity. All patients should be advised that the resulting scar must be covered with grafts in subsequent transplant procedures.

Medication for Scalp Reduction Procedures

Preoperative:

1. Valium PO 20 mg, 1 hour before surgery
2. Nitrous oxide during administration of local anesthetic
3. Lidocaine 0.5% (20 mL total) in a ring block, followed 15 minutes later by bupivacaine (Marcaine) 0.25% (total 20 mL) in a ring block

Postoperative:

1. Repeat ring block with bupivacaine 4 hours after procedure.
2. Percocet 1 g 4 to 6 hours PRN for pain
3. Prednisone 40 mg daily for 5 days

GROOMING

The need to attend to the aesthetics of hair transplantation does not end with the design of the frontal hairline and other areas but extends to providing the patient with proper advice concerning grooming. As soon as patients commit themselves to hair replacement surgery, the requirement for ongoing styling and grooming must be addressed. Proper advice and the recommendation of grooming aids are necessary to maximize the effectiveness of the transplant and the satisfaction of the patient.

There are many reliable grooming aids on the market that enrich the texture of the hair and give an appearance of greater thickness. A hairstyling blow-dryer is essential for achieving the full effect. In patients with thin, straight hair, a body permanent treatment may be desirable. Although many men are reluctant to visit a stylist, this reluctance is misplaced and should be overcome. It may be necessary for the physician to propose or even insist on a permanent, especially in patients with grades C or D hair quality.

Some patients may benefit additionally from fogging the scalp with a Couvré scalp cover or by using a scalp camouflage cream. These types of products deflect light in thin areas and render them less obvious. The proper length of the hair should be determined for the individual, and it is helpful to routinely enlist the aid of an expert stylist in this matter.

It is the hair replacement surgeon's obligation to counsel and direct patients in these areas because the patient's ultimate appearance is a critical factor in the overall success of treatment.

FEMALE ALOPECIA

Although male pattern alopecia continues to dominate the lay press and medical literature, female alopecia is commonly encountered by dermatologists.[12] The most common presentation of female baldness is in the form of diffuse frontovertical thinning. Women with a strong family history of alopecia may develop either the diffuse thinning or a male pattern loss. In this genetically predisposed subset, varying degrees of baldness may occur even when androgen levels are normal.

Recently, it has become feasible to treat females who have diffuse alopecia provided that they have adequate donor hair density in the occipital area. The use of smaller grafts in female pattern baldness has become a useful and effective method for increasing the apparent density of hair in females, particularly in the vertex and frontovertex areas (Figs. 26–17 and 26–18). A number of quarter grafts are interspersed between existing hairs, and the end result appears as an increase in density. With the technique of incisional-slit grafting, which removes no recipient bed tissue, there is maximum preservation of existing hairs.

In females with male pattern hair loss, the treatment and transplant approaches and objectives are the same or similar to those developed for male patients.

COMPLICATIONS OF TRANSPLANT PROCEDURES

Syncope

During the initial visit, syncope may occur following injection of the first few milliliters of anesthetic. It also occurs rarely in the latter stages of the procedures. Placing the

Figure 26–17 Typical female pattern alopecia.

Figure 26–18 The same patient as in Fig. 26–17 after six sessions of incisional-slit grafting.

patient in a horizontal position initially will ordinarily prevent this condition.

Bleeding

The occipital region is most commonly the area of arterial bleeding. This bleeding is best controlled with sutures. Pressure is often essential for adequate hemostasis. For this reason elastic bandages are routinely used to apply a moderate, persistent pressure to the donor area for 15 to 20 minutes after harvesting the grafts and closing the wound. After completion of the entire session, a pressure bandage is put in place and maintained for the following 8 to 12 hours. If bleeding develops after the patient has left the physician's office, the patient is advised that persistent manual pressure with a clean bandage or handkerchief may be necessary. When hemostasis is not achieved by this method, a ligature is indicated. If bleeding occurs in the recipient spaces while implants are being inserted, it may be necessary to remove the graft and suture the bleeder. After healing, a small scar will usually remain that can later be excised and replaced with a small graft if necessary.

Edema

Postoperative edema over the scalp and forehead is common, especially if extensive grafting has been performed. This may be reduced by use of oral prednisone. It will subside as healing takes place.

Infection

Infection occurs in less than 1% of cases but should nevertheless be guarded against and treatment instituted should it develop.

Scarring

Scarring resulting from small-graft hair transplantation is rarely of sufficient scope to be a matter of serious concern. In blacks, keloids may sometimes be observed. When a patient's history indicates a possibility of keloid development, there should be a waiting period of 3 months after the initial session. This will allow adequate time for any possible keloid development, and a decision can then be made regarding the advisability of continuing treatment.

Poor Hair Growth

Ischemia, poor hair survival, or even sloughing of grafts may result from crowding recently placed implants. Some patients with fine hair may show marginal growth of transplanted hair, regardless of the transplant method used.

Miscellaneous

Occasionally, individuals may undergo varying degrees of spontaneous effluvium over the scalp. In patients with only a limited number of transplants and normally thinning hair, the temporary loss of hair may be distressingly apparent, but the patient should be reassured that regrowth is imminent. Arteriovenous fistulas may occasionally be encountered in the occipital region. Simple dissection and ligature of the fistula are indicated.

POOR RESULTS

What many laypersons interpret as a poor result is often an incomplete transplant or a case of inadequate grooming. Statistics based on 25 years of experience indicate that 85% of hair replacement patients were happy and would repeat the procedure. Of the 15% who would not repeat the procedure and were not totally satisfied, approximately 90% did not complete the procedure as prescribed. Thus, the vast majority of unhappy patients were those who failed to complete a minimum of work. With the advent of new techniques, a higher percentage of patients are satisfied, and the realm of treatable disorders has been extended.

SUMMARY

There has been a revolution in the field of hair transplantation. The older approaches that used large round grafts without attention to hair quality are now archaic. As a result of technological advances, treatment may now be provided for a wider range of hair loss etiologies and patterns. With today's techniques and sufficient attention to detail, hair restoration can approach its goal of the perfect transplant: a natural hairline and an overall appearance that offers little discernible evidence of surgical intervention.

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Chapter 27

Otoplasty

Nathan E. Nachlas

The plethora of otoplasty techniques that have appeared in the literature over the past century makes it a unique study in our field. More than 200 techniques to correct the lop-ear deformity have appeared since Ely's description of this procedure in 1881.[1] As with all facial plastic surgical techniques, the modern themes of conservatism and minimalism have dominated recent studies.

Otoplasty is the surgical correction of the lop-ear deformity. Analogous to rhinoplasty, achieving the optimal result begins with a three-dimensional analysis of the deformity. Surgical correction requires relating the components of the auricle to the underlying bony skeleton. Furthermore, these components—the helix–antihelix, concha, tragus–antitragus, and lobule—must be evaluated preoperatively and placed in harmony intraoperatively to maintain a natural auricular appearance.

HISTORICAL PERSPECTIVE

Deformities of the auricle have inspired much creative analysis over the years. In fact, certain characteristics (e.g., prominent Darwin's tubercles and flattened helical margins) have been suggested as predisposing to criminal behavior.[2] The particular deformity addressed in this chapter is actually a group of deformities that have a common overall appearance of the prominent auricle. This may result from the classic absence of the antihelix, from overprojection of the concha, or from a combination of these deformities. Less frequently, a twisted or overprojected lobule may exacerbate the deformity.

Since the nineteenth century, techniques have been described to restore the normal relationship of the auricle to the scalp and underlying mastoid bone. The first written description of otoplasty is attributed to Ely, who reduced a prominent ear by excising a through-and-through piece of auricle consisting of anterior auricular skin, auricular cartilage, and posterior auricular skin.[1] Similar techniques followed (Haug, Monks, Joseph, Ballenger, and Ballenger), all involving a reduction approach to otoplasty that attempted to reduce prominent ears by the removal of skin or cartilage.

In 1910, Luckett correctly attributed the classic lop-ear deformity to the absence of the antihelical fold.[3] This new revelation as to the correct anatomic defect enabled him and subsequent authors to devise correction techniques. Earlier techniques involved incisions in the auricular cartilage anterior and posterior to the desired antihelix position. In Luckett's technique, a crescent-shaped excision of skin and cartilage was performed at the site of the intended antihelix. The remaining cartilage edges were then sutured. Becker's technique also included anterior and posterior incisions around the intended antihelix. He then formed the new antihelix with fixation sutures and posterior abrasion.[4] A further variation is seen in the technique of Converse, whereby the anterior and posterior incisions were followed by suturing the antihelical segment to form a tunnel.[5]

Modern techniques stress the importance of avoiding the surgical appearance. Visible edges of cartilage are to be avoided, and a smooth, pleasantly shaped auricle in normal relation to the skull is desired. We discuss the pertinent anatomy and embryology and then outline the two basic approaches to otoplasty—cartilage suturing and cartilage sculpting—and the multiple variations that have been developed for both techniques.

ANATOMY AND EMBRYOLOGY

The external ear is a cartilaginous structure except for the lobule, which contains no cartilage (Fig. 27–1). This flexible elastic cartilage is covered with skin, which is closely adherent anteriorly and more loosely attached posteriorly. The plate of cartilage has a definite shape and may be described as a combination of ridges and hollows incompletely surrounding the bony external auditory canal.

The normal auricle protrudes 20 to 30 degrees from the skull (Fig. 27–2). When measured from the lateral edge of the helix to the mastoid skin, this distance is usually 2 to 2.5 cm. When analyzed from a superior viewpoint, the angulation is seen to result from a combination of a conchomastoid angle of 90 degrees and a conchoscaphalic angle of 90 degrees. The average length and width of the male auricle are 63.5 and 35.5 mm, respectively. Corresponding measurements in the female are 59.0 and 32.5 mm.[6,7]

Analysis of the convolutions of the normal auricle begins with the helix and antihelix. They begin inferiorly at the level of the tragus and diverge as they extend superiorly. They are separated through their course by the scaphoid fossa. As the antihelix is followed superiorly, it divides into a smoother, wider superior crus and an inferior crus, which characteristically is narrower and sharper. The fossa triangularis lies between the superior crus and the inferior crus. From the frontal viewpoint, the helix forms the most lateral extent of

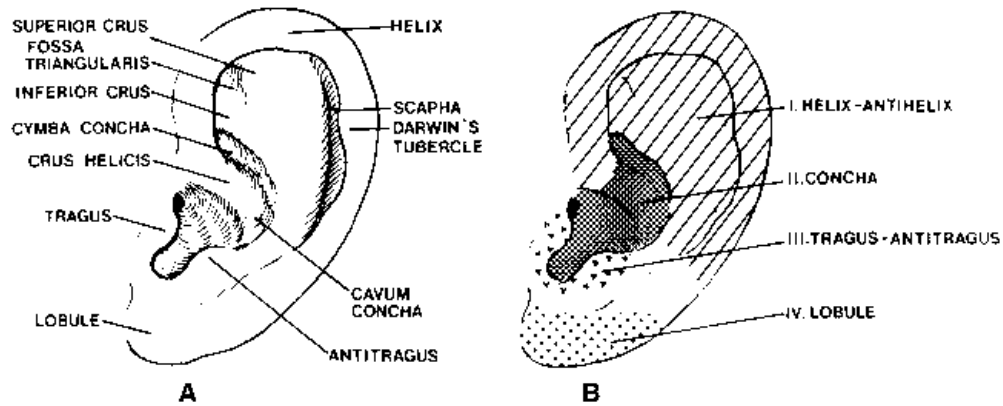

Figure 27–1 **(A)** Landmarks of the normal auricle. **(B)** Four components of the auricle.

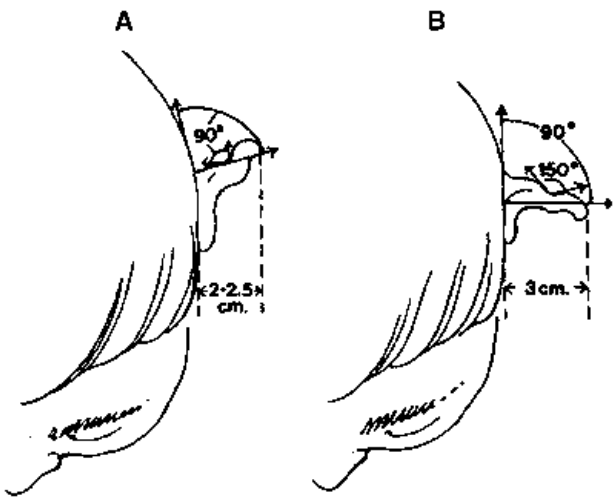

Figure 27–2 Relationship of auricle to scalp. **(A)** Axial view of the normal ear demonstrating the relationship of the auricle to the scalp. The conchomastoid angle of 90 degrees is combined with the conchoscaphalic angle of 90 degrees. This produces the auriculomastoid angle of 30 degrees. **(B)** Analagous angles demonstrated in the lop ear with conchoscaphalic obtuse angle of 140 to 150 degrees.

the auricle superiorly and should be just visible behind the antihelix and superior crus.

The cartilage is attached to the skull by three ligaments. The anterior ligament attaches the helix and tragus to the zygomatic process of the temporal bone. The front portion of the cartilaginous external auditory canal is free of cartilage but is bridged by a ligament passing from the tragus to the helix.

The ear has both intrinsic and extrinsic muscles supplied by the seventh cranial nerve. These small muscle masses form in definite areas and create soft tissue thickness with an associated increase in blood supply. These muscles have essentially no function, although some people can wiggle their ears.

Figure 27–3 depicts the arterial blood supply of the auricle. Contributions are primarily from the superficial temporal artery and the posterior auricular artery, although some branches also feed from the deep auricular artery. Venous drainage is via the superficial temporal and posterior auricular veins. Lymphatic drainage is to preauricular and superficial cervical nodes.

Sensory innervation to the external ear is derived from multiple sources (Fig. 27–4). The auriculotemporal branch of the mandibular division of the fifth cranial nerve supplies the anterior limb of the helix and part of the tragus. The remainder of the anterior auricle is supplied chiefly from the greater

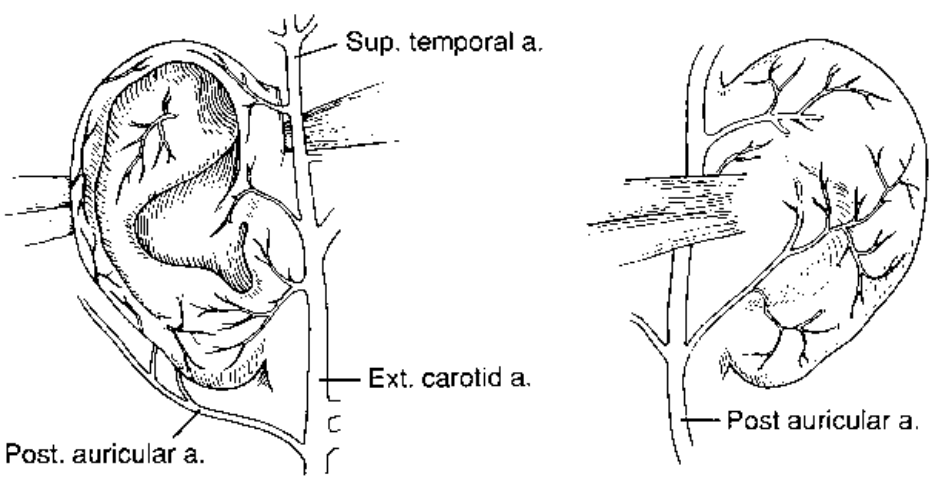

Figure 27–3 Arterial blood supply of the external ear.

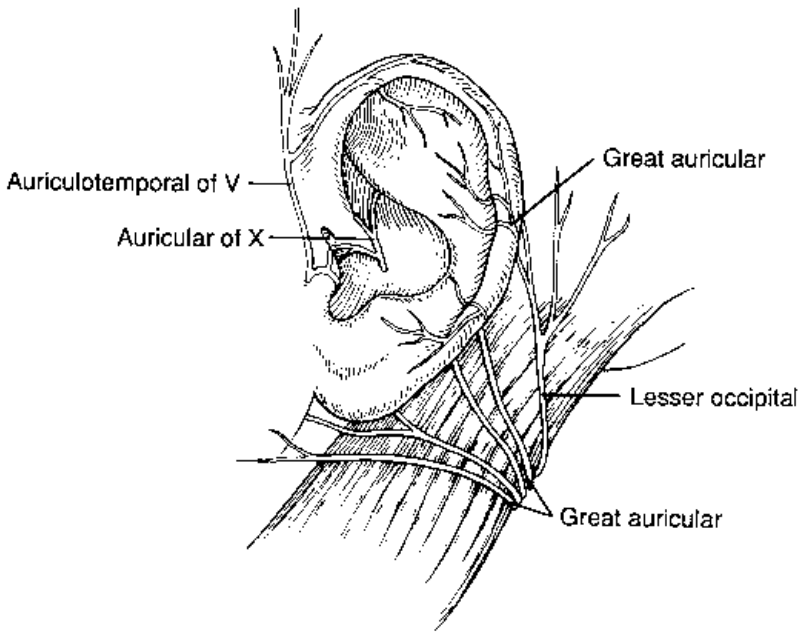

Figure 27–4 Nerve distribution to the external ear.

auricular nerve, whereas the posterior surface receives its innervation from the lesser occipital nerve. Minor contributions are also made from the seventh, ninth, and tenth cranial nerves.

The "hillocks of His" refer to a description by that author of six visible protruberances in the 39-day embryo that develop into the auricle. Although His originally traced the origin of the first three hillocks to the first branchial arch and that of the second three hillocks to the second branchial arch, subsequent studies have challenged this theory. It now appears that only the tragus may be traced to the first branchial arch and that the remainder of the auricle is derived from the second branchial arch (Fig. 27–5). This is supported by the location of congenital preauricular pits and fistulae located along the anterior incisura and incisura intertragica. As these regions anatomically represent the dividing line between the first and second branchial arches, these anomalies would therefore arise from the first pharyngeal depression.[2,8,9] The majority of auricular deformities are inherited in an autosomal dominant pattern.[10] Similar inheritance patterns are also seen in preauricular pits and appendages.

FUNCTION

The function of the auricle in lower animals has been extensively studied.[4] Sound localization and protection against water entry are two of the documented functions. Water protection is afforded by apposition of the tragus and antitragus. These physiologic functions are not documented in humans.

PREOPERATIVE EVALUATION

Like all facial plastic surgical procedures, otoplasty requires precise preoperative evaluation and analysis. Each ear must be evaluated separately, as the deformity or deformities present may be very different between the two ears. The auricle should be evaluated as to its size, its relationship to the scalp, and the interrelationship between its four components (helix, antihelix, concha, and lobule). Typical measurements recorded during the preoperative examination include the following:

1. The mastoid–helical distance as measured at the superior aspect of the helix
2. The mastoid–helical distance as measured at the level of the external auditory canal
3. The mastoid–helical distance as measured at the level of the lobule

Additional measurements included by some authors are the distance from the top of the helical rim to the junction of the inferior and superior crus, and the distance from the helical rim to the antihelix (Fig. 27–6).

Preoperative photographs include an anterior full face view, a posterior full-head view, and close-up photographs of the involved ear(s) with the head positioned so that the Frankfort plane is parallel to the floor.

The abnormality most commonly observed in the protruding ear is the overgrowth or protrusion of the conchal cartilage. Such deformities are not corrected by otoplasty techniques designed to recreate the antihelix. These ears require an alteration of the relationship between the concha and the mastoid cortex. Protuberant lobules may be the only deformity present in an otherwise normal ear. This may be secondary to an abnormally shaped cauda helicis (Fig. 27–7).

OTOPLASTY TECHNIQUES

The typical patient for otoplasty is a young child, age 4 to 5 years, who is referred by the pediatrician or parents for overprojecting auricles. This is the ideal age for correction, as the auricle is fully developed, and the child has not yet entered school where he or she would be subject to peer ridicule.

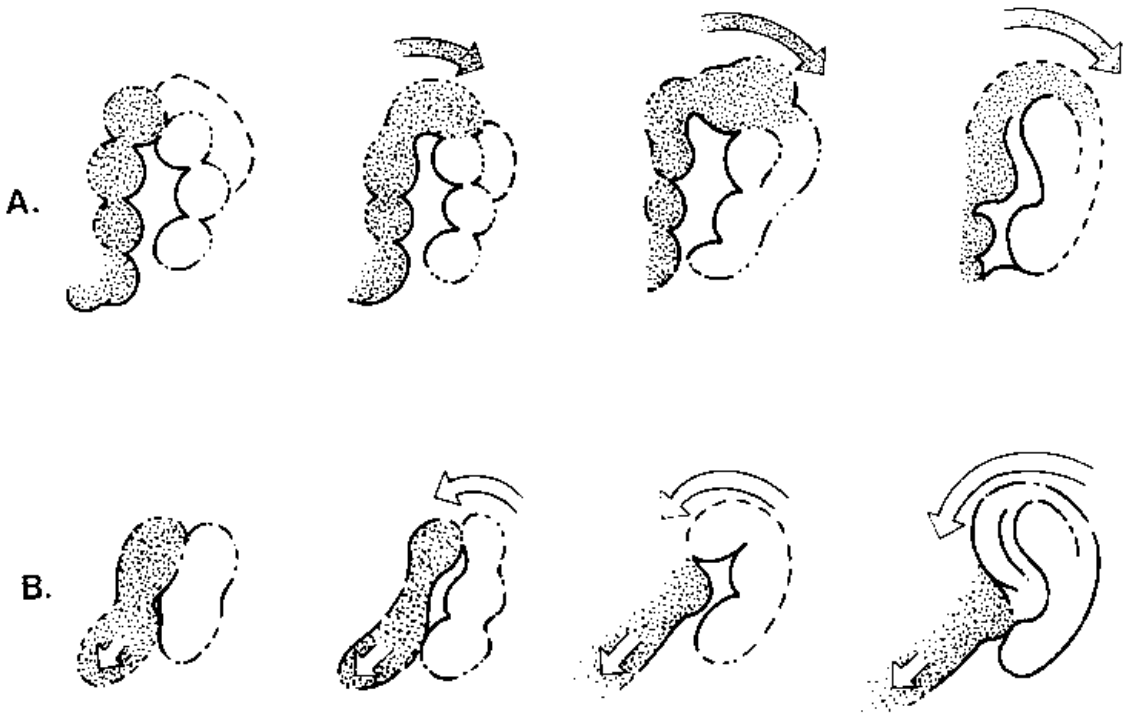

Figure 27–5 Embryology of the auricle. **(A)** In the original description by His, the auricle is derived equally from the first and second branchial arches. In this theory, the first three hillocks were derived from the first branchial arch, whereas hillocks four through six were derived from the second branchial arch. This would place the division between the first and second branchial arches at the tuberculum auriculae. **(B)** Current embryologic theory as described by Wood-Jones and I-Chuan.[9] In this description, the first branchial arch contribution is limited to the tragus. In this theory, the separation between the first and second arch contributions would lie along the anterior incisure and the intertragic incisure.

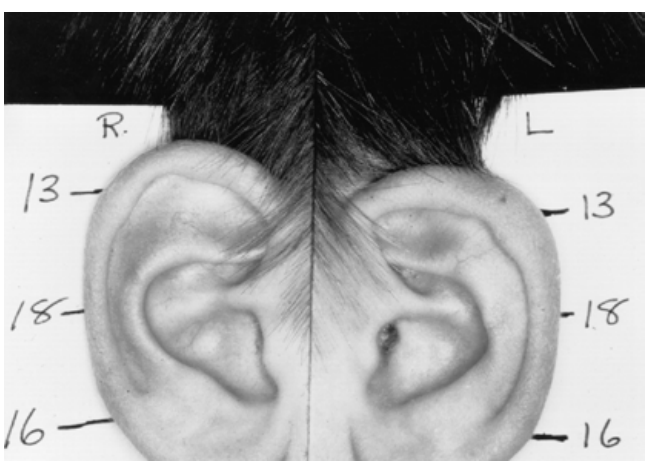

Figure 27–6 Right and left normal ears, showing distances in millimeters from the mastoid skin to the anterior surface of the ear at the top, midportion, and lobule. (Courtesy of Smith and Keen.)

In the young child, general anesthesia is most often utilized. In older children and adults, intravenous sedation is preferred. The patient is placed on a headrest with both ears exposed during the procedure.

The surgical techniques used in correction of the lop-ear deformity are dependent on the preoperative analysis. Often conchal protrusion is present, either as the lone deformity or, more commonly, associated with an antihelical deformity.

Conchal Setback

Returning the concha to its correct anatomic position with respect to the mastoid bone is accomplished with sutures, with or without concomitant trimming of the lateral aspect of the concha cavum. The traditional conchal setback technique as originally described by Furnas [11] remains the technique of choice for conchal protrusion. This technique involves wide exposure of the posterior auricular surface as well as the mastoid periosteum. Permanent sutures (author's preference 4-0 Mersilene) are placed through the conchal cartilage and then through the mastoid periosteum in such a manner as to fix the

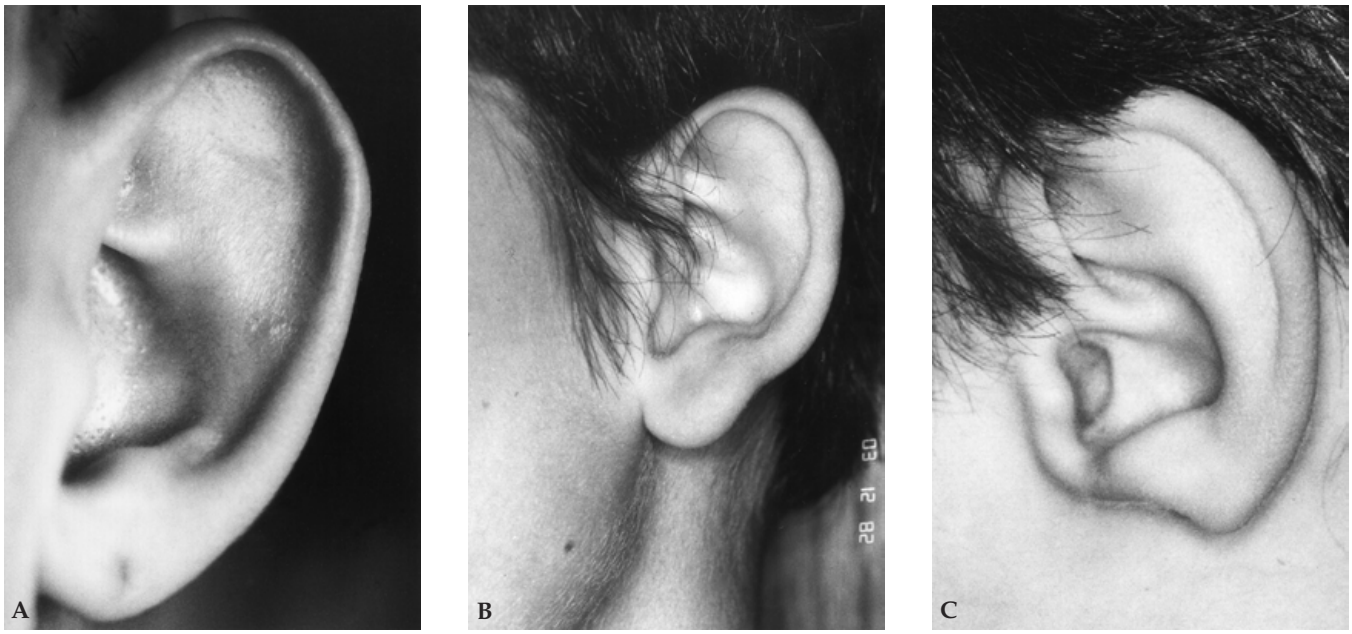

Figure 27–7 Examples of prominent ears. **(A)** Classic lop ear. The concha and lobule are normal in appearance. **(B)** Combined conchal-antihelical deformity. Correction requires conchal setback followed by antihelical correction. **(C)** An example of congenital lobule deformity, which requires primarily soft tissue techniques for correction.

concha in a posterior and medial direction. Care must be taken not to place the mastoid periosteal suture too far anteriorly or the external auditory canal may be compromised (Fig. 27–8). Additional correction of conchal protuberance may be achieved by removing a lateral strip of conchal cartilage. By delineating the lateral extent of the conchal cartilage with anteriorly placed 25-gauge needles tattooed with methylene blue, an incision may be made in the lateral extent of the conchal bowl. An elliptical wedge of conchal cartilage may then be removed to allow additional medialization of the auricle.

An alternative conchal procedure is described by Spira and Stal.[12] In this lateral flap technique, a laterally based flap

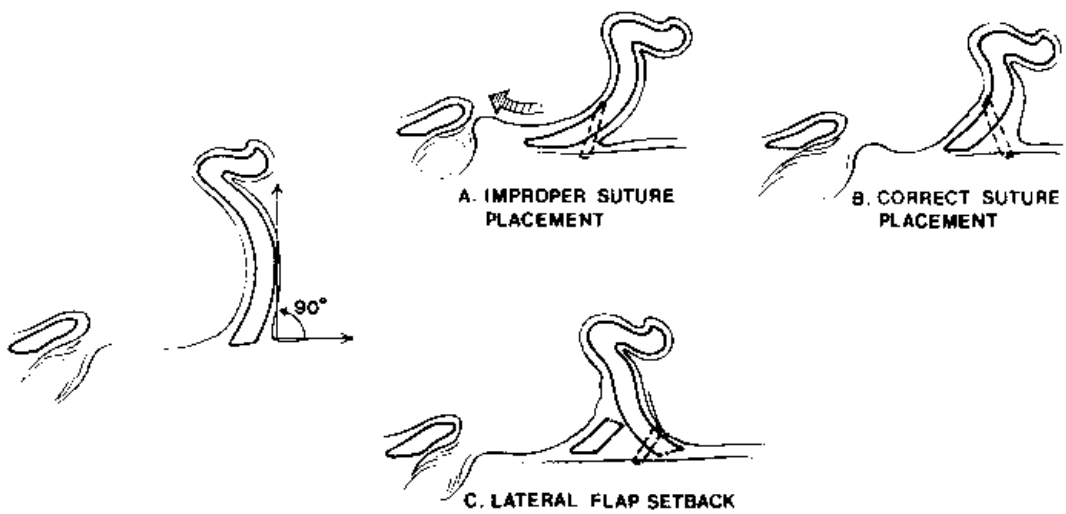

Figure 27–8 Conchal setback techniques. **(A)** The conchal suture technique as described by Furnas.[11] This demonstrates improper suture technique, where the mastoid periosteal suture is placed too far anteriorly and the external auditory canal is compromised. **(B)** Correct suture placement in the Furnas technique. The mastoid periosteal suture is placed far enough posteriorly to provide adequate correction without compromise of the external canal. **(C)** The lateral flap technique as described by Spira and Stal.[12] In this technique, a laterally based conchal cartilage flap is developed and sutured to the posterior mastoid periosteum.

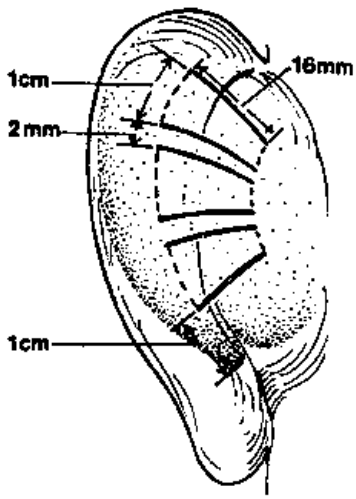

Figure 27–9 Mustarde's suture otoplasty technique. Posterior view of the auricle demonstrating suture placement in the mattress suture technique of Mustarde. The sutures must be placed through cartilage and anterior perichondrium but not through the anterior skin. They should be placed close enough together that the ear does not buckle when they are secured. Dimensions cited are from Bull and Mustarde [14]

of conchal cartilage is developed and subsequently sutured posteriorly to the mastoid periosteum (Fig. 27–9). Proponents suggest that this decreases the likelihood of compromise of the external canal.

Antihelix Deformities

The plethora of procedures described to recreate a missing antihelix underscores the lack of total satisfaction with any one technique. As otoplasty techniques were developed in the middle of the twentieth century, two schools of thought emerged. The first, following the teachings of Mustarde,[13] performed the procedure using sutures to recreate the antihelix. The second group of techniques all involved surgical alteration of the cartilage, whether through incisions, dermabrasion, or scoring. Most current techniques represent a combination of the two, using sutures to fix the final position of the antihelix but adding a cartilage-modifying technique to lower the risk of reprotrusion.

Suture Techniques

For most otoplasty procedures, the exposure and landmark identification is similar. A postauricular incision is made and wide undermining performed in the supraperichondrial plane. The area of intended neoantihelix may be demarcated by placing 25-gauge needles through the anterior auricular skin at the intended site of antihelix creation and bringing the needle out posteriorly. The cartilage is then marked with methylene blue.

The Mustarde procedure consists of inserting three or four horizontal placement sutures to permanently recreate the antihelix. We have found 4-0 Mersilene to be most suited for this purpose, but a wide variety of sutures have been reported. The suture placement is critical to achieve smooth correction and to avoid buckling of the superior auricle.[14] The suture is placed through the cartilage and anterior perichondrium but not through the anterior skin. If the suture does not incorporate the anterior perichondrium, then there is the risk of pulling through the cartilage. If the suture is placed too far anteriorly, then it may catch the underside of the anterior auricular dermis and an ulceration at the insertion site may result.

Suture placement should mimic the suggestions by Bull and Mustarde[14] as closely as possible. The sutures must be placed close enough to each other to avoid buckling. If placed too closely, then the cartilage may weaken between suture sites. Furthermore, if the outer bite of the suture is too close to the auricular summit, then a postlike deformity may result. The measurements in Fig. 27–8 are from Bull and Mustarde.[14] They propose outer cartilage bites of 1 cm separated by 2 mm. The distance between outer and inner cartilage bites is 16 mm. The most inferior stitch should be placed to allow retrodisplacement of the cauda helicis. In some cases, this is actually trimmed.

The technical challenges in the standard Mustarde otoplasty all relate to accuracy of suture placement. Securing the sutures is often done blindly, with the surgeon gauging the appropriate tightness of the suture by observing the folding of the antihelix from the anterior aspect of the auricle. All sutures should be placed prior to final tightening. Several authors have described a technique using temporary sutures placed anteriorly to fix the desired antihelix into place while the posterior sutures are being secured.[15–17] Burres described the "anterior–posterior" technique whereby the conchal setback is performed through a posterior incision but the helical sutures are placed anteriorly through a series of anterior stab incisions.[15] Alternatively, these sutures may be placed externally but buried through small stab incisions.[18] The scores of adjunctive procedures described since Mustarde's original paper[13] mostly address the tendency of the auricle to reprotrude over time. This results from several factors. First, incorrect placement of the suture whereby it does not include an adequate bite of cartilage results in tearing of the cartilage and reprotrusion. Second, failure to include perichondrium in the suture promotes cartilage tearing. Assuming that great care is taken to assure correct suture placement, the most common reason for reprotrusion is resilience of the cartilage. Therefore, different maneuvers have been described to lessen this memory. Adhering to physiologic principles, scoring of the anterior surface of the auricle would promote bending of the cartilage in the desired direction. The original studies for this derive from the work of Gibson and Davis,[19] who showed that scored rib cartilage would bend in the opposite direction. Using rib cartilage, they demonstrated that if one side of the rib was denuded of perichondrium, then the cartilage would bow to the side with the perichondrium intact. When attempting to create a new antihelix from a flat piece of auricular cartilage, weakening the anterior surface of the cartilage produces bowing with a convex anterior surface. Scoring the anterior surface of the auricular cartilage at the site of the new antihelix may be done with a needle, an abrader, or a burr. Care must be taken not to be overly aggressive in this maneuver

or sharp edges could be evident. Exposure to the anterior surface may be achieved by an anterior auricular incision, undermining around the helical rim through a postauricular incision, or in the technique described by Spira, scoring the cartilage with a needle introduced by a stab incision anteriorly. Spira describes his modification in more than 200 otoplasty cases with minimal complications.[20]

Burring down the posterior surface of the auricle is technically simpler than the anterior techniques, as the exposure has already been accomplished. Physiologically, the cartilage will have a tendency to bend in the direction opposite to that desired for the neoantihelix, but the suture placement readily overcomes this. More than 300 otoplasties were performed by Pilz and associates, with reported excellent results.[21]

Cartilage Sculpting Techniques

The cartilage sculpting techniques date back to the very first otoplasty procedures.[1] They have in common a reshaping of the auricular cartilage. If done successfully, these procedures do not require permanent suture placement. This lessens the foreign body–related risks associated with Mustarde procedures.

The cartilage splitting otoplasty technique was originally described by Nachlas and associates in 1970.[22] Based on earlier work by Cloutier,[23] this procedure utilizes the Gibson and Davis principle to form the new antihelix. The incision is a standard postauricular incision, whose placement is determined following the placement of 25-gauge needles tattooed with methylene blue through the intended neoantihelix (Fig. 27–10). An elliptical piece of skin is usually excised. Sometimes an hourglass-shaped excision is performed if there is a prominent earlobe. The needles are then withdrawn. Standard wide postauricular undermining is then performed, exposing the cauda helicis, fossa antihelicis scapha, and conchal cartilage. An incision through the auricular cartilage is then made with a Cottle knife. This incision should be made approximately 5 mm anterior to the tattoo marks indicating the apex of the neoantihelix. The incision will be curvilinear, parallel to the helical rim, and extend from approximately 5 mm from the superior aspect of the helical rim to the cauda helicis. Resection of the cauda helicis helps to eliminate postoperative bowing of the lobule. Triangular wedges are removed perpendicular to the superior and inferior edges of the cut. At this point in the dissection, the lateral segment of cartilage is attached to its medial counterpart only at the superior rim. The perichondrium is dissected off of the anterior surface of the cartilage for a distance of 1 cm. The anterior surface of the medial cartilage is then burred, using a diamond burr, until a round smooth neoantihelix and superior crus is formed. The anterior surface of the lateral cartilage is also beveled. The medial beveled cartilage is placed anterior to the lateral cartilage, restoring the normal contour of the ear. No sutures are placed in the cartilage. The skin is closed using a running subcuticular closure.

In the cartilage splitting otoplasty technique, the cut edges of cartilage are facing posteriorly; the only cartilage surface visible on the anterior aspect of the auricle is the smooth convexity of the new antihelix. A modification of the technique was described by Schuffenecker and Reichert utilizing a large V-shaped cartilaginous flap at the site of the intended antihelix.[24] Instead of the single curved cartilage incision at the site of the new antihelix, they elevate a flap of cartilage hinged superiorly. The desired convexity is then achieved by scoring the anterior surface with a blade.

Choosing the right otoplasty technique depends on the surgeon's comfort level and experience with any one procedure. For the beginning otoplasty surgeon, the Mustarde technique is the most straightforward. Weakening the posterior cartilage with the diamond abrader adds little difficulty to the procedure and greatly lowers the risks of reprotrusion. In more demanding cases, the cartilage splitting otoplasty in this author's hands allows more predictable results while avoiding suture complications associated with the Mustarde techniques.

Irrespective of the otoplasty technique utilized, proper dressing of the ears is critical in maintaining position of the auricles without undue stress. Cotton soaked in mineral oil is placed in the grooves of the auricle to prevent postoperative anterior edema. Kerlex fluffs followed by a Kerlex wrap, followed by Coban taping is routinely performed. The use of drains is recommended. The ears are inspected on the first postoperative day. The patient is instructed to bring a tennis headband to the office at the time of the first dressing change. This headband is positioned by the surgeon after removal of the dressings and is left in place until suture removal 1 week later. The patient is instructed to wear the headband at night for 2 months following the procedure to avoid inadvertent distraction of the auricle.

Results

Otoplasty in general is a highly satisfying operation both to the patient and to the surgeon. Achieving symmetry between the ears and producing ears with smooth convolutions and grooves are the goals of otoplasty (Figs. 27–11 to 27–15). As these results may be achieved with any of a number of techniques, it becomes increasingly important to select a technique that is associated with the fewest complications and the best long-term results. Many authors have satisfactory results with a large variety of techniques, so the selection of the particular technique is probably not as critical as facility with that technique.

COMPLICATIONS

Early Complications

The most feared early complications of otoplasty are hematoma and infection. Cartilage necrosis may result from the excess pressure placed on the auricular cartilage by a hematoma. Infection may lead to perichondritis and suppurative chondritis, with resulting necrosis and deformity of the auricular cartilage. The incidence of hematoma is around 1%. In a series of 3200 ears treated with a cartilage sculpting technique, Schuffenecker and Reichert reported two incidences of hematoma.[24]

Avoiding hematoma formation begins with a careful preoperative documentation of bleeding or bruising tendencies. In the absence of clinical or family history suggestive of a bleeding disorder, coagulation studies are not performed

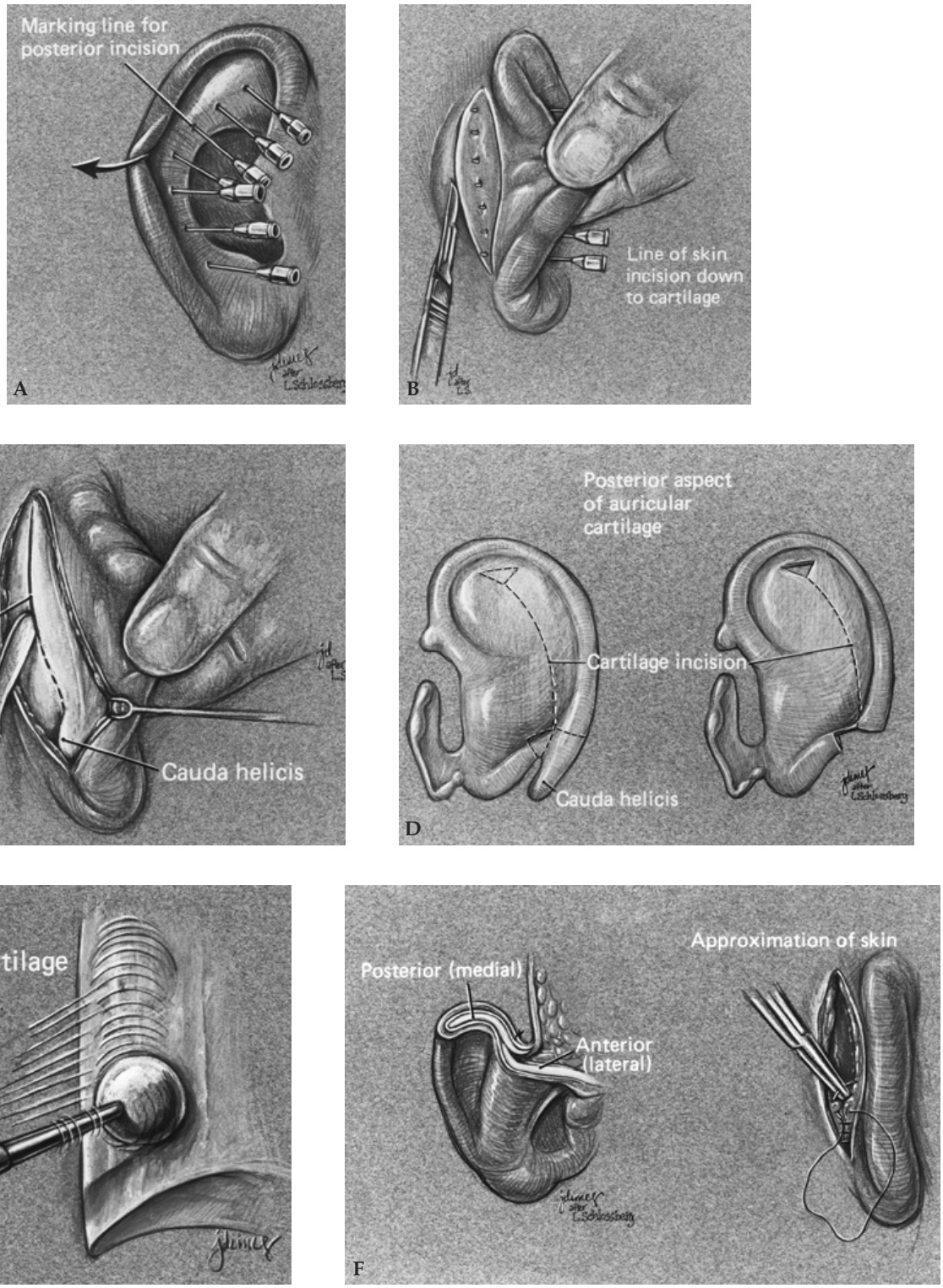

Figure 27–10 Cartilage splitting otoplasty. **(A)** The ear is folded in a normal position. Using 25-gauge needles, the auricle is penetrated from an anterior to posterior direction at the line of the proposed new antihelix. The needles are then tatooed with methylene blue. This tatoos both the posterior skin and the auricular cartilage. **(B)** On an elliptical piece of skin is placed a mark approximately 1 cm in width. This may be altered to to an hourglass incision if there is a prominent earlobe. **(C)** The posterior aspect of the auricular cartilage, showing the incision in the cartilage following wide undermining. The incision should be approximately 4 mm laterally to the previous cartilage tatoo marks. **(D)** The relationship of the cartilaginous incision to the auricular cartilage landmarks. Note the resection of the caudal helicis. Also note the inverted triangle at the superior aspect of the cartilaginous incision. This allows overlapping of the segments later without buckling. **(E)** Beveling of the anterior aspect of the lateral and medial cartilaginous flaps. Beveling is accomplished using a diamond burr. Beveling is done until the cartilage assumes a gradual convexity approximating the appearance of a normal antihelix. **(F)** Overlapping of the lateral segment over the medial segment of cartilage is done, restoring the normal contour to the ear. No sutures are placed in the cartilage. The skin is closed with a running subcuticular stitch.

Figure 27–11 A 10-year-old boy with bilateral auricular deformity. **(A)** Preoperative and **(B)** postoperative frontal view following cartilage-splitting otoplasty.

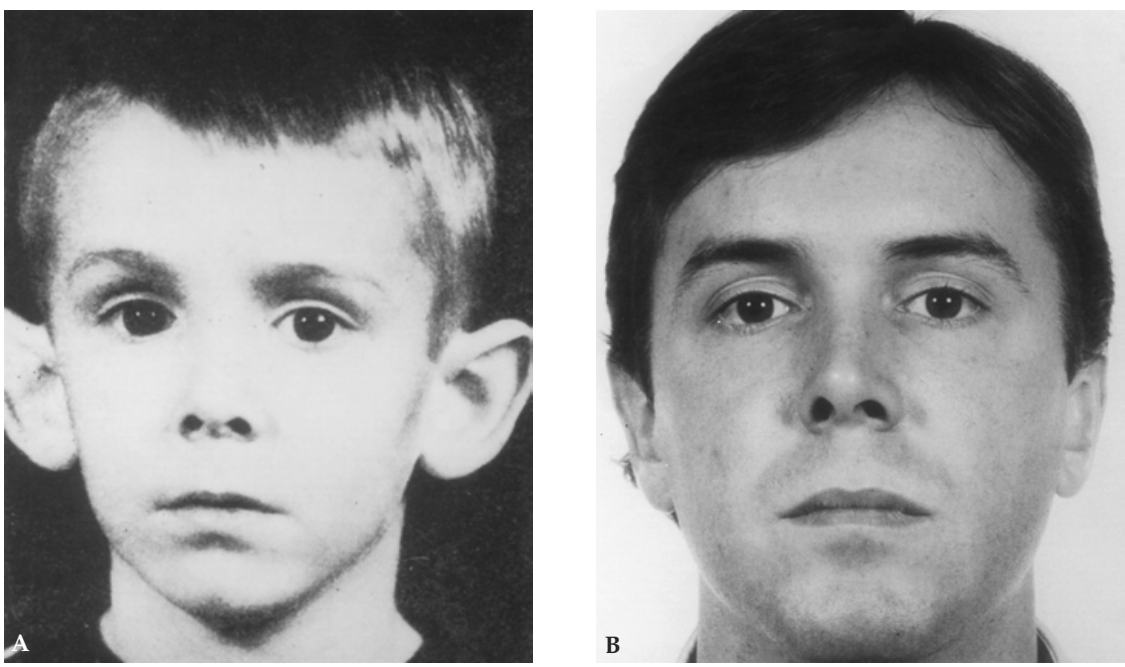

Figure 27–12 A 5-year-old boy with bilateral auricular deformity. **(A)** Preoperative and **(B)** 18-year follow-up showing maintained correction following cartilage-splitting otoplasty.

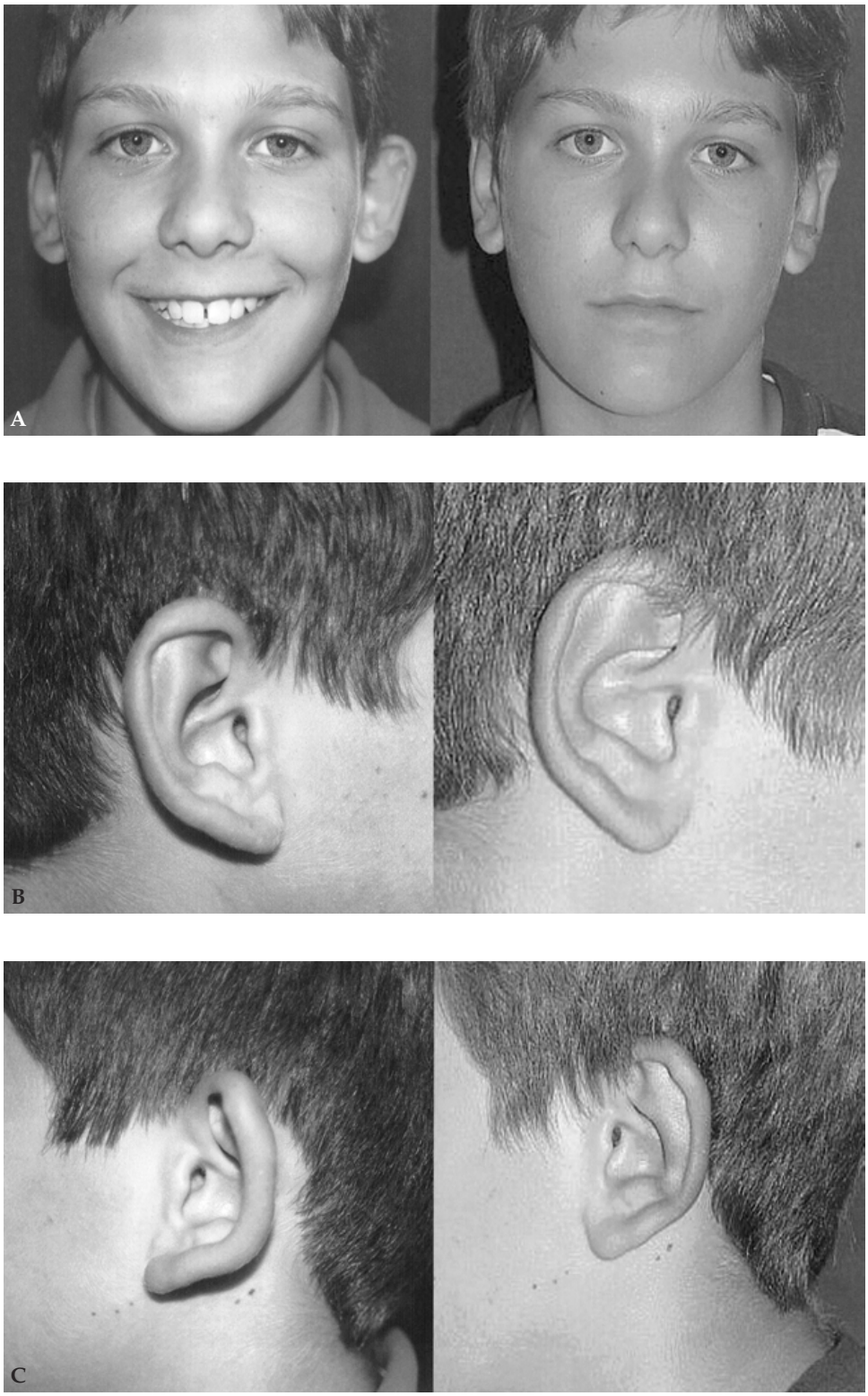

Figure 27–13 A 10-year-old boy with assymetric auricular deformity. Left auricle demonstrates marked auricular and conchal deformity. The right auricle was over protruding secondary to conchal deformity. Bilateral conchal setbacks were performed. The left ear also had a modified Mustarde procedure with posterior cartilage abrasion. **(A)–(C)** Preoperative (left) and postoperative (right) frontal, right auricle, and left auricle views.

Figure 27–14 Preoperative and 2-year postoperative views of 9-year-old with predominantly antihelical deformity. Correction was done by cartilage-splitting otoplasty.

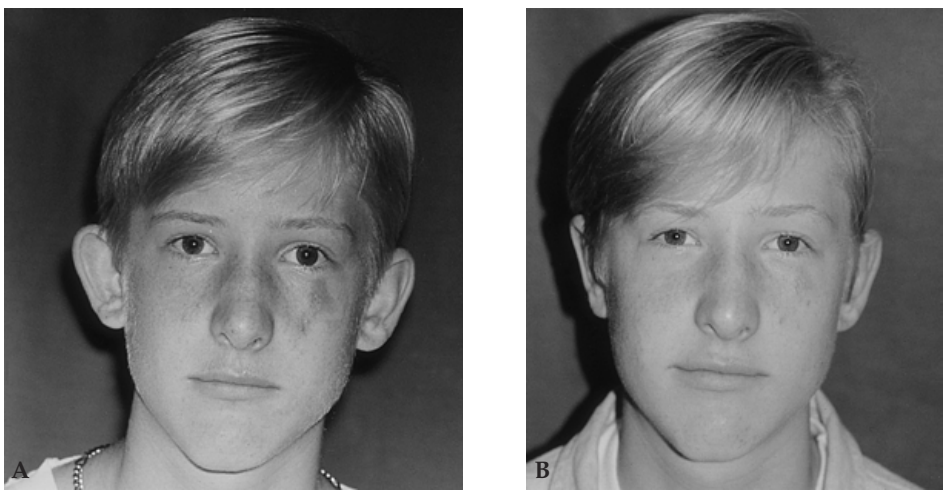

Figure 27–15 Preoperative and 2-year postoperative views of adolescent with antihelical deformity corrected with cartilage-splitting otoplasty.

routinely. Intraoperatively, a bipolar cautery is used to avoid necrosis of the auricular cartilage. In cases of bilateral otoplasty, the first ear must be treated with a conforming soaked-cotton dressing before the contralateral side is treated. After the contralateral otoplasty is performed, the initial ear must be reexamined to ensure that no hematoma has formed. A small rubber-band drain is left in the postauricular sulcus and is brought out through the incision until the first dressing change.

Unilateral pain is the earliest warning sign of developing hematoma. In general, the otoplasty patient is in minimal discomfort during the first 48 hours after surgery. Any unusual discomfort should be investigated by removing all bandages and inspecting the wounds. The presence of a hematoma necessitates reopening the wound, controlling the bleeding, irrigating with an antibiotic solution, and reapplying the dressing.

Wound infections usually manifest on postoperative day 3 or 4. Erythema of the wound with pustular drainage may be present in the absence of significant pain. Wound infection must be treated aggressively before perichondritis or chondritis occurs. Administration of systemic antibiotics, including coverage for *Pseudomonas aeruginosa,* is required in these cases. Suppurative chondritis is a rare but serious complication in which the infection has spread into the cartilage, with resulting necrosis and resorption. The heralding sign is

pain, and it is deep and boring in nature. The physical findings are often unimpressive compared with the symptoms. The diagnosis is established after conservative methods have failed to control wound infection. Treatment principles include systemic antibiotics, again covering for *Pseudomonas*, debridement, and wide drainage. Repeated conservative debridements are usually required. Resolution of the infection is evidenced by amelioration of the pain and improvement in wound appearance. Long-term sequelae of chondritis can be devastating. Cartilage necrosis leads to permanent auricular deformity.

Late Complications

Late complications after otoplasty include suture extrusion and aesthetic complications. Suture extrusion is not uncommon following Mustarde procedures and may occur at anytime in the postoperative period. It may result from incorrect suture placement, from excess tension on the auricular cartilage, or from infection. Treatment is the removal of the offending suture(s). Early suture extrusion requires revision surgery to restore the correction. Later extrusions may not require revision surgery because the auricle may retain the corrected shape.

Aesthetic complications include abnormalities in the relationship of the auricle to the scalp and distortion of the auricle itself. The former category includes inadequate correction of the protruding ear, reprotrusion, and overcorrection. Distortions of the auricle include telephone deformity, reverse telephone deformity, auricular buckling, visible cartilage edges, and bowstringing of sutures.

Inadequate correction may result from error in diagnosis. Ears whose main deformity is conchal protrusion will not be corrected by techniques designed to recreate the antihelix. Accuracy of preoperative and intraoperative measurements is critical in achieving the degree of correction desired. Other possible factors include suture extrusion and loosening of sutures. Some degree of reprotrusion secondary to cartilage memory is reported in most ears corrected by a suture-only technique. Stal and Spira[25] report some degree of reprotrusion in all cases, most noticeably in the upper pole. Overzealous correction of the protruding ear can lead to flattening of the ear against the scalp. This is often more worrisome to the surgeon than to the patient but nevertheless can be avoided by careful intraoperative measurements.

The telephone deformity of the auricle describes an unnatural result where the middle third of the auricle is overcorrected with respect to the superior and inferior poles. This is often seen following an aggressive conchal setback where the superior pole is undercorrected. An undertreated protuberant cauda helicis may also contribute to telephone deformity. Reverse telephone deformity occurs when the midauricle protrudes after adequate or overcorrection of the superior pole and lobule. This may result from an untreated conchal protrusion. Secondary correction of either deformity may lead to excessive setback of the auricle.

Buckling of the auricular cartilage is seen with suture techniques where the sutures are placed too far apart. This may be avoided by adhering to the recommended measurements for this technique.[14]

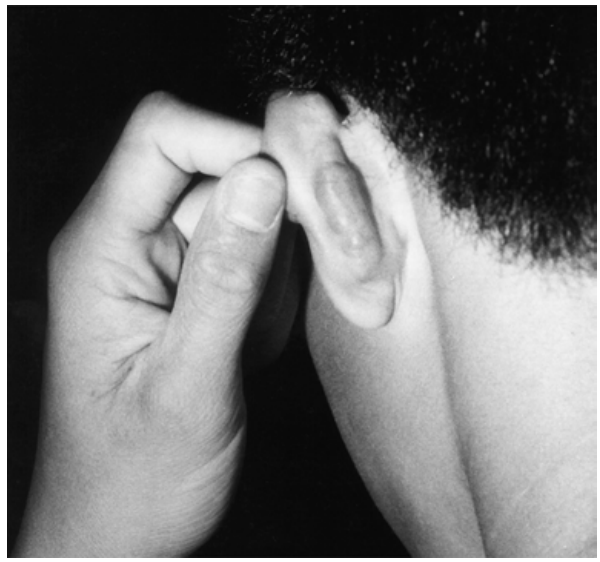

Figure 27–16 Keloid formation following otoplasty.

Unsightly postauricular scars range from bowstringing of the sutures to keloid formation (Fig. 27–16). Bowstringing is seen only in suture otoplasty, where excess suture tension causes draping of the skin around the sutures. This produces an unsightly postauricular scar. Any otoplasty technique where the postauricular incison is closed under excess tension may result in hypertrophy of the scar. Keloid formation is unusual, although its incidence in black patients is higher. In a large series reported by Baker and Converse, the incidence of postoperative keloid formation is 2.3%.[26] Treatment of keloids is initially conservative, with injections of triamcinalone acetonide (10, 20, or 40 mg/mL) every 2 to 3 weeks. The mechanism of action of steroids appears to be to decrease collagen activity and enhance collagen breakdown.[27] If surgical excision is required, a conservative excision using the carbon dioxide laser is used. Some authors advocate leaving a rim of the keloid tissue to prevent restimulation of keloid production.[28] Steroid injections are used in the postoperative period, as are pressure earrings in female patients. Low-dose radiation therapy has also been reported with some success in the management of recurrent keloids.

SUMMARY

Otoplasty is one of the most challenging and rewarding procedures in facial plastic surgery. Emphasis is placed on precise preoperative analysis and measurements, predictable operative techniques, and the avoidance of a surgical appearance of the ear. Although no surgeon can be versatile in all otoplasty techniques, a fundamental knowledge of the principles of otoplasty will permit correction of a wide variety of deformities with any given approach.

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Chapter 28

Cosmetic Surgery of the Asian Face

John A. McCurdy, Jr.

In surgical parlance, the term *Asian* is currently applied as a designation for individuals belonging to the Mongoloid race of peoples. It should be noted, however, that consistent with the geographic immenseness of the Asian continent, its native inhabitants demonstrate racial diversity exceeding that of Europe, Africa, and the New World. The indigenous people of western Asia are essentially Caucasian, whereas those of southern Asian regions are largely Indo-pakistani or Malay. The surgical appellation "Asian" applies to the population of eastern Asia, a region historically termed the Orient. Thus while technically a misnomer, the term "Asian" when used in this chapter will, in the interest of conforming to contemporary surgical linguistics, refer to the group of people originating in east Asia who have been previously known as Oriental.

Although the physical characteristics of the Asian face differ substantially from those of the Caucasian, justifying separate discussion of the unique surgical approaches devised for aesthetic modification, it should be noted that, as in the Caucasian face, considerable individual variation exists as a result of alteration of the gene pool by centuries of migration and intermarriage. The most common of the anatomical features for which surgical manipulation requires formulation of distinctly different approaches are the eyelids, the nose, and the maxillary (midfacal) region, and the majority of this chapter will focus on these areas. Surgical procedures designed to modify other components of the face are essentially comparable to their counterparts in the Caucasian patient, and discussion of these procedures will be limited to a few specific observations and technical considerations, which may facilitate such operations.

The past three decades has witnessed an exponential increase in the incidence of cosmetic surgery of the Asian face, a situation attributable to increasing influence of and immigration to the West as well as general affluence in developing Asian nations. It is essential to understand, however, that the nature of requests for cosmetic facial surgery has changed dramatically since the 1960s and 1970s when a predominant desire was for "westernization." In contemporary times, however, Asian patients seldom request westernization, desiring instead relatively conservative modifications that improve facial balance and harmony while maintaining ethnic identity. It has been my distinct observation that patient dissatisfaction following surgery performed by Western surgeons is often related to overly aggressive surgery, whereas dissatisfaction following surgery performed in the Orient is more likely related to an overly conservative approach.

GENERAL CONSIDERATIONS

As in Caucasians, skin texture and pigmentation of Asians exhibits substantial individual variation. In general, those individuals originating from more southerly latitudes show darker pigmentation, whereas a substantial percentage of natives of central and northern East Asia (i.e., Northern Chinese, Koreans, Japanese) have more lightly colored, even milky white skin pigmentation often described as exhibiting a yellowish hue. This yellow tint of Asian skin is largely a consequence of the number and distribution of melanin granules rather than differences in the structural skin lipoproteins themselves.

Regardless of the extent of skin pigmentation, Asians generally demonstrate thicker dermis than equivalently pigmented Caucasians. A consequence of greater collagen density, this situation is associated with a tendency toward a more vigorous fibroplastic response during wound healing, which may result in hypertrophic scarring and prolonged redness during scar maturation in an incidence worthy of note even in lightly pigmented Asians. Clinically, hypertrophic scarring is most common in the epicanthal region and the postauricular (and occasionally temporal) incisions following rhytidectomy. For unknown reasons, hypertrophic scarring rarely if ever occurs on the lower eyelids or following alar base excision. In spite of the fact that hypertrophic scarring is common in the noted areas, frank keloid formation is rare, occurring most commonly in the ear lobule after piercing.

Increased dermal thickness may account for a substantially lower incidence of fine facial rhytides in both darker and fair Asians as compared with Caucasians of equivalent age. On the other hand, Asian skin tends to respond to sun exposure and the aging process with an accelerated development of pigmented dermatoses (lentiginous actinic keratoses, seborrheic keratoses, etc.) as compared with Caucasian skin. However, skin malignancies of all types are markedly less common in Asians than in Caucasians.

CULTURAL CONSIDERATIONS

An understanding of cultural differences among Asian nationalities is perhaps as important in achieving optimal surgical results as thorough comprehension of anatomical factors. Effective communication between patient and surgeon is of utmost importance in preoperative planning as well as in management decisions during the postoperative healing period. Appreciation of cultural and personality characteristics facilitates precise interpersonal communication. Miscommunication predicated on failure to understand such differences is all too often the basis for inappropriate surgical decisions and manipulations (initial or corrective).

In spite of the significant influence of the Western world on the East, the tremendous differences between Western and Eastern cultures soon becomes obvious to Westerners who associate with native Asians. These differences may exert significant effects on patient perceptions about surgery (and the surgeon), as well as expectations and behavior during the postoperative period. Although cultural differences are less defined in the generations descended from the immigrant populations, certain powerful cultural influences often persist, and these may exert significant effects on attitudes concerning (or behavioral reactions following) cosmetic surgery. As stressed previously, a basic appreciation of these cultural factors is of great assistance in providing insight into the psychological makeup of the diverse Asian nationalities and will enable the surgeon to communicate more effectively with, and respond more appropriately to, the concerns and desires of Asian patients.

One of the basic foundations of Asian philosophy is a strong belief in fate, destiny, and the importance of luck, both good and bad, in daily affairs. Many Asians have strong beliefs in certain maxims, proverbs, and superstitions and apply these beliefs and superstitions to important situations encountered in their daily lives.

Asian cultures also place great significance on physiognomy—the relationship of physical traits or characteristics to behavior and personality, as well as to prospects for success in business, friendship, marriage, and other human relationships.

Most Asians exhibit great respect for higher education and for persons in a position of authority. This degree of respect may result in a deference to surgeons that may impair effective communication. Questioning the physician is considered to be a sign of disrespect; thus, patients may be reluctant to request clarification of matters that they do not understand completely.

Asian patients frequently feel that their surgeon will automatically know (and do) what is best. However, an unsatisfactory result frequently fragments this patient–physician bond, unleashing emotions and behavioral forces that could have been attenuated by effective preoperative communication.

IMPORTANCE OF BEAUTY

Physical beauty is particularly important to Asian women, as in Oriental cultures it is generally considered that a major duty of a wife is to maintain attractiveness so that she can be a source of pride to her husband and family. There is a general cultural belief that if a woman does not remain attractive to her husband, he has every right to wander in search of other sources of affection. Before the advent of cosmetic surgery, a fatalistic attitude toward appearance was predominant, a stance that to a large extent—at least in more urbanized areas—has been supplanted by a strong desire to undergo surgery for improvement in appearance. Submission to cosmetic surgery, however, often results in subconscious feelings of guilt that in some cases may complicate the healing period. A major source of such guilt is a strong attachment to family and the belief that it is disrespectful to one's parents to alter physical characteristics that were "given" to an individual by the parents. The strong belief in the importance of beauty and its relationship to personal success has, to a large extent, superseded this cultural tradition.

Alternatively, guilt over having undergone cosmetic surgery may result in withdrawal ("hiding") from family and friends. Such self-imposed isolation may rob the patient of much needed emotional support during the critical postoperative period that may contribute to obsessive or delusional concerns. The surgeon must be cognizant of these potential disruptive forces during the early postoperative healing period and firmly resist requests for premature or inappropriate revision procedures. One prominent Vietnamese surgeon admonishes his patients in printed informational material, "Please do not look in the mirror for you will surely be disappointed!"

The Asian appreciation for harmony and symmetry, the basic elements of beauty, as well as an eye for detail are manifested in the precision of Oriental craftsmanship. However, this appreciation for perfection may translate to unrealistic anxiety about postoperative asymmetry and other minor imperfections during the healing period, requiring considerable patience and understanding on the part of the surgeon. Asian patients, in contrast to the average Westerner, openly discuss cosmetic surgery with their acquaintances and often solicit the opinions of family and friends about their appearance during the early postoperative period, being very susceptible to unflattering comments during this stage. Such behavior is a common source of early postoperative unhappiness and dissatisfaction, and the surgeon must firmly resist requests for inappropriate revision procedures during this time.

NATIONAL CHARACTERISTICS

Although many of the basic cultural nuances noted previously are common to all Asian cultures, each ethnic group shares certain common behavioral and personality traits and attitudes that, while certainly not universal, tend to characterize and distinguish members of these nationalities.

The concept of "national identity" is certainly familiar to Westerners. The British, for instance, are often characterized as polite but formal, having a "stiff upper lip," and Germans are stereotyped as stern, diligent, and perfectionistic. In the United States, the characteristics of citizens from different regions provide a basis for similar stereotyping. Texans, for example, are characterized as friendly and relaxed with a tendency toward exaggeration, whereas New Yorkers are often thought of as impatient, blunt, and sarcastic.

In the same manner, Asian nationalities recognize certain typical characteristics among themselves and stereotype various nationalities according to commonly observed traits. Whenever I lecture on surgery in Asian patients, without

exception, one of the most common questions asked is, "I just can't seem to get through to my Asian patients. How do you communicate with them effectively?" An understanding and appreciation of ethnic differences and stereotypical traits of the many Asian nationalities may be helpful in this endeavor.

INTERACTING WITH THE ASIAN PATIENT

As a group, Asian patients tend to be reserved and self-effacing, necessitating open ended, somewhat probing discussions to extract pertinent information and encourage formation of realistic expectations, both before and after surgery. The surgeon should (1) encourage the patient to communicate any fears, worries, or disappointments honestly and (2) be, likewise, frank and straightforward when discussing expectations, likely results, and possible complications.

BLEPHAROPLASTY IN THE ASIAN EYELID

General Considerations

Surgical modification of the upper eyelid has become increasingly popular in Asia since World War II and is currently the most commonly performed aesthetic operation in the Far East. Although surgery of the Asian eyelid is similar to blepharoplasty in other ethnic groups, important anatomical and technical differences do exist, and the surgeon must be familiar with these variations to maximize aesthetic results.

As a group, approximately 50% of Asians exhibit a "single eyelid," so-called because in the absence of a superior palpebral fold the lid hangs like a curtain from the supraorbital ridge. Creation of a palpebral sulcus divides the lid into well-defined pretarsal and palpebral segments, producing the "double eyelid" desired by many Asian women as well as an increasing number of men.

The incidence of the single eyelid, of course, is higher in Asian populations that have remained homogeneous (i.e., Japanese, Northern Koreans), whereas double eyelids are more common in heterogeneous populations (i.e., Vietnamese, South Koreans, Southeast Asians, and Filipinos). However, most Asians with natural double eyelids exhibit a small fold accompanied by abundant periorbital and submuscular fat as well as excess upper eyelid skin that exhibits considerable pretarsal laxity.

It would be erroneous to assume that the popularity of the double-eyelid operation is related solely to Western influence. Asian cultures have long regarded the bright-eyed look associated with the double eyelid as an aesthetically desirable feature. Many Oriental women produce double eyelids by using various tapes and glues to encourage temporary adherence of the pretarsal upper lid skin to preseptal skin, resulting in a palpebral fold. As such rituals are time consuming and temporary, surgery is frequently requested after a girl has reached the age of 15 or 16.

Given the fact that many Asian cultures regard the double eyelid as an aesthetically desirable facial feature, it is important that the surgeon understand that a request for surgical modification of the single eyelid is generally not a request for westernization of the lid. Many patients, particularly those who have been born in North America, simply desire a small double eyelid while maintaining ethnic character.

Westernization of the eyelid, on the other hand, requires reduction of the characteristic puffiness of the Asian lid via removal of excess skin and fat and, in many cases, modification of an epicanthal fold. In general, recent immigrants to Western countries tend to request creation of a large eyelid (i.e., higher palpebral fold), whereas individuals born or raised in Western society usually request a more "natural" lid with preservation of their ethnicity.

Anatomical Considerations

Despite the popularity of the double-eyelid operation, controversy exists among surgeons regarding the precise anatomical basis for the supratarsal fold and thus the most effective method for creation of a natural and durable crease.

The most commonly proposed anatomical explanation of the differences between single and double eyelid is as follows: In the Caucasian eye, filaments of the levator expansion penetrate the orbital septum and orbicularis muscle and attach to the overlying dermis, creating a superior palpebral fold when the eye is opened. In the Asian lid, the levator aponeurosis does not penetrate the orbital septum of the orbicularis muscle but terminates on the superior margin of the tarsus. It must be noted, however, that the levator filaments postulated to be responsible for formation of the double eyelid have never been conclusively demonstrated in gross or histogolic studies.

Moreover, recent studies, suggest that the anatomical basis for formation of the superior palpebral fold is somewhat more complex. Rather than attaching directly to the dermis, filaments of the levator aponeurosis appear to extend inferiorly into the pretarsal portion of the lid, interdigitating with fibrous septa coursing from the tarsus (penetrating the pretarsal orbicularis) to the pretarsal skin, thus producing adherence between the pretarsal skin, orbicularis muscle, and tarsus. The actual mechanism of lid fold creation appears to relate to this adhesion of pretarsal skin, orbicularis, and tarsus. The preseptal skin, in contrast, is nonadherent to the preseptal muscle and thus relatively mobile. As the levator contracts, the mobile preseptal skin folds over the relatively rigid pretarsal lid (skin, orbicularis, and tarsus) that is elevated as a unit, thus forming the fold; or, stated in another way, the components of the pretarsal lid are retracted together in a board-like fashion posterior to the mobile preseptal skin on levator contraction. This concept is consistent with the fact that in eyelids without a well-defined palpebral fold, the pretarsal skin is redundant because it lacks attachments to the pretarsal muscle and tarsus. Surgical procedures that create a superior palpebral fold can be used to achieve this goal by virtue of the fact that the process of supratarsal fixation effectively produces an adhesion between the pretarsal skin and the lid opening mechanism, thus allowing its elevation and invagination posterior to preseptal skin as a single unit on levator contraction. This modified understanding of the anatomical basis for the lid fold has clinical implications in double-eyelid surgery because a more stable adhesion in the pretarsal lid and tightening of the pretarsal skin can be achieved by undermining the pretarsal skin for several millimeters prior to placement of fixation sutures.

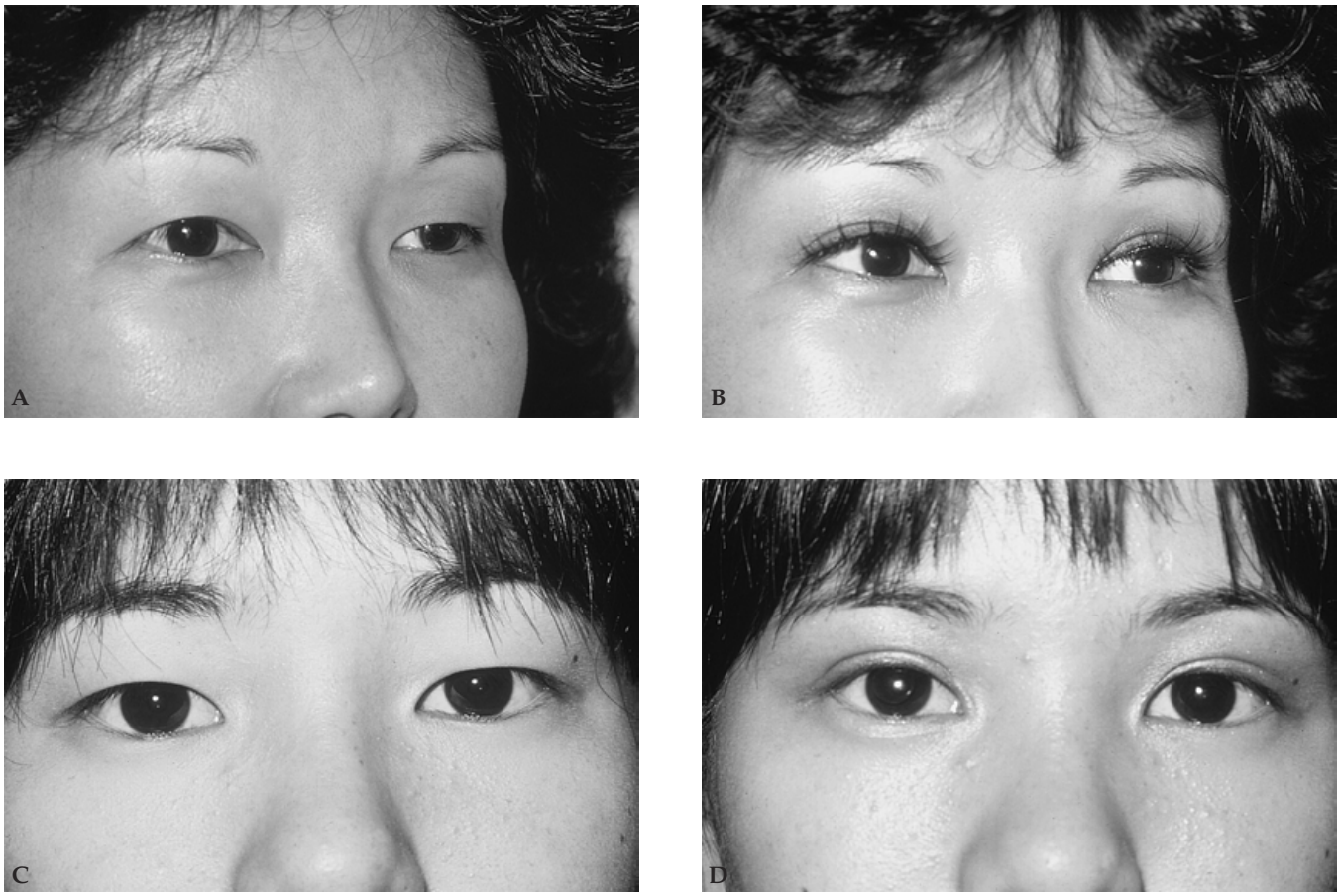

Figure 28–1 **(A, B)** Pre- and postoperative photographs showing surgical creation of a small double eyelid that is round in configuration with an inside fold. **(C, D)** Surgical creation of a double eyelid that is oval in configuration with an inside fold. *(continues on next page)*

Furthermore, the lack of adherence between pretarsal skin, orbicularis, and tarsus allows a wedge of periorbital fat (bounded anteriorly by the levator aponeurosis and posteriorly by the orbital septum) to descend inferiorly, anterior to the tarsal plate, producing the characteristic puffiness of the pretarsal lid. An abundant layer of suborbicularis fat is often present in the Asian lid, contributing to fullness in the pretarsal area. Interestingly, the location of the palpebral fold in all ethnicities appears to coincide with the point of fusion between levator aponeurosis and orbital septum, with the descending wedge of fat bounded by these structures acting as a barrier preventing adherence of pretarsal skin, orbicularis, and tarsus. Clinically, this barrier of fat must be surgically excised inferior to the point at which the palpebral fold is created to create permanent adhesion of pretarsal tissue layers. Failure to adequately remove this tissue is frequently the cause of "falling out" of the surgically created fold (i.e., postoperative fold failure) and occurs most commonly in the lateral aspect of the eyelid.

Preoperative Considerations

The major objective of blepharoplasty in the Asian upper lid is creation or enhancement of a crisp, well-defined, and natural palpebral fold. Because of the many possible variations in achieving this goal (i.e., the level of the palpebral fold, the depth of the palpebral sulcus, as well as the appearance of the epicanthal region) that can be controlled by modifications of surgical technique, careful preoperative evaluation and counseling of each prospective patient are mandatory when planning this operation. Many patients desire only the creation of a palpebral fold and wish to retain the other characteristics of the Asian eyelid. Others, however, prefer a less conservative transformation or even a westernization procedure that requires modification of the epicanthal fold as well as reduction of lid puffiness by removal of large volumes of redundant skin and fat.

Several methods assist the surgeon and patient in selecting the type of eyelid transformation desired. In my practice, patients are advised that three basic decisions are necessary: (1) size of the "new" eyelid, (2) shape of the new eyelid, and (3) disposition of the epicanthal fold. For purposes of counseling, double eyelids are arbitrarily divided into small, medium, and large, depending on the amount of visible pretarsal skin and the depth of the palpebral sulcus. Likewise, eyelids are classified as having one of two shapes: round or oval. Patients are then shown pre- and postoperative photographs illustrating the various sizes and shapes of eyelids (Fig. 28–1). In many patients, it is possible to demonstrate the approximate size and shape of the lid (while the patient is looking into a mirror) by manipulating the eyelid skin with a bent paper clip or forceps. In discussing the epicanthal

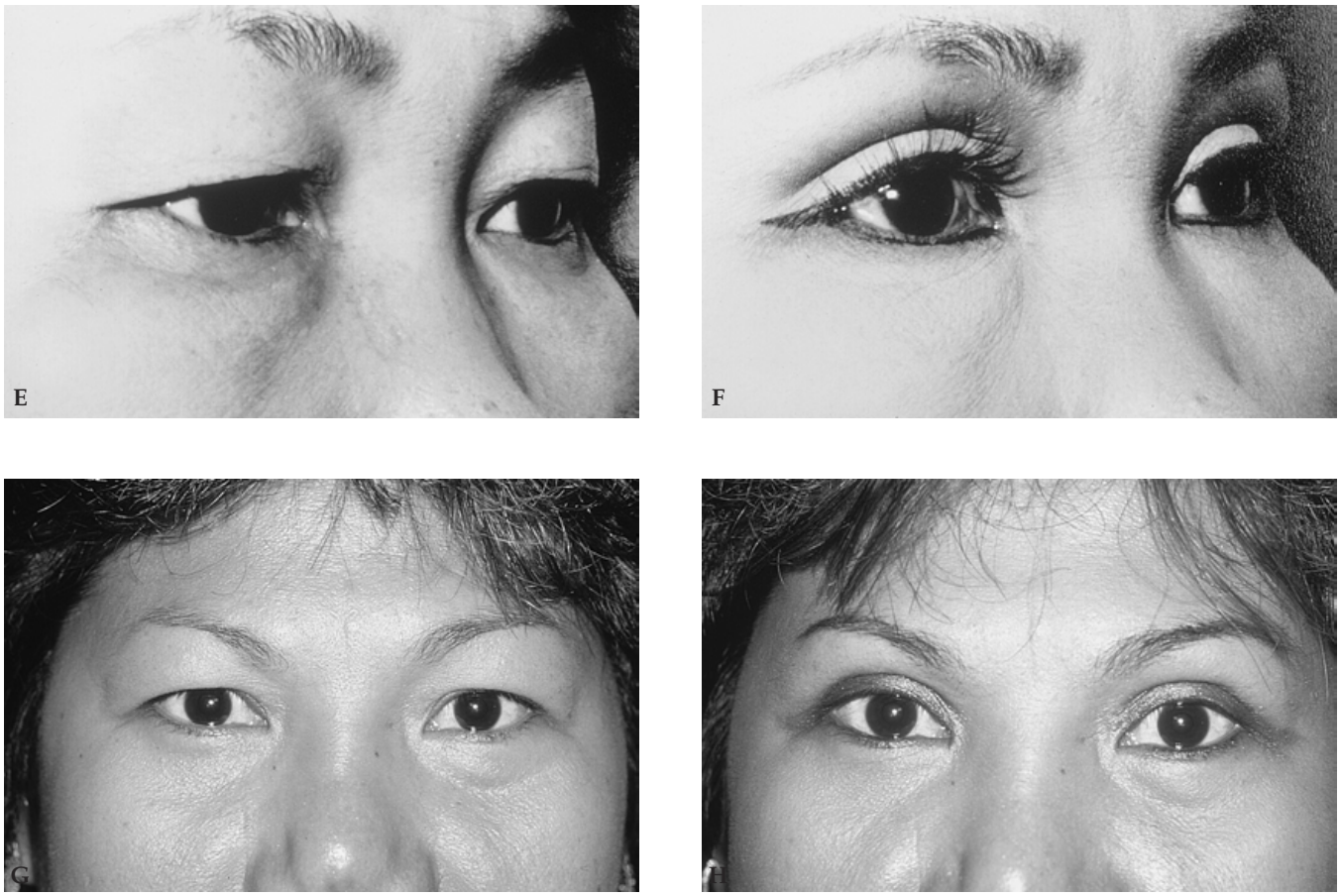

Figure 28–1 *(cont.)* **(E, F)** Pre- and postoperative photographs showing surgical creation of a large double eyelid with an outside fold. **(G, H)** Pre- and post-operative photographs showing surgical creation of a medium-size double eyelid with an outside fold.

region, differences between the so-called "inside" and "outside" folds are demonstrated with pre- and postoperative photographs, facilitating a more rational discussion of possible variations (Fig. 28–2).

Some patients bring pictures of magazine models to their consultations, and though it must be stressed that a surgeon cannot construct an eyelid to the patient's exact specifications, examining these pictures in conjunction with pre- and postoperative photographs is often helpful in assisting the surgeon to determine the general size and shape of eyelid that an individual desires.

Anesthesia

The operation is performed under local anesthesia using anesthetic solution with fresh, unbuffered epinephrine (0.5 bupivacaine or 1% lidocaine with epinephrine 1:50,000) with intravenous sedation. To minimize intraoperative bleeding (which slows surgery, interferes with judgment of symmetry, and increases edema and ecchymosis, prolonging the healing period), anesthetic solution with fresh, unbuffered epinephrine (0.2 cm^3 epinephrine 1:1000 per 10 cm^3 plain 1% lidocaine) is prepared prior to each procedure. The vast majority of cases are performed as outpatient procedures in an office surgical facility. As frequent opening and closing of the eyes during surgery is helpful in the evaluation of symmetry, general anesthesia is not recommended. For the same reason, the level of sedation during surgery should be light. Diazepam and midazolam are best avoided as both agents frequently interfere with

Figure 28–2 The left eye exhibits an outside fold, while the right eye exhibits an inside fold, maintaining the epicanthus.

lid opening. Methohexital or propofol are excellent agents for eyelid surgery because their rapid onset and brief duration of action allow for painless anesthetic infiltration and a comfortable and reasonably cooperative patient intraoperatively.

Operative Procedure

The key to success in upper lid blepharoplasty in Asian patients is to perform each step (from preoperative marking to final suturing) with the goal of achieving eyelid symmetry. The sequence for preparation and surgical intervention is as follows:

I. Proper preoperative markings (Fig. 28–3) are of the utmost importance and are determined by the size (small, medium, large) and shape (round, oval) of the desired eyelid transformation. The most important factor in determining the level of the superior palpebral fold is the distance from the ciliary margin at which the inferior lid incision is drawn. This distance ranges from 6 to 10 mm.

   A. For creation of a small double eyelid, the incision is placed 6 to 7 mm above the ciliary margin, whereas in patients desiring a medium-size lid, the incision is placed 8 mm above the ciliary margin. For a large eyelid, the incision is marked 9 to 10 mm above the ciliary margin.

   B. Prior to marking, it is important to tense the pretarsal skin to the point of lash eversion. An initial mark is placed at the desired height at the level of the lateral limbus following which the entire inferior incision is drawn.

      1. To create an eyelid with an oval shape, the incision is configured so that it is 1 to 2 mm more inferior when it reaches the medial canthus while remaining at approximately the same level at the lateral canthus as in the center of the lid. The incision is then extended slightly superiorly and laterally so that it will fall in a periorbital line.

      2. If a round eyelid is desired, the lateral aspect of the incision is drawn so that it is approximately 2 mm more inferior at the level of the lateral canthus than at the level of the lateral limbus (also being 2 mm more inferior medially).

   C. Individual desire regarding management of the epicanthal region determines the location of the lid incision in this area.

      1. If an inside fold (i.e., no epicanthal modification) is requested, the incision is drawn lateral to the existing epicanthus (Fig. 28–3A).

      2. If an outside fold (epicanthal effacement) is desired, the incision terminates medial to the epicanthal web (Fig. 28–3B, C).

II. The level of the superior incision, which determines the amount of skin to be excised, is determined by pinching the skin with forceps and asking the patient to open and close the eyes as in a standard blepharoplasty procedure. The average amount of skin excised is 3 to 10 mm, depending on the age of the patient and the type of eyelid desired. It is important to individualize the amount of skin removed according to the size of eyelid requested, as this factor is important in determining the amount of pretarsal "show."

   A. In the patient who desires a small double eyelid, only 2 to 3 mm of skin is excised.

   B. For creation of a medium-size lid, half of the maximal amount of skin that can be removed (as determined by forceps pinching) is actually removed; that is, if 12 mm of skin can be maximally removed, the incision is placed 6 mm above the level of the inferior skin incision.

   C. If a large, westernized lid is desired, 2 to 3 mm less than the maximum amount of skin that could be removed as determined by forceps pinching is actually excised.

III. The superior incision is marked so that it courses parallel to the previously marked inferior incision, joining it at the medial and lateral canthal areas.

IV. Following infiltration of local anesthetic, skin and subcutaneous tissues are excised exposing the orbicularis muscle.

   A. A 3- to 5-mm strip of orbicularis is excised above the tarsal plate.

   B. The orbital septum is then incised, exposing periorbital fat.

      1. If a deep "Western" palpebral sulcus is desired, removal of all visible fat in the central and lateral compartments is performed so that the levator expansion is completely cleared.

Figure 28–3 Incisions used for the creation of an inside fold **(A)**, an outside fold **(B)**, and a fold terminating on the origin of a small epicanthus **(C)**.

2. Removal of medial fat is more conservative, as creation of a deep hollow in the medial aspect of the lid does not produce the aesthetically desirable effect that often results from sculpturing this area in the Occidental eye. Excessive fat removal medially also predisposes to hypertrophic scarring as more tension is placed on the skin closure.
3. Little or no fat in any compartment is excised if a small double lid is desired; in such cases, the fat is carefully separated so that the levator expansion can be identified.

V. Prior to placement of fixation sutures, a 2- to 3-mm strip of muscle is removed from beneath the skin at the level of the inferior skin incision (Fig. 28–4). This maneuver effectively undermines the skin 2 to 3 mm, providing a wider base of adhesion for formation of the palpebral fold, and allows tightening of pretarsal skin during fixation.

VI. Fixation sutures of 5-0 nylon are then placed, incorporating the skin edge of the inferior incision, the levator aponeurosis, and the superior skin incision (Fig. 28–5).
   A. Buried "internal" fixation sutures of permanent or absorbable suture incorporating only the inferior skin edge and levator may be substituted for the "external" fixation suture, but including the upper skin edge in the fixation enhances interoperative determination of symmetry as the extent of "hooding" contributed by the suprafold tissues is more easily determined.
   B. Three fixation sutures are utilized: laterally at a point approximately one half the distance between the lateral canthus and lateral limbus, centrally at the midpupillary level, and medially at the level of the medial limbus.
      1. The lateral fixation suture is placed initially, followed by the middle and medial sutures.
      2. Assessment of symmetry is enhanced if the sutures are placed sequentially in the right and left eyelids (i.e., the lateral fixation suture is placed in the right eyelid following which lateral fixation suture placement is performed in the left lid). With the eyes open, symmetry is assessed by inspection and direct measurement following which the middle fixation sutures are placed, etc.
      3. One or two additional medial fixation sutures are often placed in the medial aspect of the lid to efface the epicanthal fold if desired. On occasion, more advanced techniques of epicanthoplasty are necessary.

VII. The entire incision is then approximated with a running suture of 6-0 nylon. Both fixation sutures and the running cuticular suture are removed in 7 days.

VIII. To minimize the incidence of hypertrophic scar formation in the medial canthal region, 0.2 cm^3 triamcinolone (10 mg/cm^3) is routinely injected into the subdermal tissues of this area. In addition to causing a marked decrease in hypertrophic scarring, this procedure results in healing with considerably less palpable induration that may produce local distortion of the palpebral fold.

Postoperative Course

The early postblepharoplasty period is characterized by marked edema of the pretarsal portion of the lid as well as by variable degrees of blepharoptosis. The extent and duration of this ptosis are directly related to the level of fixation as well as the amount of skin and fat excised, being more significant if a larger lid is created. Blepharoptosis is generally not objectionable following removal of the fixation sutures

Figure 28–4 Excision of a 2- to 3-mm strip of muscle beneath the skin at the level of the inferior skin incision.

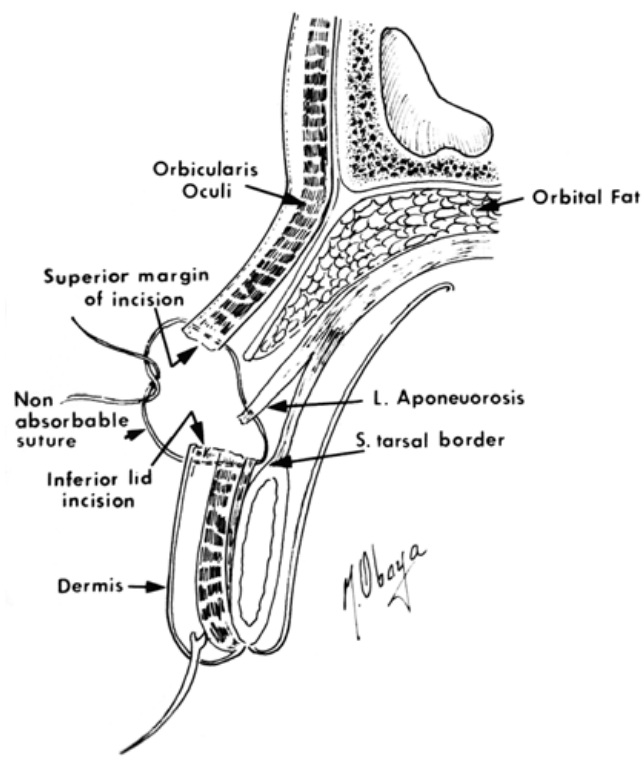

Figure 28–5 Placement of an external fixation suture (5-0 nylon).

on the seventh postoperative day but may occasionally cause persistent concern because of resultant asymmetry if it is more marked unilaterally. Slowly resolving asymmetrical ptosis is often related to hematoma or edema of Müller's muscle. Occasionally, residual pretarsal edema may be detectable for up to 6 months but is usually satisfactorily camouflaged by cosmetics following suture removal.

Complications of Upper Lid Blepharoplasty

Perhaps the most common source of dissatisfaction in Asian patients undergoing upper lid blepharoplasty is postoperative asymmetry of the lid folds. This problem occasionally occurs even in the hands of the most experienced surgeon.

Postoperative asymmetry is more likely to occur when lid or brow asymmetry exists preoperatively, and each prospective candidate for upper lid blepharoplasty must be carefully evaluated in this regard. Minimal ptosis, often unnoticed preoperatively, also predisposes to postoperative asymmetry. If asymmetry exists, it must be carefully pointed out to the patient, explaining that exact postoperative symmetry will be more difficult to achieve. Preoperative asymmetry, of course, must be carefully documented in the medical record as well as by preoperative photographs.

Strict adherence to certain technical points minimizes the occurrence of postoperative asymmetry:

1. The preoperative markings on the upper eyelid must be performed while the skin is stretched cephalically. The skin is tensed until the eyelashes begin to evert—a checkpoint that will facilitate symmetrical placement of the preoperative marks bilaterally.
2. After completion of the markings, they are rechecked for symmetry using a ruler prior to infiltration of anesthetic. On rechecking the incisions, it will be surprising how often a millimeter of asymmetry is discovered, allowing appropriate correction before beginning the operation.
3. After placing the initial fixation suture (usually at the lateral-most fixation point), a corresponding fixation suture is placed in the opposite lid, following which the patient is asked to open the eyes so that they can be inspected for symmetry. The height of both sutures above the ciliary margin is also carefully measured. In placing this initial suture as well as subsequent fixation sutures, the pretarsal skin is stretched to the point where the eyelashes begin to evert—a visual check also utilized in preoperative marking as described previously. If a difference of even 1 mm is noticed on measuring the height of the initial fixation sutures, or asymmetry is noted on inspection of the opened eyes, it must be corrected at this time. Following placement of subsequent fixation sutures, a similar measurement coupled with inspection of the opened eyes is performed, allowing prompt replacement of these sutures if necessary.
4. Avoid excessive sedation during the operative procedure because it may interfere with voluntary lid opening, making it more difficult to assess the symmetry following placement of fixation sutures.

   Use of an external fixation suture that incorporates both upper and lower skin incisions facilitates intraoperative assessment of the palpebral fold as the contribution of the upper skin segment to the final eyelid size and shape can be visually assessed during actual construction of the fold, as described previously.

   Slight asymmetry in the early postoperative period is very common because of differential swelling of the eyelids as well as the mild ptosis that may temporarily follow fixation procedures. Although many patients are concerned about this asymmetry, the surgeon should carefully explain the problem and firmly refuse to consider revision until edema has resolved. Occasionally more marked lid asymmetry due to obvious failure of one or more fixation sutures deserves earlier correction, with repair easily being accomplished by replacement of the failed suture through a small incision in the area of failure.
5. Measure, remeasure, then measure again!

Other possible complications of the double eyelid operation are the same as those in standard upper lid blepharoplasty. As the skin of the Asian eyelid tends to be thicker than that of the Caucasian lid, the incidence of prolonged induration and erythema is somewhat higher. However, frank scar hypertrophy is unusual except in the biologically predisposed medial canthal region. As noted previously, uncomplicated healing in this area is greatly enhanced with the routine use of intraoperative triamcinolone.

MANAGEMENT OF THE EPICANTHUS

Although approximately 90% of Asians exhibit an epicanthus, the size of the fold, although varying widely among individuals, is usually relatively small; thus, aesthetically successful effacement only rarely requires complex procedures that have been described for management of this condition in the Caucasian eye. A major reason for the relative ease in managing the Asian epicanthal fold is that, in contrast to epicanthus encountered in Caucasians in which a vertical shortage of skin is problematic, the epicanthal fold in the Asian lid is usually associated with skin redundancy of the entire upper lid. This can be demonstrated by medial displacement of the skin with a cotton-tipped applicator. Successful effacement of the fold can thus be conceptualized as a medial advancement of the epicanthal web. The goal of this advancement, in addition to removal of the fold itself, is to elongate the entire palpebral fold in a medial direction. Further benefits of this maneuver are the illusion of an enlarged eye and eyelid and a narrowing of the nasal bridge, a wide bridge and small widely separated eyes being concerns of many individuals with prominent epicanthal folds.

Determining the Approach to the Epicanthal Fold

In many patients, no specific intervention in the epicanthal area is necessary. This group includes those who desire an inside fold as well as other patients with a small, almost rudimentary epicanthus in whom the surgical approach used to create the palpebral fold results in sufficient medial advancement of the epicanthus to achieve satisfactory effacement.

The major advantage, of course, in minimizing surgery in the medial canthal region is the reduced risk of hypertrophic scarring. This region exhibits a biological predisposition to hypertrophic scar formation, and thus even the most

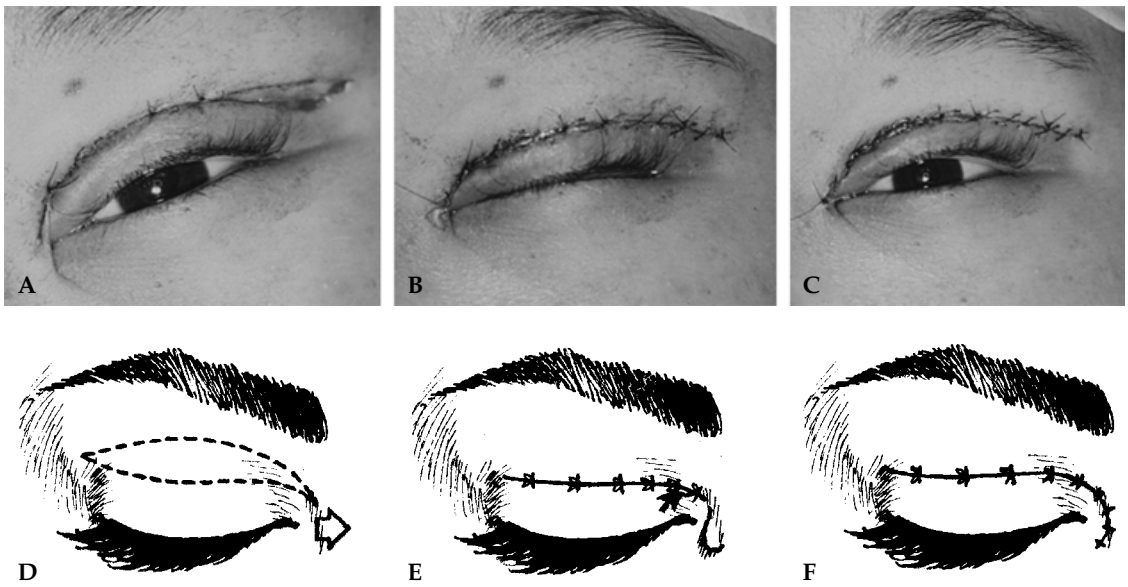

Figure 28–6 Effacement of a small epicanthus by medial fixation sutures combined with excision of a small "dog ear." (**D–F** from McCurdy JA. *Cosmetic surgery of the Asian face*. New York: Thieme Medical Publishers, 1990. With permission.)

meticulously performed procedure in this area may be complicated by the presence of an aesthetically unpleasant scar.

In keeping with the known propensity for scar formation in the medial canthal area, it is best to encourage patients who are either unaware of their epicanthal folds or uncertain if they really desire modification of this region to defer epicanthaplasty at the time of primary surgery. Such patients are counseled that epicanthal modification can be performed as a secondary procedure should they so decide.

Epicanthaplasty, if desired or indicated, is usually performed in conjunction with upper lid blepharoplasty. One of three approaches is used to efface the epicanthus, depending on the size of the fold requiring modification. Each procedure is based on the general principle that effacement can be successfully accomplished by medial advancement of the existing fold.

1. Advancement of a small fold is performed in conjunction with the incisions used for creation of the palpebral fold. These incisions are carried medially and inferiorly to the level of the lacrimal caruncle. The pretarsal skin in the area of the epicanthus is undermined to within 1 to 2 mm of the ciliary margin. Underlying soft tissue, including orbicularis muscle, is excised. The skin is then advanced medially and secured by placement of one or two external fixation sutures (Fig. 28–6). If a small dog ear develops, it is excised in the direction of the skin fold, occasionally extending onto the medial aspect of the lower eyelid. A result achieved using this technique is depicted in (Fig. 28–7).
2. If additional advancement is required, a half Z-plasty is utilized (Fig. 28–8). The epicanthal fold is incised near the medial terminus of the palpebral wound, creating a triangular flap that is undermined and advanced nasally into the triangular defect previously created. The resulting dog ear is trimmed in the direction of the skin lines as described previously. Fig. 28–9 illustrates pre- and postoperative results.

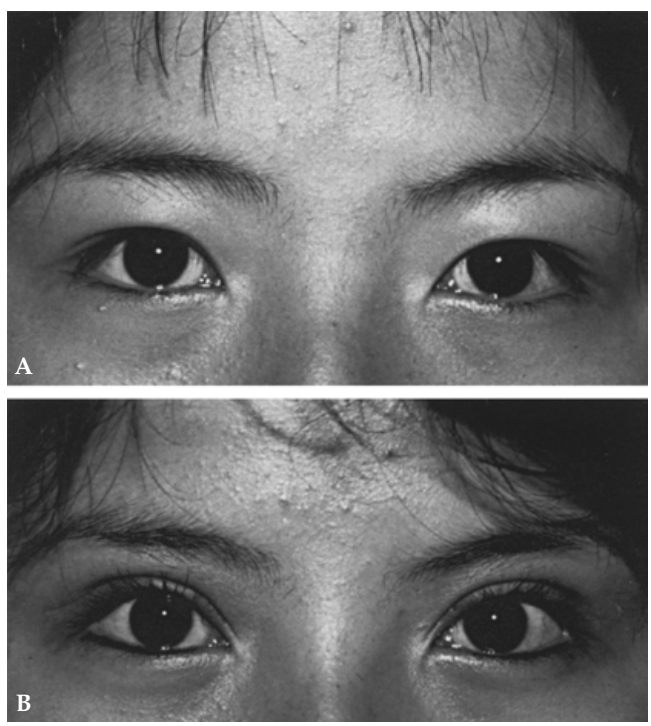

Figure 28–7 Effacement of the epicanthal fold by advancement in conjunction with creation of an "outside fold."

Figure 28–8 Effacement of the epicanthal fold using a "half Z-plasty." Figure illustrates advancement of a triangular flap and subsequent trimming of a "dog ear." (**F–G** from McCurdy JA. *Cosmetic surgery of the Asian face.* New York: Thieme Medical Publishers, 1990. With permission.)

3. Effacement of a larger epicanthus may require a greater medial advancement than is possible with Z-plasty techniques. Such a fold often terminates on the medial aspect of the lower lid, necessitating modification in this area as well. An excellent aesthetic result is generally achieved by a W-plasty advancement procedure.

   The desired position of the inner canthus is marked (this is a point approximately 2 mm medial to the desired position of the inner canthus) following which two V-shaped flaps, forming a W, are outlined. The triangular flaps have their bases on the segments of the epicanthus located on the upper and lower lids (Fig. 28–10).

   The outlined W is incised and the triangular flaps are undermined toward the inner canthus, following which the flaps are advanced and sutured with 6-0 nylon Fig. 28–11 shows pre- and postoperative results.

Always inform patients about asymmetry that exists preoperatively in the eyelids, epicanthal region, and palpebral fissures because usually it will persist or become more apparent postoperatively. Patients must understand that differences in postoperative edema between the two eyelids frequently translate to postoperative asymmetry and that judgment regarding final symmetry may be unreliable for 6 months or more postoperatively. Preoperative counseling must stress proposed management of the epicanthal fold, and if a patient is uncertain as to whether modification of the fold is desired, epicanthoplasty may be best performed as a secondary procedure. Patients must understand that once the epicanthal fold is removed, it can never be reconstructed. It is helpful to inform patients that in general effacement of the epicanthus produces a more westernized appearance, whereas preservation or slight modification of the fold preserves the Asian characteristics of the eye.

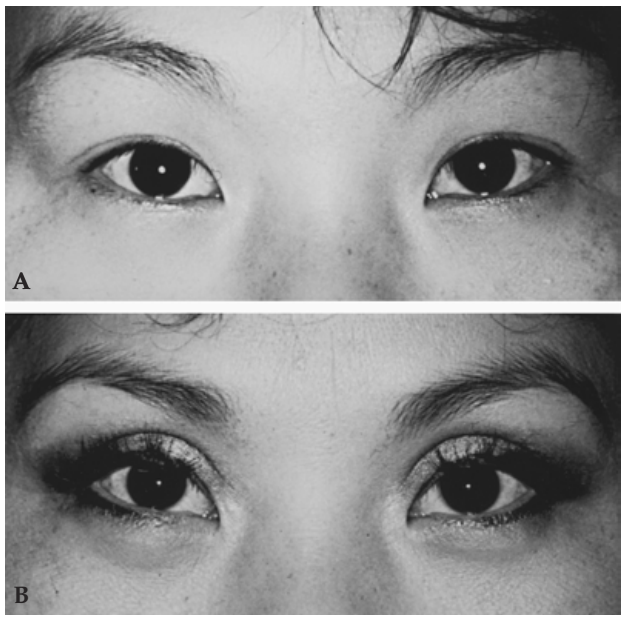

Figure 28–9 Epicanthoplasty with the half Z-plasty procedure.

Figure 28–10 Epicanthoplasty with the W-plasty advancement procedure (see text). (**E–G** from McCurdy JA. *Cosmetic surgery of the Asian face.* New York: Thieme Medical Publishers, 1990. With permission.)

Figure 28–11 Effacement of an epicanthal fold using the W-plasty advancement procedure.

In addition to improving facial balance by elongating "small eyes," epicanthaplasty improves the appearance of the nose, as the nasal bridge may appear excessively wide when the lateral dimension of the eyes is decreased by a large epicanthal fold (Fig. 28–11).

LOWER LID BLEPHAROPLASTY

As in the upper eyelid, the Asian lower lid characteristically exhibits a considerable volume of periorbital fat that frequently produces a puffy appearance even at an early age. In many patients, considerable fat is also present in the pretarsal plane (superficial to the orbital septum), accentuating eyelid fullness.

Although a wide spectrum exists, Asian skin is generally thicker than Caucasian skin, and deeply etched rhytides extending laterally (i.e., laugh lines or crow's feet) occur less frequently. Eccrine syringomas occur on the lower eyelid skin in some individuals, and such patients must understand that these blemishes will not be eliminated by blepharoplasty. Pigmented lesions (seborrheic keratoses, lentigines, etc.) are also common on the lower lid.

Hypertrophy of the orbicularis muscle is particularly common in the Asian lower lid, often producing an unaesthetic infraciliary bulge at an early age. Such patients must be counseled regarding the differences between puffiness caused by fat protrusion and orbicularis hypertrophy, as well as the aesthetic and technical limitations of partial muscle resection.

The puffiness of the Asian lower lid may tempt the surgeon to recommend a transconjunctival approach. However, many if not most Asian patients are firmly convinced that "too much skin" is a component of their problem, and thus dissatisfaction often follows with an operation that does not remove skin. This observation, coupled with the fact that transconjunctival blepharoplasty does not allow modification of orbicularis hypertrophy, makes the skin/muscle flap approach the procedure of choice for most patients, except perhaps the very young patient with no concern about skin excess or men whose only request is elimination of "bags" resulting from periorbital fat protrusion.

To achieve maximum esthetic results in skin/muscle flap blepharoplasty, the surgical plan must address all components of the lower lid "deformity," that is, skin excess and laxity, orbicularis hypertrophy, periorbital fat protrusion, and, occasionally, bone (prominence of the infraorbital rim) as determined by preoperative analysis. The skin/muscle flap approach provides excellent access to all eyelid components, the relative importance of which varies from patient to patient, necessitating individualization of the procedure.

Perhaps the most important consideration in lower lid blepharoplasty is preservation (or reinforcement) of the structures that provide critical support for the lid. Even the most accomplished and experienced surgeon must deal with the problem of lower lids whose posture was normal in the immediate postoperative period but descend relentlessly into a more inferior, aesthetically unattractive position as the healing process continues. Such lower lid malposition is frequently referred to as *ectropion*, which is attributed to excessive skin excision. However, the majority of such situations are a consequence of a process termed *retraction* (or vertical shortening) of the lower lid. The true pathologic basis of retraction is fibrosis in the plane of the middle lamella (orbital septum and capsulopalpebral fascia, often also involving the posterior aspect of the orbicularis oculi). This results in scar contracture and vertical shortening of this plane that overwhelms the often tenuous supporting structures of the lower eyelid, which are further compromised by the surgical procedure. In contrast, frank ectropion is related to shortening (whether by scar contracture or, more commonly, overzealous tissue resection) of the anterior lamella (skin and orbicularis oculi). Of course, retraction and ectropion may coexist.

The lower eyelid derives support from both static and dynamic mechanisms. Static support is provided by the tarsal plate and associated medial and lateral canthal tendons, whereas the dynamic component consists of the action of the pretarsal component of the orbicularis oculi that is firmly attached to the tarsus. Lower lid position is determined by the balance (Fig. 28–12) between the supporting structures and the forces tending to displace the eyelid inferiorly (i.e., gravitational and cicatricial forces subsequent to surgery or trauma). The surgeon must be cognizant of the fact that the static supporting mechanism is gradually attenuated by the aging process, whereas dynamic lid support is easily compromised during surgery. The key to success in lower lid blepharoplasty, therefore, is to incorporate measures designed to preserve and reinforce or reconstruct lower lid support into each and every blepharoplasy procedure. A five-point program for lower lid blepharoplasty is a valuable concept in this regard and has proven a reliable method of reducing the incidence of lower lid retraction.

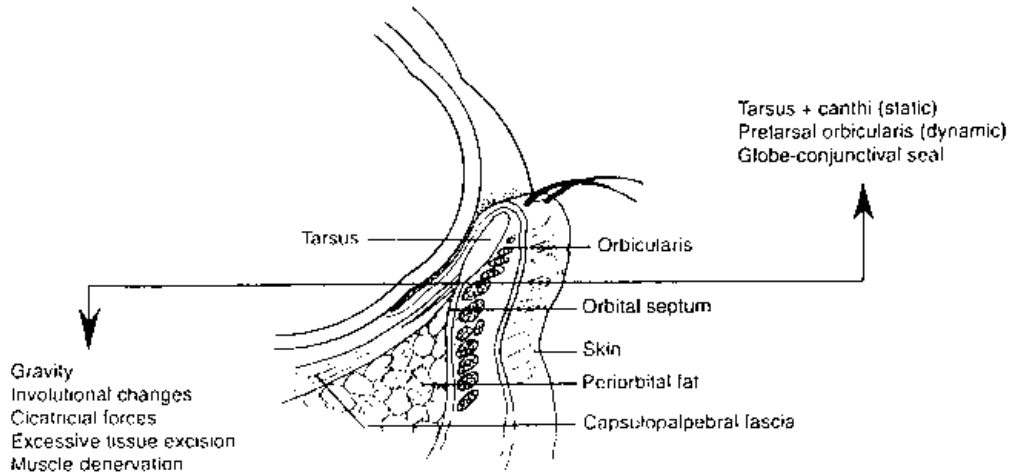

Figure 28–12 Opposing forces that determine lower lid position. (From McCurdy JA. *Cosmetic surgery of the Asian face.* New York: Thieme Medical Publishers, 1990. With permission.)

Operative Technique

The Five-Point Program for Skin/Muscle Flap Lower Lid Blepharoplasty

1. The lateral extensions of the skin incisions should be placed as horizontally as possible (in a horizontal periorbital line, i.e., not inclined inferiorly) to minimize the tendency for lateral canthal rounding and inferior displacement that may result from postoperative scar contracture in this area.
2. As the pretarsal segment of the orbicularis muscle, which is adherent to the tarsal plate, provides an element of dynamic support for the lower lid, the surgeon should ensure that a generous strip of this muscle remains adherent to the tarsus. This can be accomplished by completely undermining the skin/muscle flap via the lateral aspect of the lower lid incision. The infraciliary portion of the incision is then completed and a 3- to 4-mm skin flap developed. This abbreviated skin is then connected with the skin/muscle flap by incising the orbicularis muscle with a diagonally oriented scissors, thus preserving an adherent muscle strip on the tarsus.
3. When determining the amount of tissue to be excised from the skin/muscle flap, the flap is draped over the ciliary margin in a superior and medial direction, as opposed to the superior and lateral direction usually recommended. This offers several advantages, perhaps the most important of which is the absence of concentrated tension in the lateral aspect of the wound. A concentration of tension in this area creates force vectors that predispose to inferior and medial displacement postoperatively, resulting in intercanthal shortening producing the "sad eye" or "hound dog" look. This is of particular importance in patients in whom the lateral canthal tendon and tarsus have been attenuated by the aging process. Laterally directed traction of the flap may also contribute to the accentuation of lateral periorbital lines often noted following blepharoplasty. An additional advantage of medial draping of the flap is minimization of the length of the lateral aspect of the incision as it is not necessary to "chase a dog ear" laterally.
4. Prior to skin closure, a permanent suspension suture of 5.0 nylon is placed between the deep surface of the orbicularis muscle and lateral orbital periosteum. It is important to suspend the muscle at the level of the lateral canthus and to avoid excessive tension on the flap that might cause buckling of the tarsus on suture failure due to tearing through the orbicularis muscle. Orbicularis suspension reinforces static support of the lower lid and assists in resisting cicatricial forces that produce inferior lid displacement postoperatively.
5. 0.2 cm^3 of triamcinolone (10 mg/cm^3) is infiltrated into the plane of the orbital septum (middle lamella) prior to skin closure. This has proven to be of considerable benefit in combating the forces of contracture and greatly reduces the incidence of postoperative induration that generally precedes the onset of clinical lower lid retraction. Perhaps the most persuade argument for routine use of steroid in lower lid blepharoplasty relates to the observation that accumulation of small amounts of blood in the middle lamellar plane is a common etiologic factor in the pathogenesis of lower lid retraction, blood being a potent precipitator of fibrosis. Such blood accumulation may develop even following the most meticulous hemostasis; thus, its occurrence is entirely unpredictable.

The five-point operative plan is recommended for all patients undergoing lower lid blepharoplasty who demonstrate no preoperative risk factors predisposing to postoperative lower lid malposition. Those with preexisting lid laxity (a condition noted much less frequently in the Asian than Caucasian lid) are candidates for other ancillary techniques (i.e., tarsal suspension, etc.) performed in conjunction with the blephroplasty procedure.

Although a thorough understanding of structural and functional anatomy coupled with meticulous attention to detail during the operative procedure are the keys to success in all facial plastic surgery, they are of particular importance in eye-

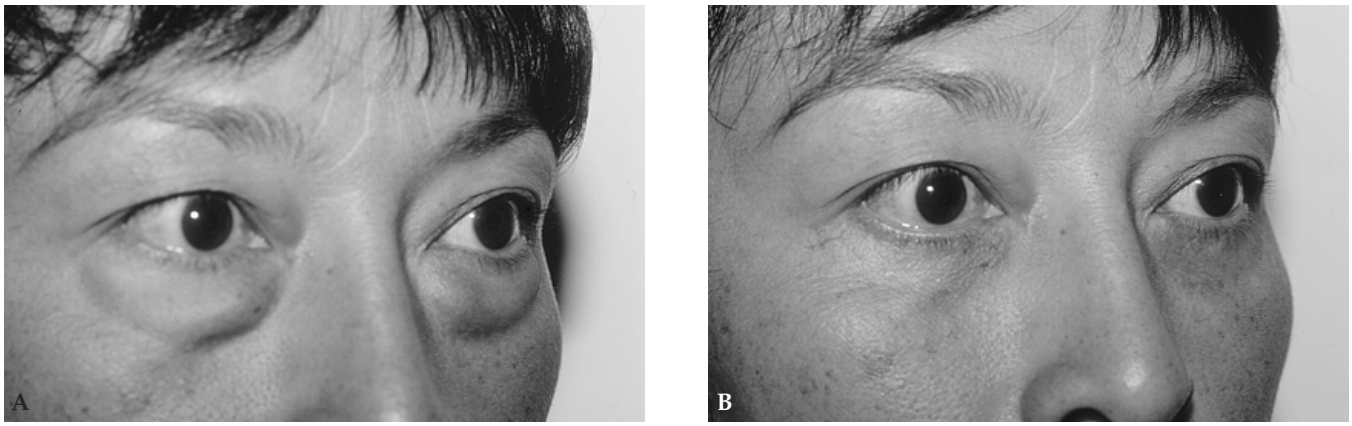

Figure 28–13 Lower lid blepharoplasty. **(A)** Preoperative and **(B)** postoperative views.

lid operations as a myriad of structures having both functional and aesthetic significance are densely packed into a small area. Surgical intervention in the eyelids must be precise and deliberate if the beauty and expressiveness of the eyes is to be enhanced, preserved, or reconstructed (Fig. 28–13).

AUGMENTATION RHINOPLASTY

The goal in aesthetic rhinoplasty of the Asian nose is similar to that in Occidental rhinoplasty: creation of a strong, smooth, natural dorsum exhibiting a prominent origin at the nasion but not competing with the tip as the leading point of the nasal profile. A delicate, well-defined, refined lobule with definite columellar "show" and an oblique anteroposterior orientation of the nares constitute an equally important but seldom emphasized goal.

The characteristic anatomy of the Asian nose requires that the surgeon plan an augmentation procedure rather than reduction rhinoplasty, and augmentation rhinoplasty is requested with increasing frequency in areas with large Asian populations. Although it might be assumed that the popularity of this operation reflects a desire for westernization, it should be noted that in many Asian cultures, the high, narrow nasal bridge is an aesthetically desirable feature, a fact of which the surgeon must be cognizant in preoperative counseling and planning.

Historically, many materials have been employed to augment the Asian nose. At the present time, Western surgeons tend to prefer autogenous material, whereas in the Orient, use of silicone implants predominates. Many Western surgeons preach against the use of alloplastic nasal implants with evangelical fervor, apparently ignoring the fact that the long-term results using this material in the Asian nose have been excellent. The incidence of infection, displacement, or extrusion is substantially lower than would be expected on the basis of experience in augmentation of the non-Asian nose with solid implants. The reasons for this tolerance are unknown but may be related to greater thickness of skin and subcutaneous tissue generally noted in the Asian nose. As with other cosmetic procedures, complications are usually attributable to technical error rather than an inherent problem with the operation and implant composition itself. Although the basic principle that autogenous material, when available, is preferable to alloplastic implants is valid, many Asian patients are unhappy with the results of nasal augmentation using autogenous cartilage and bone as satisfactory sculpturing of the lobule is often not achieved. Techniques of tip rhinoplasty that are highly successful in the Caucasian nose are frequently unsatisfactory in the Asian because the attenuated lower lateral cartilages alone are not strong enough to accentuate tip projection and support, and the lobular skin and subcutaneous tissue is too thick to reflect sculpturing of the delicate cartilage. Thus, if tip projection is to be enhanced, the surgeon must reinforce or buttress lobular cartilage with cartilage grafts.

Asian craftsmanship, renowned throughout the world, is characterized by a pragmatic concern for function coupled with a keen eye for beauty and symmetry along with meticulous attention to detail. Augmentation rhinoplasty using silicone implants has been refined by conscientious, experienced, and well-trained Asian surgeons, and any temptation to label such procedures as inherently dangerous or unreliable should be tempered with respect for the experience and accomplishments of our colleagues in the East. Evolution in the technology of silicone implants has continued as softer grades of silicone elastomer have become available for implant fabrication. Softer implants are inherently more flexible, resulting in reduced tension at the implant–tissue interface, which translates to a substantial reduction in problems that may develop as a consequence of pressure on the nasal skin.

Although frustration over the dissatisfaction of Asian patients with the results of tipplasty using techniques that produced excellent results in the Caucasian nose led me to begin exploration of the possibilities of alloplastic implants in sculpturing the entire nose as opposed to the dorsum alone, there is no question that in some noses only subtle augmentation of the dorsum is required. In such cases, autogenous cartilage or alloplastic materials, such as mersaline mesh or Gore-Tex, are viable alternatives to silicone implants in these patients. The decision to use autogenous or alloplastic material is individualized according to the desires

of each patient with regard to the extent of lobular sculpturing and dorsal augmentation. Anatomic factors, such as skin thickness and configuration of the lower lateral cartilages, assist in determining the type of procedure to be employed. Thin lobular skin constitutes a relative contraindication to the use of silicone implants. Given the current social and medicolegal environment, feelings of individual patients regarding use of foreign materials in the body must be factored into the equation.

In the final analysis, surgeons experienced in augmentation of the Asian nose generally conclude that contemporary silicone implants provide the best aesthetic solution for most patients who desire increased lobular definition or tip projection in conjunction with dorsal augmentation.

Preoperative Considerations

It is of the utmost importance that the candidate for augmentation rhinoplasty completely and carefully communicate the specifics of the nasal transformation that is desired. Many Asian patients assume that the surgeon knows best and will automatically adapt to the surgeon's specifications. If communication between patient and surgeon is unclear or imprecise, disappointment may ensue regarding such matters as dorsal height, lobular configuration, and tip projection. The surgeon must determine whether the patient wants the tip to be narrow or relatively broad. Is the desired nasion wide or narrow? Does the patient wish the dorsal profile to be straight or slightly convex? Pre- and postoperative photographs of various augmentation rhinoplasty procedures are often helpful in this regard. It should be stressed to the patient, however, that a surgeon cannot promise to construct the nose to exact specifications or guarantee that the nose will demonstrate the precise configuration of a photograph.

The goals, limitations, and possible complications of surgery are thoroughly discussed. Language barriers and preconceived notions on the part of the patient regarding the goals and limitations of the procedure should be recognized and addressed during preoperative consultation.

Surgical Technique for Alloplastic Implants

Augmentation rhinoplasty is generally performed under local anesthesia in an office operating suite. An oral cephalosporin or its equivalent is initiated on the evening prior to surgery and antibiotic prophylaxis continued for 3 days postoperatively.

1. Access to the dorsum and lobule is obtained via a marginal incision that extends into the columella (Fig. 28–14). Dissection of a precise midline pocket is facilitated by initiating the dissection via the columellar portion of the incision. The lower lateral cartilages are freed from the lobular skin but are not otherwise modified as the implant will rest on their anterior surfaces.
2. The silicone implant is not premeasured but is individually tailored at the time of surgery. This tailoring is accomplished by placing the implant into the dorsum, determining its effect, and then removing it for modification as indicated by the desires of the patient as well as the aesthetic sense of the surgeon.

Figure 28–14 Marginal incision used for augmentation rhinoplasty.

3. A columellar strut is always utilized as it stabilizes the proximal portion of the implant in the midline, thus decreasing the incidence of postoperative instability or "wobbling" and resultant asymmetry. It is important to understand that the function of the columellar strut is not to thrust the tip anteriorly; thus, the strut does not extend to the nasal spine. Overzealous attempts to enhance tip support with a strut are ill-conceived maneuvers that markedly increase the incidence of implant extrusion.
4. The distal end of the dorsal implant terminates at a point halfway between the interbrow and intercanthal lines and should be sculptured to blend inconspicuously with the nasion so that it is not readily palpable. The nasofrontal angle must be preserved.
5. If the surgeon experiences difficulty freeing both lower lateral cartilages via a single marginal incision, a similar incision should be made on the opposite side to ensure symmetrical placement of the implant in the lobular area. The subcutaneous pocket should be of generous size. If resistance is encountered on placing the implant, the pocket is too small and should be enlarged to prevent excessive tension on the nasal skin. If a small dorsal hump is present, it is generally easier to rasp the dorsum than to modify the implant to accommodate this hump.
6. Following satisfactory placement of the implant, the nasal alae are analyzed and, if necessary, an alar reduction procedure is performed.
7. Some patients may benefit from narrowing of the nasal pyramid achieved by lateral osteotomy.
8. Occasionally, a nose may require reduction of lobular bulk by excision of lower lateral cartilage and lobular subcutaneous tissue. If indicated, this is best performed via a separate cartilage-splitting incision executed following implant placement and suturing of the marginal incision.

Implant Configuration

The nasal implant that I recommend for routine use differs from other commercially available implants primarily in its columellar aspect (Fig. 28–15). The columellar strut has two

Figure 28–15 Design of a silicone nasal implant (see text).

functions: (1) stabilization of the proximal segment of the implant in the midline which results in resistance to displacement and subsequent malposition; (2) sculpturing the columella, i.e., displacement of the typically retracted columella inferiorly, thus increasing its "show." If hard elastomer is utilized for the columellar strut, it can be relatively short and thin, as the firm material is resistant to deformation by columellar tension. The fibrous capsule that naturally forms around the implant often exerts a rotational force on the implant, resulting in lateral displacement of the strut with resultant perforation in the vestibular aspect of the columella, that is, the incision (the most common site of implant extrusion). These rotational forces are less likely to be transmitted to a columellar strut fabricated from a soft elastomer because of the flexibility at the lobular–columellar junction of the implant. However, this flexibility results in superior deformation of the strut (by columellar tension) unless the strut has sufficient breadth to allow it to be wedged between the caudal septal cartilage and columellar skin. During surgery, the flared columellar strut is carefully trimmed so that it is wedged between the skin and caudal septum at the most anterior point that allows aesthetically sufficient inferior displacement of the columella (producing columellar show).

The inferior inclination (angulation) of the columellar strut with respect to the dorsal component assists in achieving this goal. (Other commercially available nasal implants are constructed so that the columellar strut projects at a 90-degree angle from the dorsal component.)

Following final trimming, the columellar strut never extends posteriorly for a distance greater than 75% of the length of the columella. Allowing the strut to contact the nasal spine results in a "tent pole" effect—an invitation to disaster in the form of implant extrusion secondary to pressure necrosis of the lobular skin. Always remember that the function of the columellar strut is not to project the lobule in a tent pole fashion. Lobular projection is achieved by the sheer volume of the rounded, slightly elevated (i.e., mound) lobular component, in a fashion similar to the cantilever effect of bone grafts utilized for total nasal reconstruction.

Because of complaints that clear silicone implants may be visible through the nasal skin under bright indoor lighting, the implant should be a neutral color (i.e., beige). Like other commercially available implants, soft elastomer is used for fabrication of the implant described previously.

Complications

Asymmetry as a consequence of improper placement of the implant or subsequent displacement of its distal aspect is the most common complication of augmentation rhinoplasty in the Asian nose. In the early postoperative period, apparent asymmetry may merely be the result of edema. Slight asymmetry is often successfully managed by instructing the patient in manipulation of the distal aspect of the implant. If noticeable asymmetry persists, however, correction can only be effected by removal and replacement of the implant.

Infection requires immediate removal of the prosthesis. Antibiotic therapy is initiated and continued according to the results of culture and sensitivity studies. The infection resolves rapidly, following which subsequent augmentation with the same implant can be performed. Although many surgeons recommend deferring revision surgery for 6 to 12 weeks, if thinned, stretched skin in the lobular region is not supported within 2 weeks of implant removal, contraction will commence, resulting in a cutaneous dimple that is difficult to efface. Support of the thinned skin is often best achieved by interposition of morselized autogenous cartilage between the prosthesis and the dermis.

Delayed extrusion is the most worrisome complication of augmentation rhinoplasty in the Asian nose. The incidence of this complication is extremely low and is generally a consequence of technical error. Perhaps the most common reason for delayed extrusion is excessive tension in the lobular region secondary to ill-conceived attempts to enhance tip projection with a columellar strut. The surgeon must be conservative in attempts to increase tip projection and explain the reasons for this conservatism to each patient. The incidence of delayed extrusion is also reduced by ensuring that the implant does not fit too snugly in the dorsum, thus reducing tension at the host–prosthesis interface. Extrusion is also reduced by the presence of a columellar strut as this reduces instability or postoperative wobbling of the proximal aspect of the implant.

Impending extrusion is suggested by progressive thinning of the lobular skin. If recognized at an early stage, salvage of the implant can often be achieved by prompt removal. The implant is sculptured to a smaller size; a dermal, temporalis fascia, or crushed cartilage graft secured over the lobular component, and the implant replaced in the existing nasal pocket.

Remember that the major goals of rhinoplasty in the Asian nose include augmentation of the nasal dorsum in conjunction with refinement of the lobule. Although various materials, as noted previously, may be used to achieve these goals, individually sculptured solid silicone implants are presently the most commonly used prostheses. Some surgeons currently advocate the use of cartilage grafts to enhance tip projection while continuing the use of silicone implants for dorsal augmentation. Although I remain firmly convinced of the advantages of silicone implants because of their proven efficacy and reliability (as well as for their cost to benefit ratio), I applaud the efforts of those surgeons exploring the possibilities of more successful use of autogenous materials in the Asian nose. Although recent reports suggest that long-term survival of cartilaginous grafts of the onlay type in the nose is excellent, consider that the fate of columellar struts, which are subjected to stresses of a different magnitude, may well be different. Is it significant that proponents of such grafts recommend "overcorrection"?

The surgeon should be conservative in selection of implant size, remembering that subtle enhancement often produces substantial aesthetic benefit. Conservatism is of utmost importance in attempts to enhance tip projection as excessive tension on the lobular skin is a prime factor in delayed extrusion of alloplastic implants. Infection is a secondary cause of implant extrusion; such abscesses most commonly develop in the columellar region (Fig. 28–16) but can occur over any portion of the implant.

Successful aesthetic rhinoplasty in the Asian nose requires knowledge of anatomic variables, appreciation of nasal aesthetics and social and cultural concerns, thorough preoperative evaluation and patient counseling, along with careful attention to detail.

Careful and considered use of silicone implants in augmentation rhinoplasty offers facial plastic surgeons an opportunity to utilize their aesthetic senses to the fullest extent, enabling them to produce dramatic changes in nasal appearance (Fig. 28–17). When such surgery is properly planned and

Figure 28–16 Impending exposure of columellar strut.

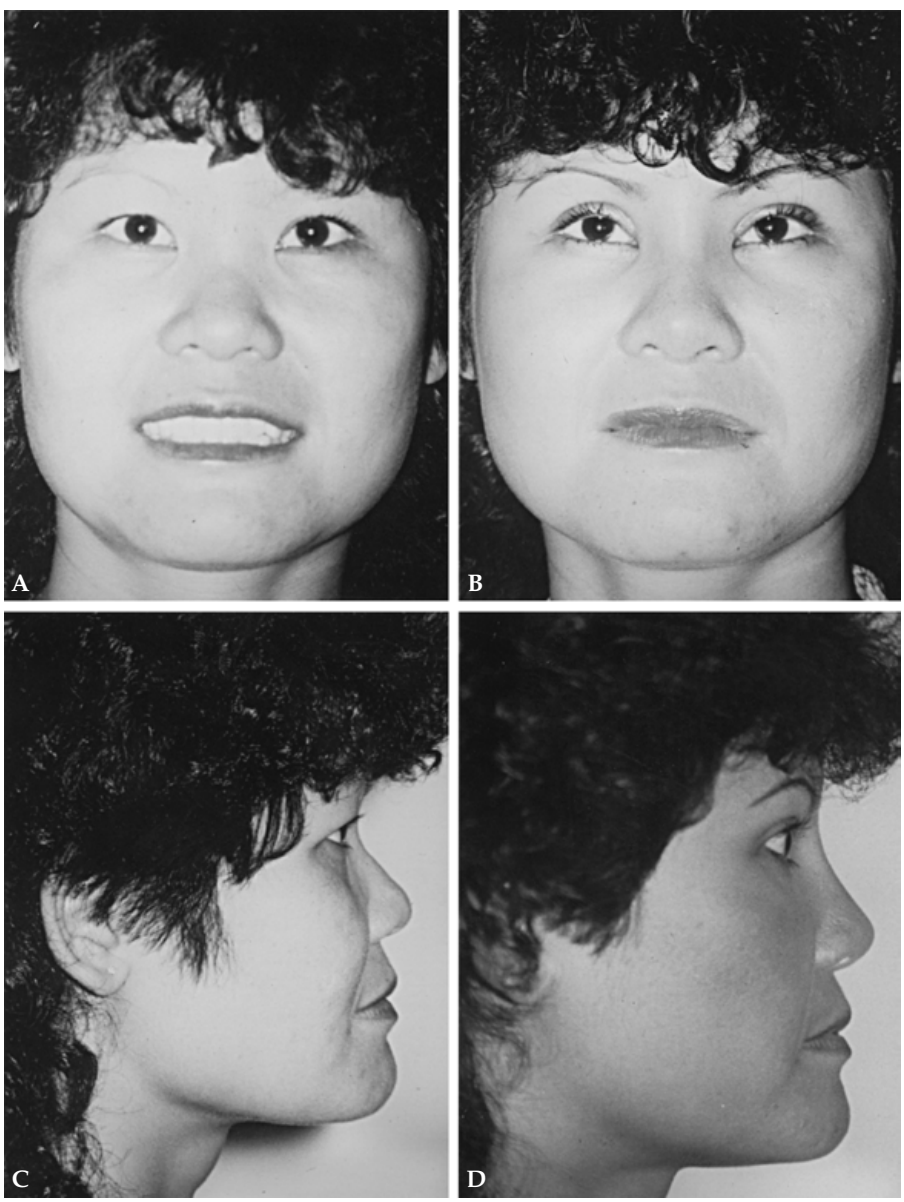

Figure 28–17 Pre- and postoperative photographs demonstrating the results of augmentation rhinoplasty using a silicone implant.

executed, the incidence of complications is low. It must be reemphasized that complications following augmentation rhinoplasty with alloplastic implants are usually the result of technical errors and are not due to inherent deficiencies in the operation or implant composition per se. A thorough understanding of the basic principles and important safeguards when using such materials in the nose is essential for successful surgery.

MAXILLARY IMPLANTS

Bimaxillary protrusion resulting in relative depression of the midfacial region is a relatively common characteristic of the Asian face, often being accentuated by an anterior inclination of the maxillary incisors. With increasing age, such a midfacial configuration tends to be associated with deepening of the nasolabial folds.

Although correction of this facial disproportion is an aesthetically rewarding procedure, the number of patients who are willing to undergo a relatively simple corrective operation is amazingly small.

Correction of midfacial retrusion can be effected by using either silicone or mersaline mesh implants. Mesh implants can be placed via an intranasal approach for correction of small degrees of retrusion, but the intraoral approach affords better visualization for correction of larger "deformities."

The implant is placed in a supraperiosteal plane via a vertical transfrenular sublabial incision. When mesh implants are utilized, the lateral aspect of augmentation extends beneath the origin of the nasolabial fold.

Preformed silicone premaxillary implants (Guinta design) are available in two sizes. Regardless of the size selected, these implants usually require further sculpturing to fit individual facial anatomy (Figs. 28–18 and 28–19).

Figure 28–18 Preformed silicone premacillary implant (Guinta design) placed via a sublabial approach.

CERVICOFACIAL RHYTIDECTOMY

Anatomic Considerations

Although the goals of facial rejuvenation are identical in both Caucasians and Asians, anatomic variations as well as differences in the aging process justify some modification in the planning and execution of the operative procedures utilized to achieve these goals. Differences between the Caucasian and Asian face are manifested in skin thickness and texture, patterns of fat accumulation, and, perhaps most importantly, skeletal structure. When considering these anatomic differences, it is important to note that just as in the Caucasian, considerable individual variations in anatomy exist among the various Asian populations.

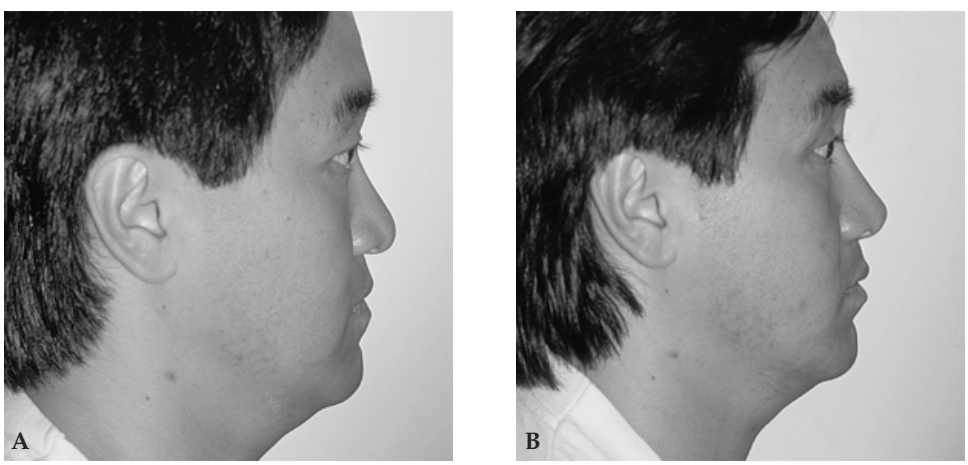

Figure 28–19 Pre- and postoperative photographs illustrating the results of maxillary augmentation using a silicone implant.

Skin

A wide variation in skin texture and thickness exists among Asians, the dermis being thicker and more fibrous in individuals with darker pigmentation. This greater collagen density is manifested in a tendency to more vigorous fibroplasia during wound healing, which may result in hypertrophic scarring or prolonged erythema during scar maturation. This observation also applies to more lightly pigmented Asian faces. In surgery for facial rejuvenation, hypertrophic scarring is most common in the postauricular regular region and occurs occasionally in the inferior aspect of the temporal incision. Frank keloid formation is unusual.

Fat

During the aging process, the Asian face typically accumulates a greater volume of fat than the Caucasian face. Such fat accumulation tends to be concentrated in the jowl, cheek (naoslabial mound), and buccal regions. The clinical significance of such fat accumulation is often enhanced by skeletal deficiency of the midface, accentuating the "cheeky" appearance. However, fat accumulation in the neck producing the so-called double chin is less common in younger Asians than in their Caucasian counterparts, but becomes more common in the aging Asian face.

Platysma Muscle

Although the platysma muscle is generally thicker in the Asian neck than in the Caucasian, the incidence of diastasis is considerably less, occurring in approximately 30% of patients who undergo cervicofacial rhytidectomy as compared with an approximately 60% of Caucasians undergoing the procedure.

Skeletal Structure

Perhaps the most significant anatomical differences between the Caucasian and the Asian face are related to skeletal structure. The Asian face is characterized by prominent malar eminences associated with relative deficiency of the maxillary region, resulting in shallowness of the midfacial area. Wide, prominent mandibular angles are often noted, contributing to a square, fat appearance of the face. Microgenia is less common than in the Caucasian face, as is the cervical deformity attributed to low hyoid placement.

Cervicofacial Rhytidectomy

The basic procedure for cervicofacial rhytidectomy is essentially the same for both the Asian and the Caucasian. However, special attention, must often be directed to the midface. As a consequence of fat accumulation and skeletal deficiency, ptosis of the malar fat pad of the midface produces especially prominent nasolabial mounds and deep nasolabial folds. Although any recent innovative surgical procedure designed to correct midfacial ptosis can be utilized, I have found that a direct approach to subperiosteal dissection of the midface that can be performed via the exposure of a standard cheek flap (i.e., obviating the necessity to initiate subperiosteal dissection through a coronal approach) allows excellent, often dramatic rejuvenation of the face (Fig. 28–20).

Surgical Technique for Direct Subperiosteal Dissection of the Midface

If subperiosteal dissection of the midface is to be performed, the temporal aspect of the incision is extended superiorly to a level superior to the lateral brow. Skin undermining begins in

Figure 28–20 Cervicofacial rhytidectomy. **(A)** Preoperative; **(B)** postoperative.

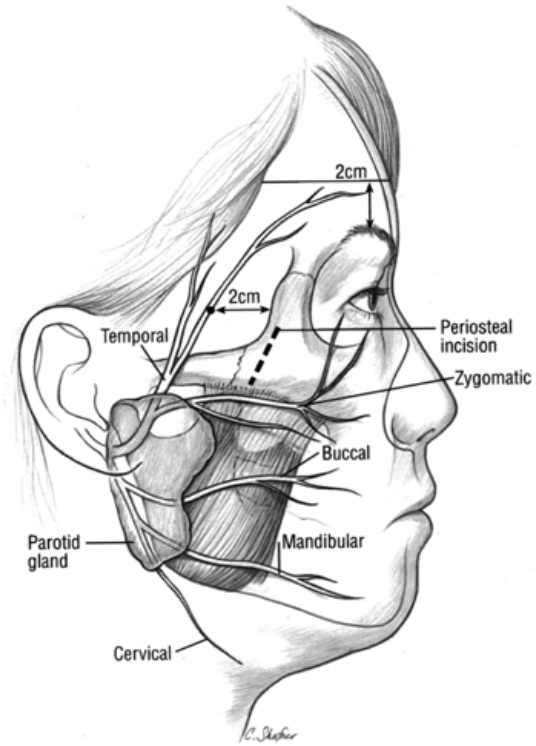

Figure 28–21 Constant anatomic relationships of the temporal and zygomatic branches of the facial nerve.

the temple in the subdermal plane at a level sufficiently deep to preserve hair follicles. Dissection at this level (i.e., superficial to the superficial layer of temporal fascia rather than deep to this fascial layer) provides additional protection for the temporal branch of the facial nerve. Undermining extends anteriorly to the lateral aspect of the brow, the lateral temporal region, and 1 cm anterior to the anterior border of the masseter muscle. The dissection then extends over the mandibular margin to join the cervical flap.

Attention is then directed to the midfacial region. The anatomic foundation of this simplified approach to subperiosteal dissection of the malar fat pad/zygomatic muscle complex relates to the constant relationship between the temporal and zygomatic branches of the facial nerve in this region (Fig. 28–21). Initiation of the subperiosteal dissection just posterior to the junction of the zygomatic body of frontal process of the zygoma ensures that both branches are protected. The subperiosteal dissection proceeds inferiorly and medially into the canine fossa toward the pyriform aperture beneath the nasolabial fold. The key to successful mobilization and elevation of these tissues is release of this composite flap (Fig. 28–22) from its attachments to the tendinous anterior aspect of the masseter, easily and safely accomplished by blunt dissection. Should flap mobilization prove difficult, the tendency on the part of the inexperienced surgeon would be to extend dissection medially. Such dissection, however, proves fruitless. Additional flap mobilization can only be obtained by dissection more posteriorly along the zygoma and inferiorly along the tendinous portion of the masseter muscle. Additional subperiosteal section along the body of

Figure 28–22 Dissection of the subperiosteal malar flap.

the zygoma ensures that all fibers of the zygomatic ligament are released. Approximately 1 to 1.5 cm of posterosuperior, composite flap advancement is then possible, resulting in effacement of the nasolabial fold and repositioning of the malar fat pad in a more youthful position (Fig. 28–23). The flap is imbricated, being fixed to the superior aspect of the original flap incision (to avoid strangulation of more superiorly located facial nerve branches) with two or three sutures of 3.0 nylon (to provide "permanant" fixation) supplemented with 4.0 polydioxanone.

Because of the extensive mobilization and elevation of the midfacial region, the skin flap must be dissected to the level of the orbital rim to avoid bunching. Such dissection allows exposure and modification of the orbicularis muscle, if indicated. In some patients, the midfacial skin is dissected over the malar region and to the nasolabial fold to enhance draping of the skin flap. Although subperiosteal dissection of the midface may benefit by this increased skin undermining, tension on the skin flap is actually reduced by prior advancement or suspension of the composite flap. This is in marked contrast to the extraordinary tension placed on the skin flap by advocates of the deep-plane or composite facelift operations who utilize the skin as a vehicle for advancement of the malar fat pad.

Because the nasolabial fold has been effaced by the composite malar flap, wide Superficial Musculo Aponeurotic System dissection toward the central face is unnecessary.

Considerable improvement to the jowl region is often achieved by spot liposuction of jowl fat via a stab wound in the labiomental fold utilizing a 14-gauge needle cannula (Fig. 28–24). Maximal effacement of the jowl may require skin flap elevation to the oral commissure to reduce the tethering effect of the mandibular ligaments.

Segmental Operations for Correction of Cheek and Temple Ptosis

Many Asian patients demonstrate manifestations of aging in the facial area that are not associated with the problems in the cervical region. Management of cheek ptosis and fat accumulation without associated neck fullness or redundancy can be managed successfully with a cheeklift operation, the incisions for which are illustrated in (Fig. 28–25). This procedure is not a

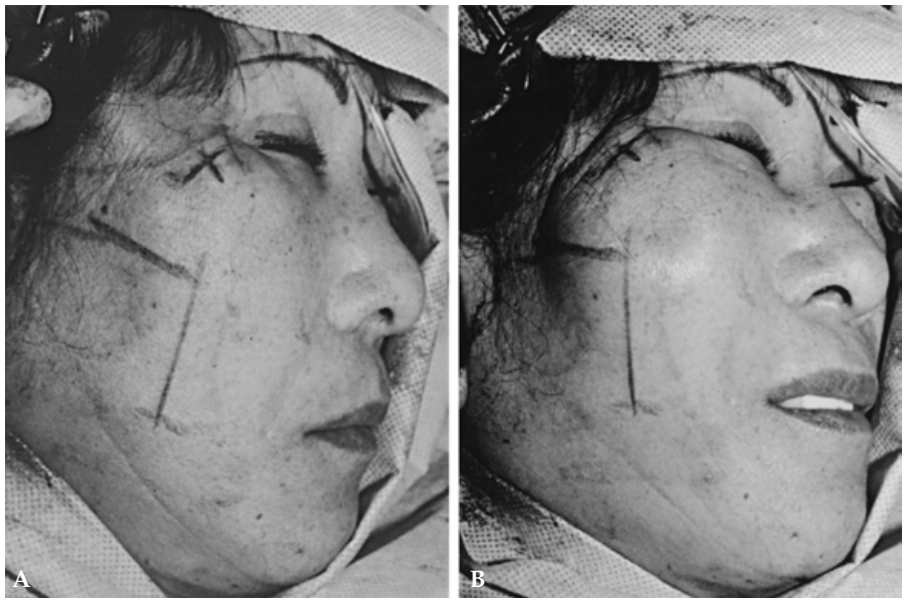

Figure 28–23 Interoperative traction on subperiosteal malar flap demonstrating the extent of cheek mobility possible.

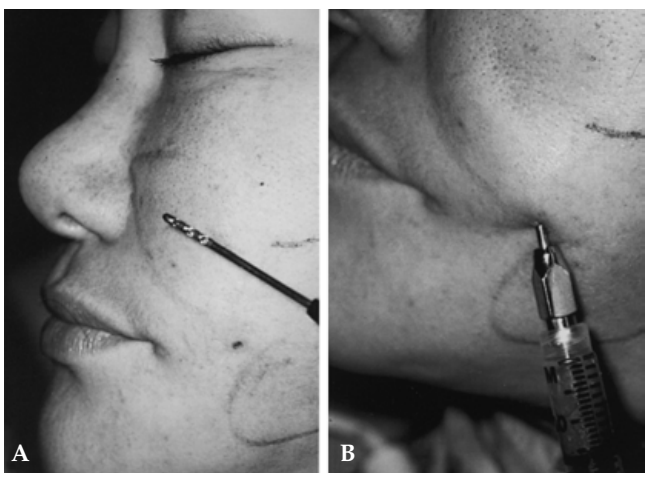

Figure 28–24 Spot liposuction of the jowl and nasolabial mound.

Figure 28–25 Cheeklift incision.

"minilift" as it involves considerable skin undermining, most often accompanied by subperiosteal dissection of the midface described previously. The results of such procedures (Fig. 28–26) are often enhanced by spot liposuction of the jowl and nasolabial mound using a syringe technique (Fig. 28–24).

If indicated, the temporal aspect of the cheeklift incision can be extended superiorly, resulting in another segmental operation termed the cheek/temple lift.

Complications Following Facial Rejuvenation Surgery

Complications of these operations are identical to those occurring after surgery in the Caucasian face (i.e., bleeding, hematoma, infection, scar formation, flap necrosis, hair loss, nerve injury, and asymmetry).

Older Asian patients tend to exhibit a high incidence of hypertension; thus, the surgeon should ensure that adequate control of blood pressure has been obtained preoperatively. As is true in Caucasians, hematoma is more common following facelift procedures in men.

Flap necrosis is somewhat less common in Asians because of the increased thickness of their skin. The incidence of hypertrophic scarring is, however, higher in this group. Such scars occur most commonly in the postauricular region but occasionally manifest themselves in the preauricular and temporal areas. In most cases, satisfactory management of hypertrophic scarring is achieved with intralesional steroid injections.

Figure 28–26 Cheeklift. **(A)** Preoperative; **(B)** postoperative.

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Chapter 29

Aesthetic Surgery of the Lip

Brian P. Maloney

Lips not only serve a very significant functional role, such as in speaking and eating; they are an important aesthetic feature of the face. Full lips imply youth, health, and strength. Because of society's quest for these attributes, the number of lip procedures has increased dramatically as people strive to achieve these goals. Cosmetic surgeons now have the ability to enlarge, reduce, refine, shorten, and lengthen lips in accordance with patients' goals. This chapter reviews the embryology, anatomy, aesthetics, and goals of lip surgery. The chapter concludes with a description of many contemporary lip procedures.

LIP EMBRYOLOGY AND ANATOMY

An understanding of the embryology of lips serves as a foundation for understanding the basis behind the multitude of lip surgeries currently performed. The upper lip forms during development from two distinct pairs of structures: maxillary swellings and medial nasal swellings. The lateral maxillary swellings fuse with the paired medial nasal swellings to form the upper lip. Thus, the characteristic undulations of the philtral ridge and cupid's bow reflect the union of these different structures (Fig. 29–1). The lower lip forms from the merger of the paired mandibular swellings, resulting in a simpler and less defined structure. Because of the embryologic difference, the upper and lower lips function very differently from one another. The upper lip tends to be much more mobile than the lower lip.

The defining points of the upper lip rest in the central cupid's bow complex. This complex is formed by the two high points of the vermilion lying along each philtra ridge with a "V"-shaped depression between them (Fig. 29–2). The greatest vermilion show of the lower lip lies on parallel points to the upper lip with no central depression. Another characteristic feature of the lips is the presence of the white line or roll. This structure is a raised line of skin, which separates the vermilion from the cutaneous portion of the upper and lower lip. Its function is unknown; however, Giles hypothesized that the white roll serves as a reservoir of skin that allows the lip to perform its many complex motions, such as puckering, smiling, talking, and eating.

The cutaneous portion of the skin contains hair, sebaceous glands, and eccrine glands. The vermilion of the lips is red due to a lack of keritinization and the underlying capillary plexus. The lip vermilion is composed of a dry and a wet portion. The dry mucosa is exposed to the air and is generally the visible vermilion of the lip. It borders the cutaneous portion of the lip anteriorly and is separated from the wet mucosa posteriorly by the wet line.

The bulk of the lip consists of the orbicularis muscle. The vermilion and adjacent cutaneous portion is separated from the

Figure 29–1 A 6-month-old child highlights the embryologic difference between the upper and lower lip.

Figure 29–2 Oblique view of the lips showing a well-defined white roll, central tubercle, and cupid's bow area.

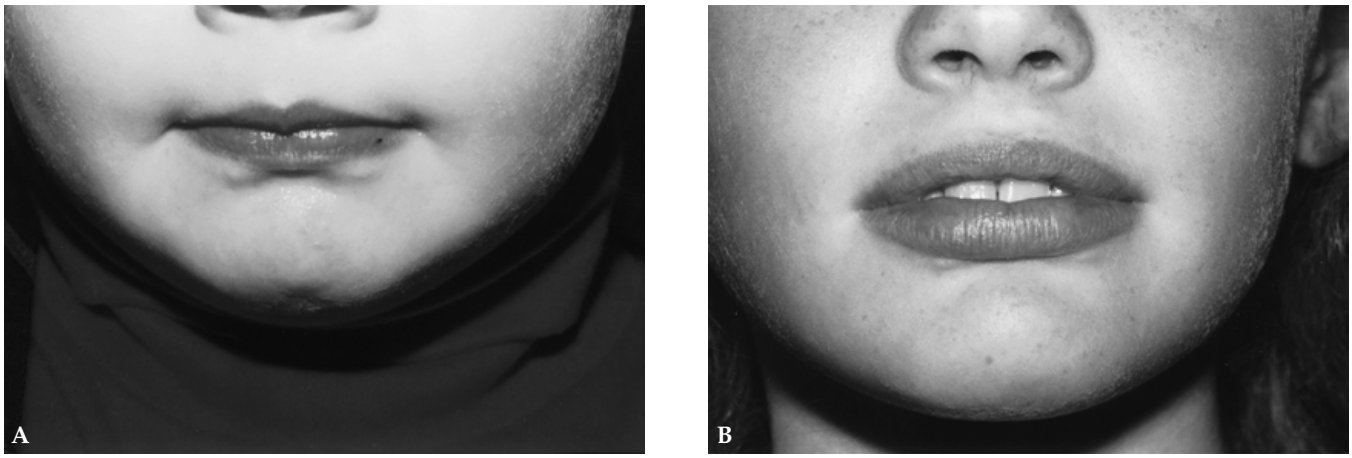

Figure 29–3 **(A)** A 3-year-old girl showing well-defined lip shape. **(B)** Same child 6 years later showing the hypertrophy of the lip tissues resulting in aesthetically full lips.

underlying muscle by a thin fascial layer. In the center of the upper lip the orbicularis fibers decussate and insert into the contralateral philtra ridge. The commissure of the lips represents a complex area where the orbicularis muscle decussates and the lip elevators, lip depressors, and the buccinator muscle join.

LIP AESTHETICS

There is no ideal standard for the perfect lip. Everyone has a different concept of what constitutes a beautiful lip. Many people like a fuller lower lip, whereas others prefer a more projecting upper lip. Despite individual preferences, there are some fundamental proportions and anatomic features that contribute to attractiveness.

The distance from the menton (the lowest point of the chin) to the subnasale (the point where the columella meets the upper lip) should be one third of the distance from the menton to the hairline. If a patient has a high forehead the former measurement should equal the distance from the subnasale to the glabella (the most prominent point on the forehead). Within the lower one third of the face, the upper lip should contribute one third and the lower lip two thirds of the distance.

On the profile, a line from the subnasale to the soft-tissue pogonion (the most prominent point of the chin) can be used to assess lip projection. Previously, some authors, such as Burstone, cited guidelines (e.g., "the upper lip should lie 3.5 mm anterior to this line and the lower lip 2.2 mm"). However, due to variances in individual aesthetic ideals, it is generally difficult to cite specific measurements for projection of the lips. A crucial point in evaluating projection of the lips is to consider the position of the teeth. The lips drape over the teeth, and therefore lip under- or overprojection can reflect underlying dental malposition.

AGING PROCESS

Thin, poorly defined lips can result from genetics, trauma, or the aging process. The aging process is a reflection of two distinct factors. The first factor responsible for aging is directed in large part by heredity, resulting in intrinsic aging. Lip size appears to increase until puberty due to hypertrophy of the muscular and glandular components (Fig. 29–3) and then begin a gradual decline. The second component consists of extrinsic factors, such as sun exposure and cigarette smoking, which can accelerate the aging process. The senile transition of lips reflects changes not only in the skin but in the supporting tissues (muscle, fat, teeth, bone). Over time the well-defined raised white roll that surrounds the upper and lower lip begins to flatten (Fig. 29–4). As this happens, there is blunting of the cupid's bow and a decrease in vermilion show. As the subcutaneous layer begins to thin and the muscles begin to lose their tone, there is a loss of lip projection. These processes also result in a downturning of the corners of the mouth. Because of the combination of loss of volume of the supporting

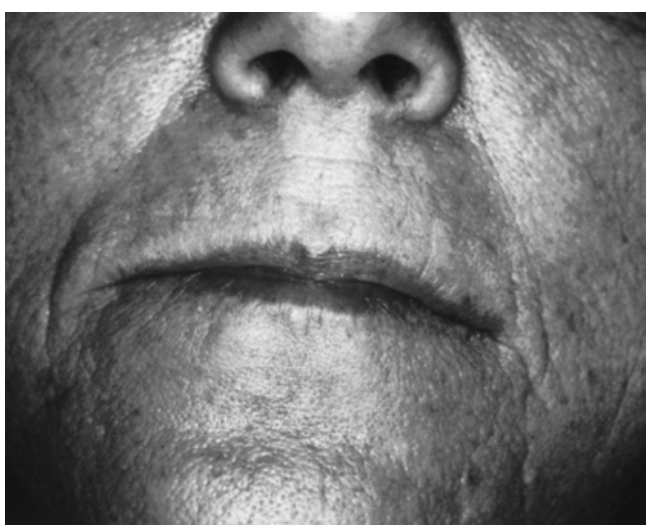

Figure 29–4 Patient showing aging-related changes to the lip: lengthening of the upper lip, blunting of central defining points and philtrum, flattening of the white roll, decreased vermilion show, rhytids, downturning of the commissures, and decreased lip projection.

elements of the lip and the loss of skin tone rhytids develop in both the vermilion and the cutaneous skin. Thus, the end-stage result is a long, poorly-defined lip with little vermilion show and minimal projection.

GOALS OF LIP SURGERY

Many patients come in with very specific ideas about their purpose in having the surgery. Others come in with less precise goals and more generalized concepts. During the consultation period, it is very important for the surgeon to identify any expectations the patient has regarding the lip surgery. That is, is the patient concerned about the length of the lip, definition of cupid's bow area, the amount of vermilion show, the amount of projection, presence of rhytids in the vermilion and cutaneous areas, downturning of the corners of the mouth, or possibly the lack of definition along the white roll or the filature ridges? It is very helpful to have the patient sit in front of the mirror and point to specific areas of concern, thus allowing patient and surgeon to come to a common understanding.

The review of the patient's history should include any history of previous lip treatments, surgeries, or trauma. This should include previous collagen injections, which can result in some fibrosis of the lip area, as well as a history of herpes simplex, allergies, or other significant medical conditions.

Physical examination of the lips should occur with the patient's face in a resting state. Following is an outline of the physical examination process.

1. Assessment of the underlying dental occlusion.
2. Analysis of the facial proportions: examining the vertical one third and documenting the length of the upper and lower lip.
3. Degree of cupid's bow definition.
4. Definition of the philtra ridges.
5. White roll definition around both upper and lower lip.
6. Vermilion show of the upper lip and lower lip.
7. Amount of dental show (younger patients will have several millimeters of central tooth visible, but as the lip lengthens with age this becomes less visible).
8. Position of the corners of the mouth.
9. Condition of the vermilion epithelium.
10. Condition of cutaneous lip epithelium.
11. Evaluation of lip projection.
12. Chin position (microgenia can make full lips look even larger).

By following these detailed steps, the surgeon should be able to identify existing conditions that contribute to the patient's underlying concerns. The proper diagnosis of these conditions will serve as a cornerstone for a successful outcome.

PHOTOGRAPHY

Photography has a very important roll in all cosmetic surgery. With regard to lips, it allows the surgeon to identify and confirm asymmetries preoperatively for planning purposes. It also allows patients to refer back to their preoperative condition after they have undergone the procedure(s) to identify changes that have been achieved. Photographs should be taken with the patient wearing no lipstick or makeup of any kind. The superior border of the lip series should run from the infraorbital rim superiorly to the hyoid bone inferiorly. Frontal, right and left oblique views, and right and left profile views with lips at rest and with frontal smiling and puckering views will generally suffice.

ANESTHESIA

The upper and lower lip area can be anesthetized very easily with regional blocks. Four percent lidocaine (Xylocaine) jelly is applied to the mucous membranes of the upper and lower lips (Fig. 29–5). Regional blocks consisting of 0.5% bupivacaine, 1:200,000 epinephrine mixed with an equal volume of 1% lidocaine with 1:100,000 epinephrine can be placed through the oral mucous membranes to reach the mental nerves, infraorbital nerves, and greater palatine branch. When regional blocks are accomplished, the lips can be injected locally with 1% lidocaine, 1:100,000 epinephrine, and hyaluronidase mixed in a ratio 10 mL to 1 mL, respectively. This mixture is injected along the lips in the plane of dissection. The volume of anesthetic material is limited so as to help reduce possible distortion of the lip. The wydase is not used when dermal matrix graphs are used to reduce the possibility of graft breakdown. Depending on patient sensitivities and whether or not additional procedures are going to be performed, additional anesthesia ranging from oral diazepam 20 mg, or hydrocodone bitartrate (Lortab) 15 mg, to the twilight or general anesthetic may be appropriate.

TREATMENT OF THE LIP CUTANEOUS SKIN AND VERMILION

Rhytids appear around the perioral region as a result of aging, and the process is accelerated by exposure to sunlight and cigarette smoking. Often these changes reflect damage both in the dermal layer of the skin and in the subcutaneous

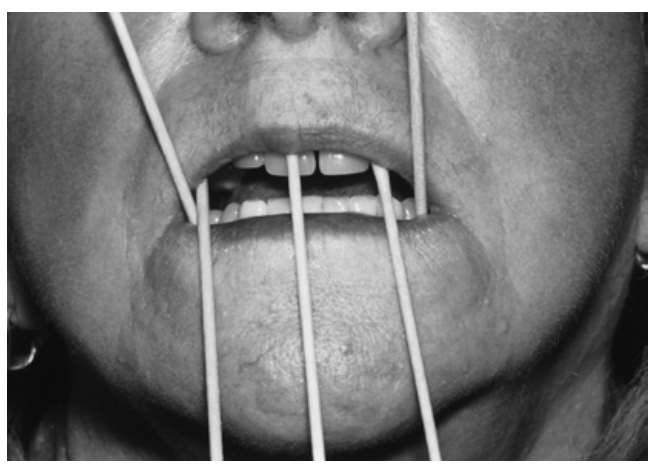

Figure 29–5 Cotton swabs with a topical anesthetic placed in appropriate locations of upper and lower lip prior to placement of lidocaine regional blocks.

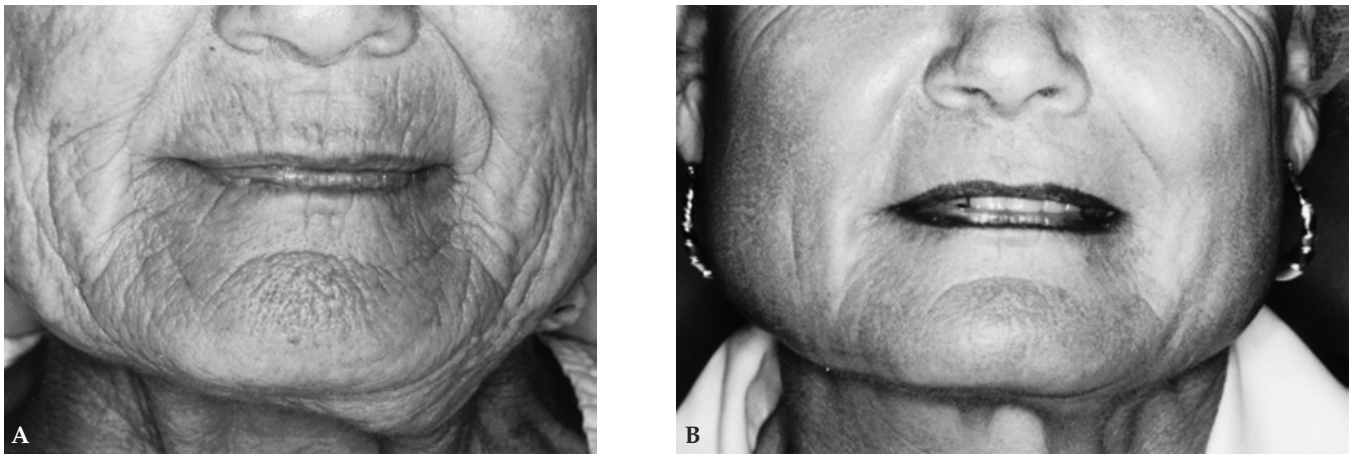

Figure 29–6 **(A)** Patient showing classic signs of aging. **(B)** After full-face carbon dioxide laser treatment. Pretreatment of the deeper lines with Baker's peel solution was performed.

layer, with a loss of volume of the lip vermilion. Short-term treatment of cutaneous rhytids involves injection of collagen into the perioral lines. However, because of the dynamic nature of the area, collagen may last for as little as 2 weeks. Longer term treatments involve resurfacing of the perioral skin. Historically dermabrasion was performed on the perioral rhytids. More recent resurfacing tools include power peeling for very superficial rhytids to chemical peels and carbon dioxide laser resurfacing for deeper rhytids. The deepest rhytids can oftentimes be pretreated with acetone followed by the application of a phenol-based Baker's chemical peel solution with a wooden end of a cotton swab. This peel solution can be applied to the dry vermilion of the lip as well. CO_2 laser resurfacing up to the vermilion surface is then performed, including the previously spot-peeled areas. This results in a softening of the lip rhytids with the effect of increased vermilion show (Fig. 29–6). Deep lines in the vermilion are often a result of loss of substance of the lip, very similar to a balloon losing some of its air. By restoring some of the bulk to the lip with current augmentation materials, the vermilion rhytids will be softened.

PROCEDURES THAT LENGTHEN THE LIP

Augmentation

Augmentation of the upper and lower lip can involve the use of autologous materials, such as dermis, fat, fascia, superficial muscular aponeurotic system (SMAS), or material such as AlloDerm (acellular human dermal matrix grafts), Gore-Tex, collagen, silicone, Dermologin, and a variety of other materials.

The basic principles of augmentation involve either increasing the vertical length of the lip or increasing the projection of the lip. The goal one is trying to achieve determines the placement of the implant material (Fig. 29–7). When lengthening of the lip is the goal, the implant material is generally placed in a submucosal plane or in a tunnel along the inferior aspect of the upper lip and superior aspect of the lower lip. If one is trying to achieve an increase in projection, the implant is either deposited in the submucosal along the anterior surface of the lip or in a tunnel along the anterior surface. Because of the dynamic nature of the lips, it has been a challenge to maintain implant materials in the lip for any length of time. Autologous materials are generally

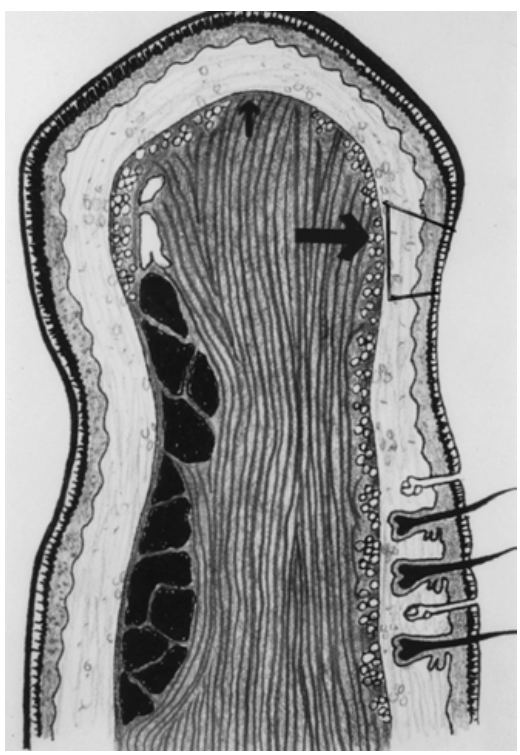

Figure 29–7 Cross-section of lip, with small arrow showing tunnel for lengthening of lip and larger arrow showing plane for increasing projection of lip. Solid line to indicate plane of dissection for lip advancement, which can be performed separately or conjointly.

readily available; however, they involve morbidity of the second site. Fat historically has survived in an unpredictable fashion, often resulting in an unevenness of the lip surfaces. The likelihood of success is increased by washing the fat with Ringer's lactate to remove damaged and broken fat cells as well as blood and serum. Dermal grafts as well as SMAS grafts have not generally survived for very long in the lip as a result of the dense cellular nature of these graft materials. Temporalis fascia is generally very thin and does not offer a significant amount of augmentation material for most patients.

Bovine collagen has the flexibility of allowing one to inject along the white roll, along the filtrum, and along the vermilion. One needs to be skin-tested approximately 4 weeks prior to its use to help identify any possible allergic reactions. Despite passing a single skin test, a small percentage of patients may exhibit an allergic reaction to the material. In the lip area, collagen may last for anywhere from 2 weeks to up to several months. It can also help to soften some of the fine lines around the mouth area. Patients should massage the injected area to reduce the possibility of lumpiness.

AlloDerm

Acellular human dermal matrix graphs were originally developed for the covering of large burned areas, however, they have been used successfully for lip implants. The graft material is procured from an accredited tissue bank. Following chemical removal of the cells within the dermis, the material is freeze-dried. This results in an acellular matrix that allows for tissue ingrowth and repopulation of the matrix (AlloDerm). Because of the constant rebuilding of one's body, by the end of a year the AlloDerm is no longer present and has been entirely replaced with the patient's tissues. This is an exciting concept of placing a temporary scaffold into one's body to encourage new tissue growth. AlloDerm can be inserted into the lips after they have been anesthetized with regional blocks through incisions in the commissure. A submucosal tunnel is created with a tendon passer along either the anterior or the inferior aspect of the lip, depending on one's goals for the procedure (Fig. 29–8). After the instrument is passed through to the opposite side, the appropriate size piece of AlloDerm is then pulled into the pocket. When using this material, the surgeon must remember that the swollen rehydrated form will be compacted in the host's tissues back to a size more comparable to the dry state. Therefore, the surgeon should estimate the amount of augmentation desired with the dry AlloDerm as opposed to the rehydrated form. Commonly, two thirds of a 3×7 cm sheet can be placed in the upper lip and one third in the lower lip (Fig. 29–9). However, it is often possible to place an entire sheet in each lip. The tunnel should be placed submucosally or sufficiently submucosally to avoid seeing any of the whitish implant through the lip material. If a small area of material is exposed in the commissure or vermilion surface postoperatively, the exposed material may be trimmed back generally without consequence. Injectable AlloDerm is currently being studied. Preliminary results appear promising. Patients can achieve the same degree of augmentation as the sheets and experience only 2 to 3 days of swelling. Because of the particle size it is used as a subcutaneous implant, in contrast to bovine collagen, which is a dermal implant. A 2-in. 25-gauge needle is inserted at the midline and threaded through the lip in the desired plane (the same plane if one were inserting sheets of AlloDerm). Micronized AlloDerm is evenly deposited on withdrawal of the syringe (Fig. 29–10). Dermologin is an acellular dermal matrix graft in which the dermal matrix is chemically dissolved. It appears that because of this chemical dissolution various proteoglycans that would help facilitate tissue ingrowth are removed. Early observations with this material have been somewhat disappointing in that the material seems to last no longer than bovine collagen.

Figure 29–8 Straight-tendon passer being used to create a tunnel along the superior lip border. The incisions are placed in the commissure so that the same incisions can be used to augment both upper and lower lips.

Expanded Polytetrafluoroethylene

Expanded polytetrafluoroethylene (ePTFE, Gore-Tex) has been used extensively over the years as a lip augmentation material. This implant material is not subject to reabsorption. However, when placed in the lip it does develop a capsule fibrosis around it, which can result in tightening and firmness of the lip. The other disadvantage is that patients can generally feel ePTFE in the lip. The complex motions of the upper lip make it very difficult for the upper lip to maintain ePTFE within it, and extrusion is not uncommon in the upper lip. The manufacturers have attempted to increase the flexibility of larger pieces of ePTFE by changing it to a multistranded implant (Fig. 29–11). This seems to work well in the lower lip; however, it has not been tolerated in the upper lip, in the author's experience.

Silicone

Microdrop silicone is a possible lip augmentation material that was used extensively in the past. However, because of its current FDA standing, microdrop silicone is not generally used by many physicians. Occasional reactions to the microdroplet could be seen, and this is possibly related to impurities within the silicon itself.

Figure 29–9 Upper and lower lip. AlloDerm augmentation (**A**, **B**) before and (**C**, **D**), after.

Figure 29–10 Injectable AlloDerm can be placed into the lips through a central incision and threading the material in the desired plane from the commissure to the midline and then similarly on the opposite side.

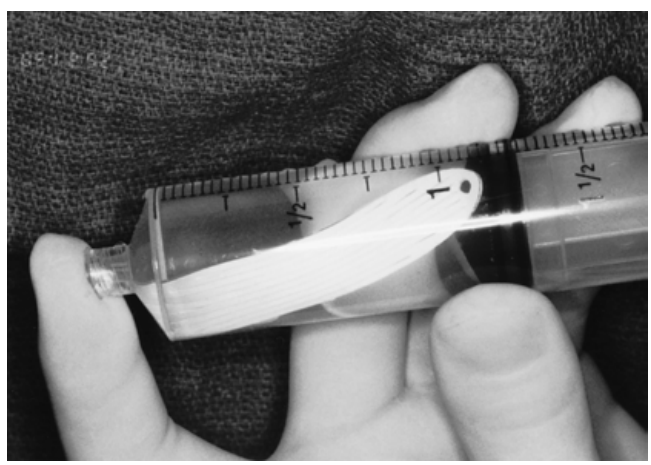

Figure 29–11 Multistrand Gore-Tex lip implant being impregnated with an antibiotic solution via a vacuum in the syringe.

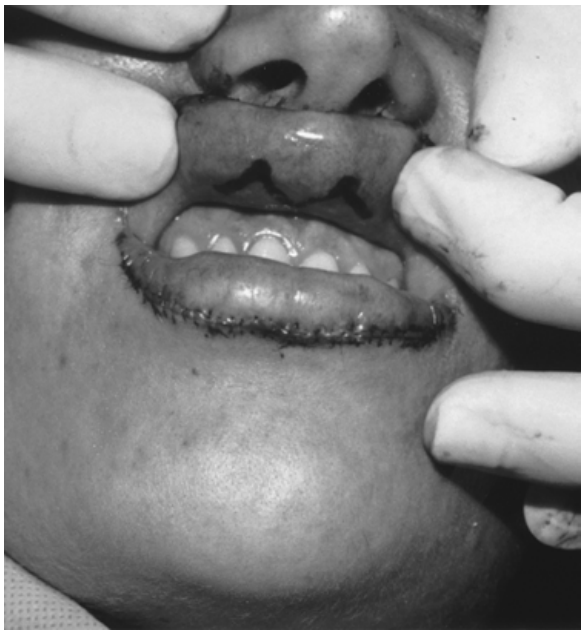

Figure 29–12 Patient who has undergone upper and lower lip advancement with V-Y advancement. The goal of the V-Y advancement was to increase the projection and bulk of the central lip. If more lateral fullness was desired the V-Y advancement would extend to the commissures.

Figure 29–13 Allowing patients to draw their desired lips in the mirror can facilitate physician–patient communication regarding the goals of surgery.

V-Y Advancement

V-Y advancement or augmentation cheiloplasty, a technique that has been around for many years and was initially used to treat the whistle-lip deformity, involves use of a V-Y closure technique at the mucosa (Fig. 27–12). The entire mucosa can be brought forward by placing two "V's" next to each other in a "W" fashion and advancing these in V-Y fashion. The exact amount of augmentation desired can be slightly unpredictable. To advance the lateral vermilion, it is necessary to extend the W-plasty to the commissures. The flaps are elevated and the incisions closed with a V-Y advancement technique. Scarring does not appear to be significant or create much firmness for the patient.

PROCEDURES THAT SHORTEN THE LIP

Lip Advancement or Vermilion Advancement

Lip or vermilion advancement was originally described by Gilles and later refined by other surgeons. It involves the removal of an ellipse of cutaneous skin adjacent to the vermilion of either the upper or lower lip. In the case of a long upper lip with little cupid's bow definition, the technique can be used to restore the central defining points. It is often handy to have patients draw with the marking pen on the upper and the lower lips to show the shape and size they would like to achieve. This can be done with them sitting in front of a mirror and allows for better physician–patient understanding of the surgical goals (Fig. 29–13). Care is to be taken to note and discuss any preoperative asymmetries. After the areas are marked, an additional 1 mm should be excised to accommodate for some lip recoil. The ellipse of skin is excised in the fascial plane, immediately beneath the skin and above the muscle (Fig. 29–14). This will help to recreate the white-roll fullness adjacent to the vermilion.

Figure 29–14 The boundaries of the areas to be excised are first scored with a no. 15 knife blade. Removal of the areas in a superficial plane can be accomplished with sharp scissors as shown. Note that the plane of dissection is superficial to the muscle.

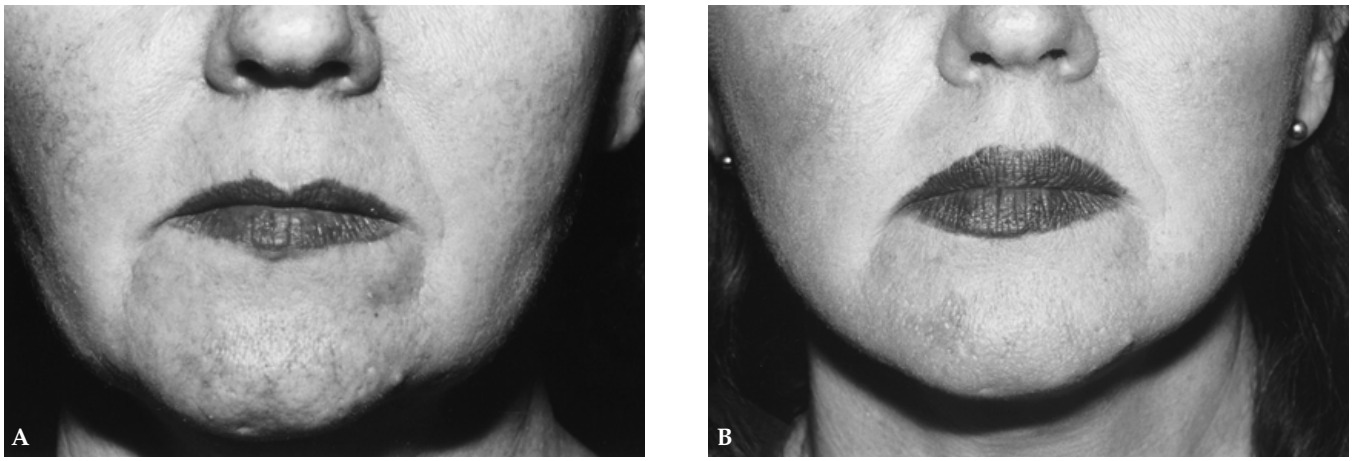

Figure 29–15 **(A)** Preoperative view of patient with significant asymmetry between the two sides of her lips. **(B)** After upper and lower lip advancement.

Care is taken not to go beneath this facial plane as scarring and tightness may result. The defining points of the upper lip are brought together with vertical mattress sutures without any undermining of the adjacent edges. Final wound closure can be performed with a running subcuticlar 5-0 Prolene suture and reinforced with absorbable sutures as necessary (Fig. 29–15).

Nasal Base Resection

Nasal base resection is an excellent procedure for patients with a long upper lip, and a well-defined cupid's bow area, and a well-defined nasal base. The ellipse of skin at the base of the nose should follow in a sea-gull fashion the contours of the base of the nose. Depending on the anatomy of the nasal sill, the incision can extend into this area. A parallel line is drawn inferior to this, thus creating the ellipse of skin to be excised. The skin is excised in the subcutaneous plane, and wound closure is accomplished in a two-layer fashion (Fig. 29–16). It is reported by Millard that the distance from the philtra origin at the nasal sill to the insertion at the vermilion varies from 18 to 22 mm. If the lip exceeds this measurement or is longer than the relative proportions of the face, the nasal base resection may be an appropriate procedure for the patient.

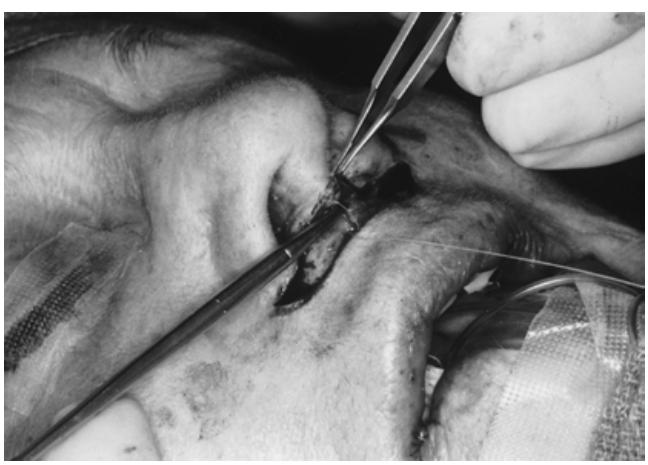

Figure 29–16 Photograph of the nasal base resection showing removal of skin from the upper lip and closure of subcutaneous tissues.

Cheiloplasty

Cheiloplasty, or vermilion reduction, can be performed by excising an equal amount of the vermilion on each side of the wet line of the lip. The goal is to maintain the incision at or slightly behind the wet line of the lip. This incision may involve more than just the mucosa, depending on the bulk of the lip to be reduced. The incisions are then closed with absorbable sutures. Generally, overresection of the lip is necessary to accommodate postoperative recoiling of the lip. Reduction cheiloplasty must address each component of lip enlargement, including increased anterior projection, vertical lip height, and wet-vermilion show. To help minimize overresection of the mucosa one can incise one side of the ellipse first, then undermine the mucosa and hyprotrophic glandular tissue and retract this posteriorly, excising the excess tissue. Care should be taken to preserve the height of the lower lip at the level of the lower incisors.

POSTOPERATIVE RECOVERY

Following lip procedures of almost any type, patients report that their lips feel "tight," as well as abnormal when smiling, for approximately 6 to 8 weeks. Although their lips may not appear abnormal, patients may feel uncomfortable during this period. Following surgery, patients are instructed to rest the lips for approximately 2 weeks. They are also instructed to avoid smoking. Patients are generally placed on a antiviral agent if there is a history of herpes simplex. If an outbreak occurs in a patient who has undergone augmentation, the patient should exercise caution. The inflamed tissues may be more friable and therefore susceptible to graft exposure. A broad-spectrum antibiotic is also routinely used in patients who have undersone any lip procedures other than collagen injection.

ADDITIONAL REFINEMENTS

Use of permanent cosmetics or dermal pigmentation can help highlight the lip shape or possibly balance out postoperative asymmetries. This procedure can be performed in the office under regional anesthetic block.

POSTOPERATIVE COMPLICATIONS

Infection and bleeding are potential complications of any surgical procedure. Because of the complex anatomy of the perioral region, it is very important to identify preoperative asymmetries because some of these may persist postoperatively. Whereas some procedures lend themselves to the correction of minor asymmetries, other lip procedures described will not correct these asymmetries and could potentially accentuate them. Significant postoperative asymmetries may be attributed to localized edema and can be treated with diluted steroid injections. Paresthesia of the lip may persist for up to 6 months.

Small extrusions of implant material may be treated by removing the exposed material, followed by local wound care. Larger extrusions or infections of the augmentation material generally require removal of the graft material. Following removal of the implant the potential space from which it came can fill with scar tissue, resulting in tightness of the lip. To minimize tightness of the lip, dilute triamcinolone injections are performed weekly or biweekly. Patients are instructed to massage and stretch the lips 6 to 10 times daily. This routine is performed for 10 to 12 weeks until the lips relax.

CONCLUSION

Lip procedures are becoming increasingly popular. The cornerstone to a successful outcome is for both the patient and the surgeon to have a solid understanding of the patient's goals and starting point. Once the surgeon has made an appropriate diagnosis, there are many tools available to help achieve the desired outcome.

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Chapter 30

Advances in Aesthetic Dentistry

Garret B. Lyons, Jr. and Roger P. Levin

The concept of aesthetic dentistry has evolved to become an underlying principle in all of the dental disciplines. The past decade has heralded tremendous technological advances, allowing patients to expect and to receive optimal aesthetic treatment from their dentist.

We live in a beauty-conscious society. The American advertising community has pushed the idea that "beautiful is better." Self-improvement is no longer the exclusive domain of the rich and famous, nor is it considered a sign of self-indulgence. Today taking steps to improve one's appearance is considered an investment in health and well-being, and is as socially acceptable as it is personally gratifying. It all begins with a smile.

In addition to expecting technical competence, American consumers expect their dentist and staff to be caring and concerned. Dentists enjoy the satisfaction that comes from delivering treatment that is both functionally gratifying and aesthetically pleasing, and that gives the patient a sense of well-being and satisfaction. Recent advances in aesthetic dentistry have changed modern dental practice dramatically. Aesthetic improvements once considered to be impossible are now considered routine. First, dentists should facilitate patient selection of the most appropriate treatment alternative. Aesthetic improvements must also encompass periodontal health, occlusion, and proper positioning and alignment of teeth, not just a postoperative appearance of a smile viewed in the mirror. Dentists must accurately inform patients of the advantages, disadvantages, and necessary precautions associated with the aesthetic treatment procedure. Dentists must maintain a high level of technical quality because there is no substitute for excellence. Cosmetic dentistry requires problem solving whereby the practitioner determines the diagnosis, formulates a treatment plan, and selects the appropriate instruments and materials. Treatment must then be dispatched in an orderly fashion with the understanding of proper technique and specific material manipulation.

COLOR ANALYSIS

The emergence of new techniques to improve patient appearance and enhance the aesthetic restoration of posterior teeth increases the complexity of color selection. Some materials available for aesthetic composite-resin bonding procedures are available in more than 15 shades. The aesthetically oriented dentist must be able to:

1. Identify color patterns and shades of natural teeth
2. Understand the color relationships of enamel, dentin, and cementum
3. Understand the ideal, natural tooth colors, including translucency near the incisal edge of anterior teeth
4. Relate natural tooth colors to shade guides of the various materials available to enhance aesthetics
5. When necessary, diagnose and communicate aesthetic color needs to laboratory technicians
6. Evaluate case results and troubleshoot problems
7. Custom-stain in aesthetic cases
8. Meet patient expectations expressed during consultation and treatment planning

UNDERSTANDING COLOR

There are three basic parameters of color that are useful to the aesthetically oriented dentist:

1. *Hue.* The quality of color that distinguishes one from another. Examples are blue, yellow, and green.
2. *Chroma.* Reflects the intensity of the hue. An example is light blue versus dark blue.
3. *Value.* The light-to-dark aspect of hue. White is the highest value, black the lowest.

Aesthetically oriented dentists can use three factors to analyze and select color. A good shade guide will reflect all three of the previous factors.[1]

Vital bleaching is becoming a viable treatment option with discolored teeth. Bleaching alone can significantly change the appearance of teeth, sometimes as a result of only one office visit, and almost always less invasively and less expensively than procedures such as crown and bridge, bonding, or veneering. Moreover, bleaching can be used as an adjunctive treatment. For example, it can improve the effect of another procedure for restoration or change of coloration and lessen the number of teeth involved in that procedure, or it may make it possible to restore affected teeth with a lighter shade than would otherwise be possible. The earliest efforts to bleach discolored teeth occurred more than a century ago, but bleaching did not become a vital part of aesthetic dentistry until the past decades when the technique gained widespread use for tetracycline-stained vital teeth (Figs. 30–1 and 30–2).

Figure 30–1 Preoperative photo of tetracycline-stained teeth.

Although the mechanisms by which bleaching removes discoloration are not fully understood and may differ, the type of stains the basic process removes almost always involve oxidation, at which time the molecules causing the discolorations are released.[2] Consequently, the success of the technique is dependent on the ability of the bleach to penetrate to the source of the discoloration and remain there long enough to overcome the stain (Figs. 30–3 to 30–6).

In the field of resins it is interesting to note the diversity of the resins and their clinical applicability. The hybrid resins are made of glass and silicon dioxide. They are of high strength and low expansion and contraction, and are associated with low polymer shrinkage. Their strength is the ease of finishing with unfortunate high wear. The microfil resins are also silicon dioxide filled about 50%. Their main use is in anterior applications, and they are noted for smoothness, translucency, and low wear, though not as strong as a hybrid. They are used many times as a veneer over a hybrid in class III and IV applications. Other hybrid resins used for posterior restorations are materials that have a low wear but are less than perfect aesthetically. They are not as strong as some of the other hybrid resins but are best used under hybrids.

Sealants are promoted as unfilled resins. They tend to be used with increasing amounts of filler content. However, they are now being replaced by flowable composites. The flowable resin composites are not very different from sealants. They are hybrid resins with lower viscosity and lower filler content than conventional restorative resin-based composites. They are used in class I restorations of pits and fissures, and sometimes they are the original material placed in a proximal box of class II resins. They have very low strength and are the most wearing of all the composites.

The packable resin-based composites today are condensable, as they come compacted but not condensed. These

Figure 30–2 Postoperative photo of bleached teeth at 8 months.

Figure 30–3 Preoperative photo before bleaching.

Figure 30–4 Postoperative photo of bleached teeth.

Figure 30–5 Preoperative photo before bleaching.

Figure 30–6 Postoperative photo of bleached teeth.

materials are used because of inadequate development of contacts on class II restorations. They are analogous to the spherical amalgams and contain large filler particles.

The last category is the superficial sealing microfils. These contain 50% silicon dioxide and are filled with clear resin-based composites. They resemble a superficial skin that is placed over a composite resin restoration. The way they are used is by being acid-etched over the top of the composite material and made to fill in voids and margins; however, their long-term significance is doubtful.

Indirect resins such as polyglass or polymer ceramic restorations have begun to experience increased usage. These materials are the relatives of in-office direct composites. All of these indirect composite restorative systems actually are modifications of existing tooth resin composites. Their chemistry is similar, though their strength, durability, filler content, and method of curing may be enhanced. Indirect composites are becoming very popular due to the fact that patients are demanding more and more metal-free restorations or metal-free dentistry. The indirect composite resins have a more life-like appearance. A composite can reflect light very similar to the way a natural tooth structure does. In addition, composites may offer more optimal shade matching than porcelain. There are two main reasons for using an indirect composite resin: (1) the size of the cavity and (2) the function of the force to which the restoration is subjected. These indirect composite resins can be made to fit very well, have terrific aesthetics, and even have low wear to opposing natural tooth and high-wear resistance to function. These materials can also be repaired in the mouth (Figs. 30–7 and 30–8).

In 1993, the porcelain laminate veneer was introduced. It combined the aesthetics and positive tissue response of porcelain with the adhesive strength of acid-etched restorations and the convenience of laboratory-fabricated restorations. Aesthetic improvement of acceptably shaped or discolored teeth by chemical means is highly desirable because of its conservative nature. The chemical agents and specific procedures used depend on a number of factors, including the type, intensity, and location of the discoloration. Porcelain veneers were introduced by Dr. Charles Pincus in Hollywood in the 1930s

Figure 30–7 Preoperative photo of amalgam due to be replaced with induct restorations.

Figure 30–8 Postoperative photo of indirect tooth-colored restorations.

to enhance an actor's appearance for movie close-ups. Dr. Pincus attached these thin veneers temporarily with a denture-adhesive powder. Indirect veneering did not progress until the 1970s, when Dr. Franck Faunce described a prefabricated acrylic resin veneer that integrated the adhesion principles of Buonocore and Bowen with an indirect veneer alternative to porcelain. These veneers were primed with an ethyl acetate or methylene chloride liquid and luted to the etched tooth with a composite resin.[3] The advent of the etched portion of the laminate veneer represents the progress of several decades of research culminating in the synthesis of the acid etch technique and dentistry's most time-honored aesthetic material, porcelain (Figs. 30–9 and 30–10).

Glazed porcelain or ceramics often offers abrasion resistance, biocompatibility with gingival tissues, and long-term color stability. The inorganic filler component of composite resins is responsible for its improved physical properties, as opposed to the older unfilled silicates and acrylics. It is com-

Figure 30–9 Preoperative photo of teeth to be laminated with veneers.

Figure 30–10 **(A)** A satisfied patient. **(B)** Postoperative photo of laminate veneers.

posed of quartz, silica, and glass composite fillers, which tend to be hard and similar to tooth structure in terms of translucency and refractive index. Many physical properties, notably fracture and wear resistance, along with polymerization shrinkage, are enhanced as the amount of filler in the composite material increases.

In 1983, Dr. Horn introduced a method to bake the ceramic laminate veneer on a platinum matrix and then etched the inside of the veneer with hydrochloric acid. A coupling agent was applied to the veneer and bonded to the tooth using a light cured composite resin. Composite resin to unetched ceramic was only 230 psi and the strength was increased to 670 psi when the ceramic was etched. It was found that by using a silane coupling agent to increase the bond strength between the ceramic and the composite resin, the strength was increased to 2080 psi. The technique of etching the ceramic veneer surface using a low concentration of hydrochloric acid made possible the development of the ceramic laminate veneers (Figs. 30–11 and 30–12).

Minimally invasive dentistry has emerged as a new concept. The earlier a dentist can intervene in a diverse process and the healthier the tooth structure encountered, the closer we can come to the statement, "First do no harm." Despite the role of fluoride in reducing common surface cavities, fluoride has had one unexpected effect. When strengthened by fluoride, enamel undermined by decay is much less likely to collapse. This result is that caries in pits, fissures, and grooves cannot be reliably directly detected with an explorer.

There is a preponderance of evidence that diagnosis of caries with only exploring x-rays will continue to result in

Figure 30–11 Preoperative photo of teeth to be laminated with veneers.

Figure 30–12 Porcelain laminates.

nondetection of decay. Air abrasion dentistry now represents a new standard of care. In air abrasion, two powders are commonly used: 27 μm for all cavity preparations and 50 μm for adjunctive bonding enhancement and application.[4] As far as fracturing the tooth structure and using air abrasion under scanning microscopy, studies show that microfracturing and chipping of the enamel prepared with a handpiece does not occur when a tooth is treated with air abrasion. It is overkill to destroy almost a third of the tooth surface with a bur, penetrating the dentin and causing histologic changes in the pulp, creating microfractures and then placing an ugly amalgam that can promote recurrent decay and loss of tooth structure. In contrast, treatment with air abrasion and restoration with composite cause none of the histologic changes, microfracturing, or excessive loss of tooth structure to which we are subject as a result of our previous decision to withhold or delay treatment. As we move forward, minimally invasive dentistry will be increasingly associated with a desirable restorative result. Minimally invasive preparations do not have the architectural beauty of the line angles and bevels of which we are inordinately proud; their beauty is in the healthy tooth structure left untouched. Although occlusal surfaces constitute only 12% of the total permanent dentition surface areas, they are the sites for the development of more than 50% of the caries reported in most school-aged children. Both permanent and primary teeth are in the pit and fissure surfaces in the molars. This constitutes over 90% of the caries detected in areas where the water is fluoridated.[5] When a pit or fissure has been determined to be caries, air abrasion is used to access and remove the decay. Short bursts of 27-Um particles at 140 to 160 psi are used to carefully widen the grooves. After access to the decay is established, the pressure may reduce to 80 or 100 psi. This enables more control, with removal of decay and greater comfort for the patient. It has been found that the decay follows unusual paths, sometimes going in a lateral direction and reversing course and proceeding seemingly unaffected toward the nerve. It is not necessary to use anesthesia when treating teeth solely with air abrasion. Patients feel either nothing or a mild tingling sensation. Most sealants fail at a rate of about 10% per year.[6] Most of the pathogenic bugs in the mouth are negative anaerobes. Most bacteria that live in the cracks of the fissures of teeth are *Streptococcus mutans* organisms. When restoring such teeth with air abrasion, the common name used is "sealant fillings."

Dentistry has taken the lead in the preventative approach to dealing with pathology. Noninvasive, nomutilative tooth preservation has enabled dentists to enjoy what many refer to as the reemergence of the "golden days of dentistry."

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Functional and Aesthetic Surgery of the Nose

Section

III

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Chapter 31

Facial Analysis of the Rhinoplasty Patient

Steven S. Orten and Peter A. Hilger

Although beauty is easily recognizable within a given culture, it is often difficult to define objectively. It may be characterized by a combination of factors that involve symmetry and aesthetically pleasing proportions and relationships. These factors have been the object of study for centuries in an attempt to standardize and define the face of classic beauty. An understanding of the proportions, angles, measurements, and relationships that are considered the standards for the attractive face gives the surgeon an appreciation for what is askew when a facial characteristic is outside the considered normal range and the patient is dissatisfied with his or her appearance. When asymmetries, disproportions, and poor relationships are present, their correction determines the surgical plan.

Successful rhinoplasty depends on careful analysis of both the nose and the surrounding facial features. The purpose of this chapter is to present clinically applicable aesthetic concepts of the nose and the face that are helpful in evaluating a patient for rhinoplasty.

NASAL–FACIAL ANALYSIS

Analysis of the patient prior to rhinoplasty begins with the assessment of nasal–facial relationships. While there is great variety in nasal and facial appearances, general guidelines regarding attractive nasal–facial proportions have been developed.[1] There have also been many different methods for analyzing facial proportions, some of which involve intricate and confusing measurements that are difficult to apply. The following diagrams provide some basic guidelines that are easy to apply both pre- and intraoperatively for the rhinoplasty patient.

The face may be divided by horizontal lines into thirds (Fig. 31–1). The forehead hairline (trichion) to the glabella, the glabella to the nasal base (subnasale), and the nasal base to the chin (menton) are approximately equal thirds. The lower third of the face may be further subdivided into thirds, with the upper lip being one third and the lower lip and chin two thirds. The nose and face may be divided by vertical lines into horizontal facial fifths, with the nasal base width equal to the intercanthal distance and the width of each eye (Fig. 31–2).

When viewed in profile, the nose should project from the face with the proportions of a 3-4-5 right angle triangle with the nasal projection being 60% of the nasal length (Fig. 31–3).[2] The nasofrontal angle begins approximately at the level of the supratarsal crease, and the chin should approximate the lower lip in its anterior projection.

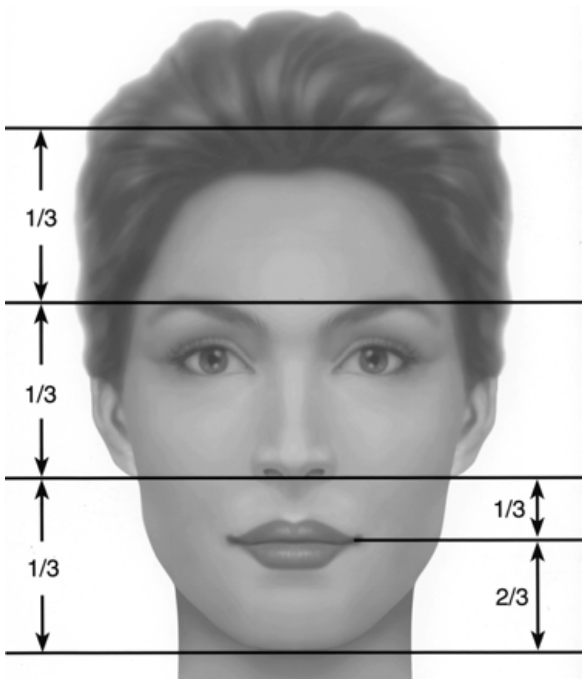

Figure 31–1 The face is divided into vertical thirds by horizontal lines. The upper third extends from the hairline to the glabella, the middle third from the glabella to the subnasale, and the lower third from the subnasale to the menton.

Within these general aesthetic guidelines variations exist due to individual or ethnic differences: however, significant variations may provide insight into why the patient is dissatisfied with his or her appearance. Most patients have facial and nasal asymmetries that should be discussed in the preoperative consultation. These asymmetries may not be noticed by the patient preoperatively; however, there is an increased likelihood that the patient will be hypervigilant to irregularities after surgery.

NASAL SKIN

The evaluation of the rhinoplasty patient should take into account the skin and soft tissue covering of the nose. Nasal skin that is thick and sebaceous does not drape well to reveal

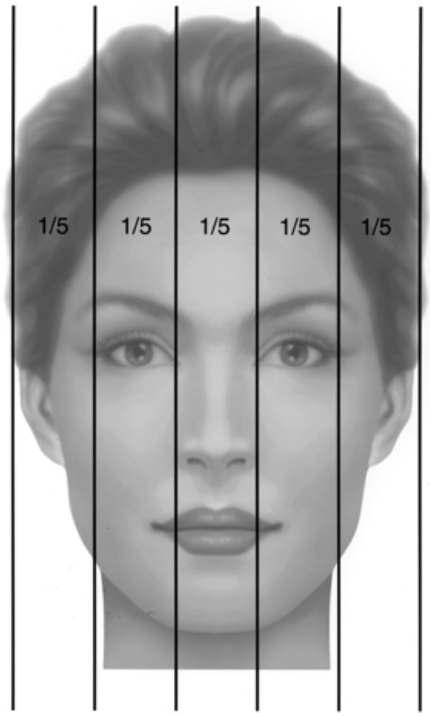

Figure 31–2 The face may be divided by vertical lines into facial fifths, with the nasal base width equal to the intercanthal distance and the width of the palpebral fissure.

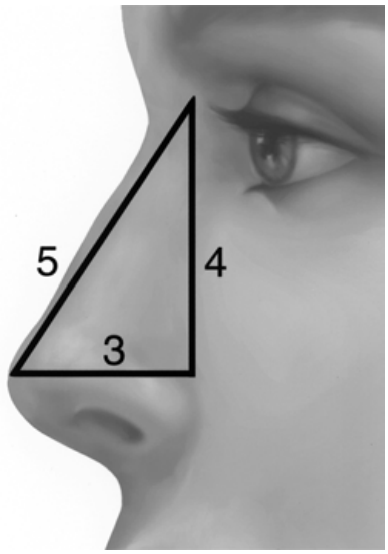

Figure 31–3 Nasal projection and length illustrated as a 3-4-5 triangle. The ratio of projection to length is represented by the ratio of 3:5, making nasal projection 60% of nasal length.

subtle changes that have been made in the bony cartilaginous framework. Many surgeons feel that edema takes longer to subside before the final results are apparent when thick, sebaceous skin is present. However, thin skin may drape too well, showing any minor deformities and irregularities underneath.

Nasal skin is generally thicker at the nasofrontal angle and becomes thinner over the rhinion (Fig. 31–4). From the rhinion to the supratip the skin becomes thicker again, with an increase in sebaceous glands. Over the nasal tip the skin may vary considerably from thin skin that outlines the underlying nasal tip cartilages to thicker skin that contributes to the bulbosity of the tip. The alar lobule skin is also thick, with a greater density of sebaceous glands, whereas the skin of the columella is generally thinner than any area of the nose.

FRONTAL VIEW

On frontal view the symmmetry of the nose can be evaluated. A curved unbroken line can be viewed sweeping from the medial brow to the ipsilateral nasal tip defining point (Fig. 31–5).[3] A line from the midglabella to the menton should bisect the nasal bridge and tip (Fig. 31–6). Any deviation or twist of the external nose should be readily apparent from this view.

The width of the nasal dorsum and alar base can best be assessed from a frontal view. The width of the alar base should be approximately the same width as the intercanthal distance (Fig. 31–7). If the alar base is significantly wider than the intercanthal distance, alar base modification can be considered. The width of the bony sidewall of the nose should be 75 to 80% of the normal alar base (Fig. 31–8). If the bony base exceeds this dimension, narrowing can be accomplished at the time of lateral osteotomy. If the width of the bony base is

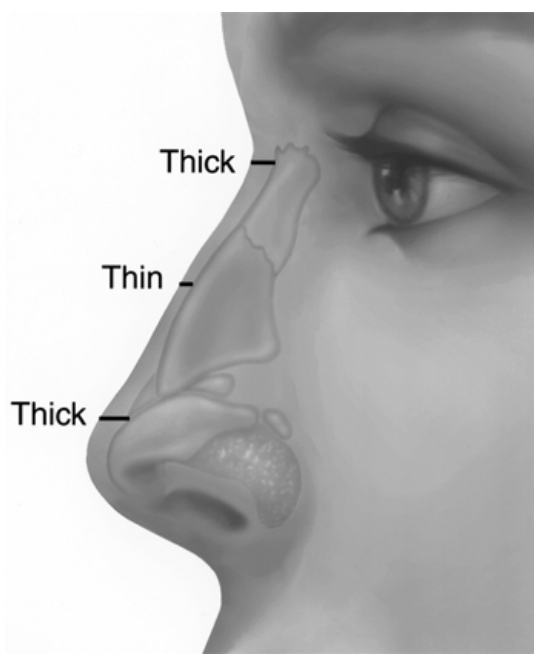

Figure 31–4 Nasal skin thickness varies over the dorsum of the nose. The thickest skin is usually at the nasal tip, whereas the thinnest skin is at the rhinion.

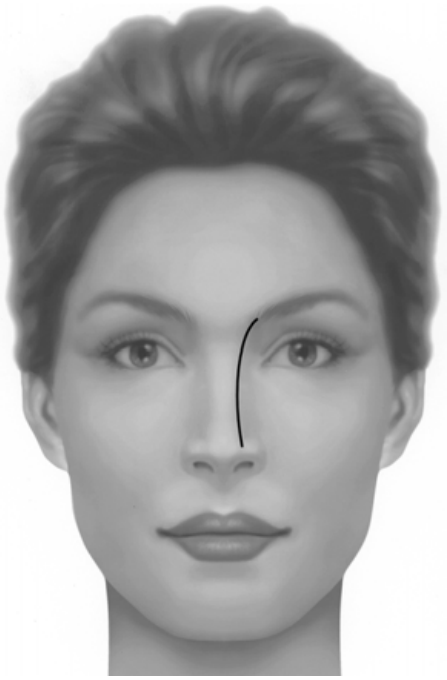

Figure 31–5 The nasal dorsum should follow a gentle curving line from the medial brow to the nasal tip.

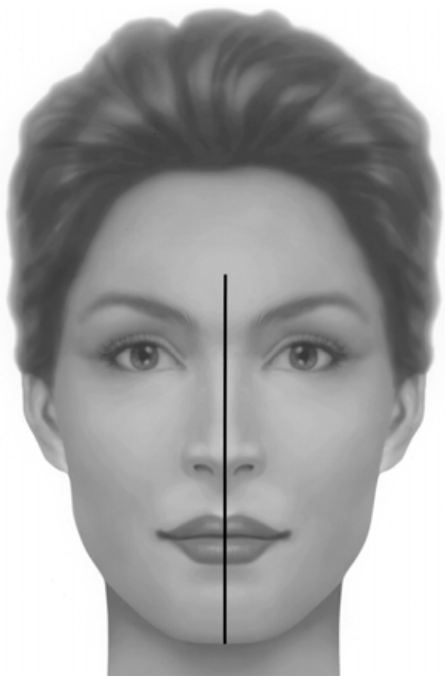

Figure 31–6 Nasal deviation is apparent when a line is drawn vertically from the midglabella to the menton.

within the normal range but the bony dorsum is wide, mobilization of the nasal bones will be required while keeping the bony base width the same.

On frontal view, the nasal tip has two tip-defining points that represent light reflection from the skin overlying the domes of the lower lateral cartilages (Fig. 31–9). Asymmetries in the domes of the lower lateral cartilage will be seen as tip asymmetries on frontal view that may require tip modification during surgery. Bulbosity of the nasal tip should be noted, which may suggest the need for attenuation of the

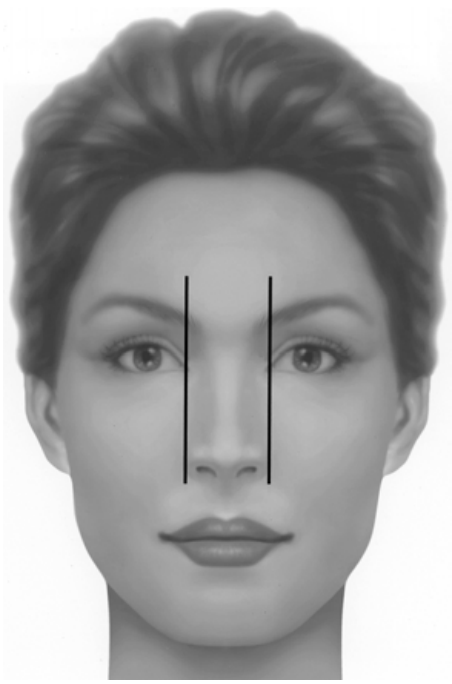

Figure 31–7 The alar base width is equal to the intercanthal width.

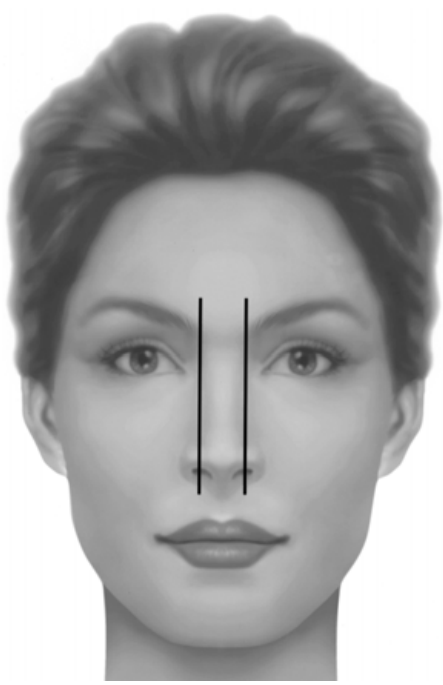

Figure 31–8 The width of the base of the bony sidewall of the nose is approximately 75% of the width of the alar base.

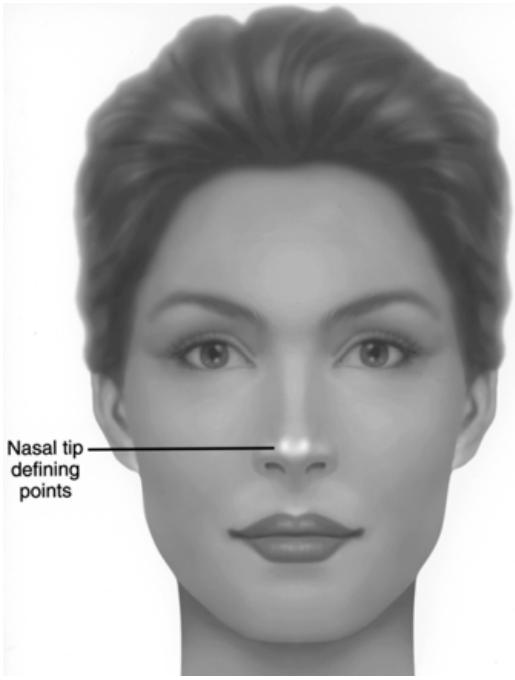

Figure 31–9 The nasal tip defining points are seen as two light-reflecting points of the nasal tip.

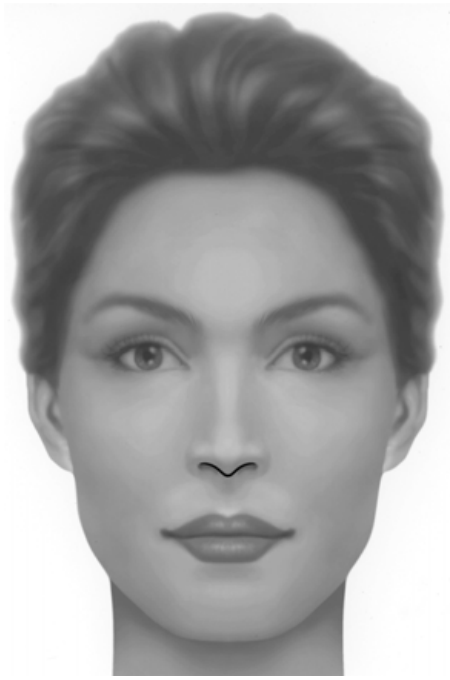

Figure 31–10 The "gull in flight" shape of alar rims and columella can be seen on frontal view.

lower lateral cartilage. If an excessive distance is found between the tip-defining points, the domes of the lower lateral cartilage may be brought closer together at surgery by a variety of techniques, including interdomal suturing.

The columella is seen to hang just inferior to the alar rims, giving the infratip lobule a gentle "gull in flight" appearance on frontal view (Fig. 31–10).[4] Too much view of the columella on frontal view indicates a protruding or hanging columella, which may require reduction. Lack of columella on frontal view signifies a retracted columella, which will need augmentation. Nostril show should not be excessive indicating the nasal tip is overly rotated. Any asymmetries of the alar rim or its attachment at the alar base should be noted at this time.

A discussion of guidelines regarding proper dimensions on frontal view must be tempered by evaluation of the nose from other projections as well as consideration of harmony with other facial proportions. For example, if the middle third of the face is long and the intercanthal distance is narrow, narrowing the alar base to match the intercanthal distance may cause the nose to appear excessively long and draw additional attention to the long midface. Recognition of these nuances and the ability to modify surgical technique to accommodate them differentiates the superior rhinoplasty surgeon from the average surgeon.

PROFILE VIEW

From the profile view, the nasofrontal angle connects the brow with the nasal dorsum. The deepest point of the nasofrontal angle is the nasion and should lie at the level of the supratarsal crease. The nasofrontal angle is formed by a line from the nasion tangent to the glabella and a line tangent to the nasal tip (Fig. 31–11). This angle is typically 115 to 130 degrees. There are no well-established parameters for determining the correct depth of this angle; therefore, one must use aesthetic judgment to determine whether it is too shallow or deep in a given patient.

Nasal tip projection is determined from the profile and is measured most simply by a 3-4-5 triangle as described by Crumley and Lancer (Fig. 31–3).[2] A line from the nasion to

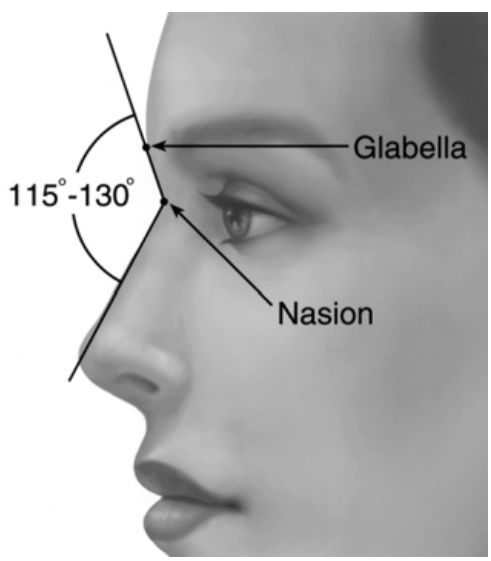

Figure 31–11 The nasofrontal angle is typically 115 to 130 degrees.

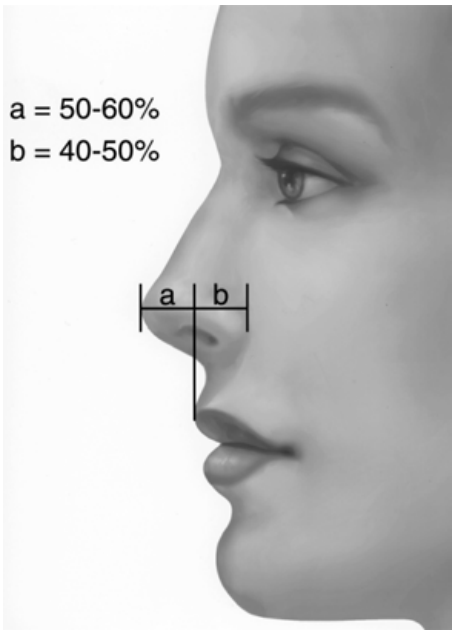

Figure 31–12 50 to 60% of the nasal projection should be anterior to the upper lip.

the tip is the hypotenuse of this right angle triangle. Nasal projection as measured from the alar-facial crease perpendicular to the Frankfort horizontal plane to the nasal tip should be 60% of the nasal length. Nasal projection may also be evaluated based on its relationship with the upper lip. Adequate nasal projection is present when 50 to 60% of the horizontal projection of the nose lies anterior to the upper lip (Fig. 31–12). If over 60% of the nose lies anterior to the lip, the nose is considered to be overprojected. If less than 50% of the nose is anterior to the vertical lip line, it is underprojected. Simons related nasal projection to upper lip length.[5] Tip projection by this method is considered appropriate if the distance from the base of the columella (subnasale) to the nasal tip is in a 1:1 ratio with the height of the upper lip from the subnasale to the upper lip vermilion border.

With the desired tip projection determined, the nasal dorsum can be evaluated. When a line is drawn from the nasion to the desired tip projection, the nasal dorsum should lie at or slightly (1 to 2 mm) posterior and parallel to this line (Fig. 31–13). If the nasal dorsum lies significantly posterior to this, line augmentation will be required. If it is an anterior to this, line reduction is indicated. A slight supratip break of the dorsum gives the nose more definition and helps distinguish the dorsum from the tip.

The nasolabial angle is measured by drawing a line from the most anterior and posterior point of the nostril on lateral view (Fig. 31–14). The angle this line makes with a vertical line dropped along the upper lip is the nasolabial angle. The ideal nasolabial angle differs between men and women. The ideal angle for men is 90 to 95 degrees and for women 95 to 115 degrees. The need for superior or inferior nasal tip rotation should be determined by the patient's nasolabial angle. Greater superior rotation is acceptable in shorter individuals as compared to their taller counterparts.

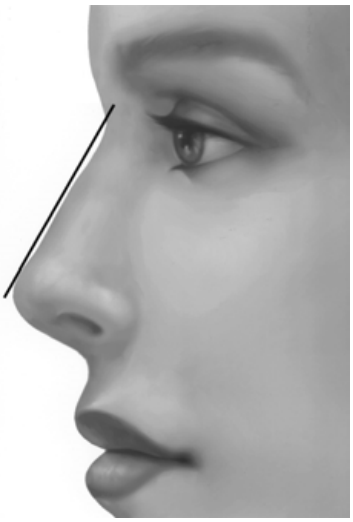

Figure 31–13 The nasal dorsum should lie at or slightly posterior to (1–2 mm) a line drawn from the nasion to the nasal tip.

On lateral view, the alar–columellar relationship should be evaluated. 2 to 4 millimeters of the columella should be visible below the alar margin on profile (Fig. 31–15). More than 4 mm of columellar show is considered to be excessive and may be a result of a retracted alar lobule or a hanging caudal septum. From the profile the columella is seen to have a double break (Fig. 31–16). The first break is defined as the point at which the tip of the nose turns posterior-inferiorly onto the infratip lobule. The second break occurs at the mid-columella, where the columella takes a more horizontal course and extends posteriorly to the subnasale.

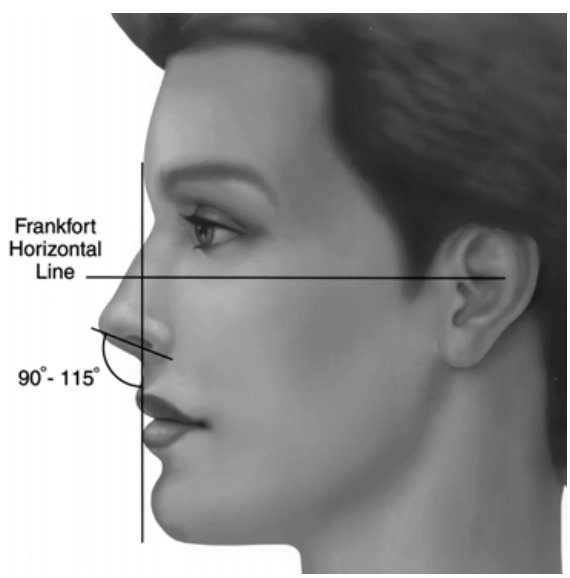

Figure 31–14 The nasolabial angle should be 90 to 95 degrees in men and 95 to 115 degrees in women.

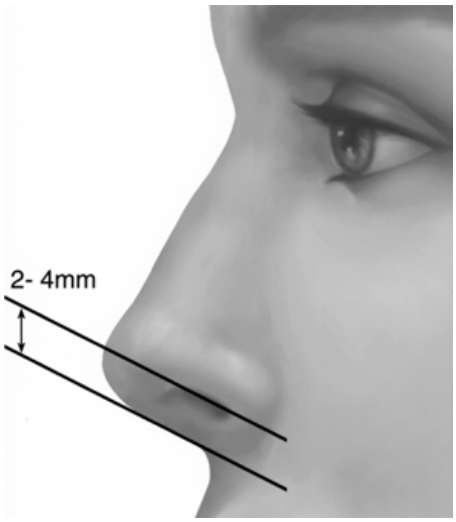

Figure 31–15 Two to 4 mm of columellar show should be visible from the profile.

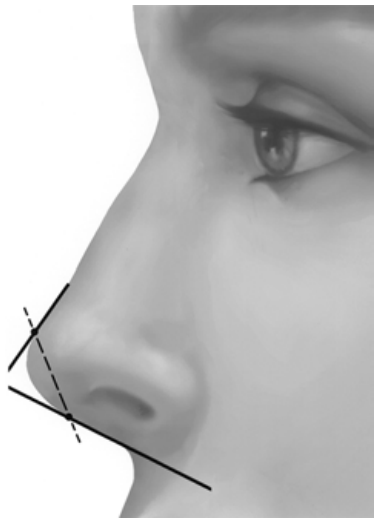

Figure 31–16 Lateral view of the nose. Note the double break between the columella and nasal tip.

BASE VIEW

Preoperative evaluation of the base of the nose should include the size, shape, orientation, and symmetry of the nostrils, the width and length of the columella, and the height of the lobule. When the nose is viewed from the base view an isosceles triangle is seen.[6] Ideally the lobule is one third of the height of the triangle, with the columella contributing the remaining two thirds (Fig. 31–17). The nostrils should be symmetrical and are seen as pear- or teardrop-shaped, with the widest portion at the nostril sill. The width of the nostrils should be about the same as the width of the columella, with their long axis oriented at a 45-degree angle to the columella in the leptorrhine nose. The columella can be seen to flare near its base, conforming to the flare of the medial crural feet of the lower lateral cartilage. The columella is narrowest at its midportion and flares anteriorly as it meets the infratip lobule.

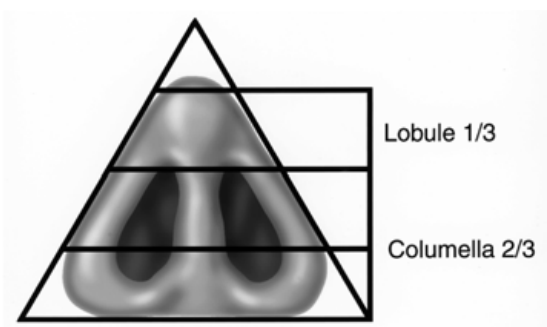

Figure 31–17 Basal view of the nose. Resembles an isosceles triangle with the infratip lobule making up one third and the columella and nostrils two thirds.

INTRANASAL EXAM

The examination is not complete without inspection of the inside of the nose for adequacy of the airway, position of the septum, nasal valve competence, and condition of the mucosa and inferior turbinates. Palpation of the septum with a cotton-tipped applicator may be indicated to determine if septal cartilage is present in a revision rhinoplasty if cartilage grafting material will be required.

NASAL–CHIN RELATIONSHIP

Frequently the patient's and surgeon's attention is directed to the nose alone and the relationship of the nose to the rest of the face is neglected. Failure to address the relationship of the nose to the chin is a common error in the preoperative evaluation of the rhinoplasty patient. In patients with deficient projection of the menton the nose appears disproportionately large even though projection may be appropriate for nasal length. Gonzales-Ulloa described the appropriate chin position by dropping a line from the nasion perpendicular to the Frankfort horizontal plane (Fig. 31–18).[7] The adequately projected chin should approximate this line. A simpler method is to drop a perpendicular line from the vermilion of the lower lip and evaluate chin projection in relation to this line (Fig. 31–19).[8] In male patients the chin should meet or closely approximate this line. Another technique to evaluate projection utilizes a line that touches the most projecting portion (the lips and chin) (Fig. 31–20). Chins of female patients should be within 2 to 3 mm of this line. Computer imaging greatly facilitates communication of this important relationship to patients.

If chin projection is inadequate, it is important to determine whether the patient has microgenia (underdeveloped mental portion of the mandible), micrognathia (underdeveloped mandible with class II occlusion), or retrognathia

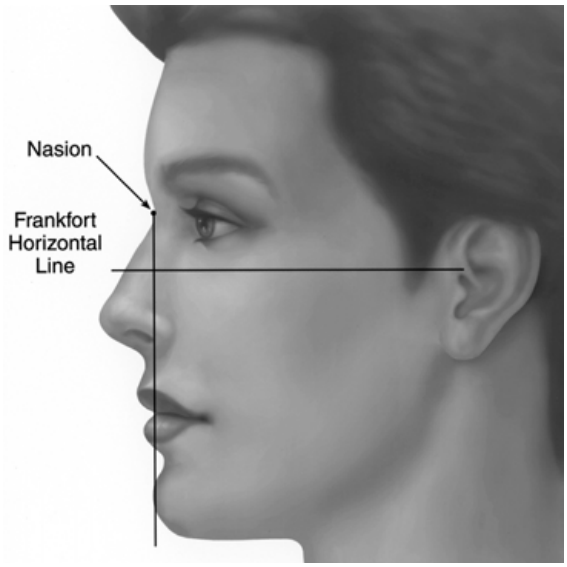

Figure 31–18 Gonzales-Ulloa describes the appropriate chin position in relation to a vertical line dropped from the nasion perpendicular to the Frankfort horizontal plane.

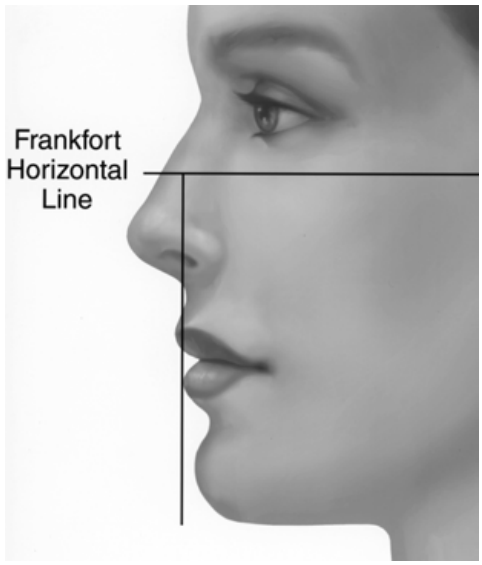

Figure 31–19 The chin should approach a vertical line dropped from the vermilion border of the lower lip.

(mandible is normal in size but retruded with class II occlusion). In the case of micrognathia or retrognathia it is important to discuss the occlusion with the patient in the event that orthognathic surgery is desired. If the patient has microgenia or does not desire orthognathic surgery for the occlusal problem, augmentation mentoplasty may be a consideration.

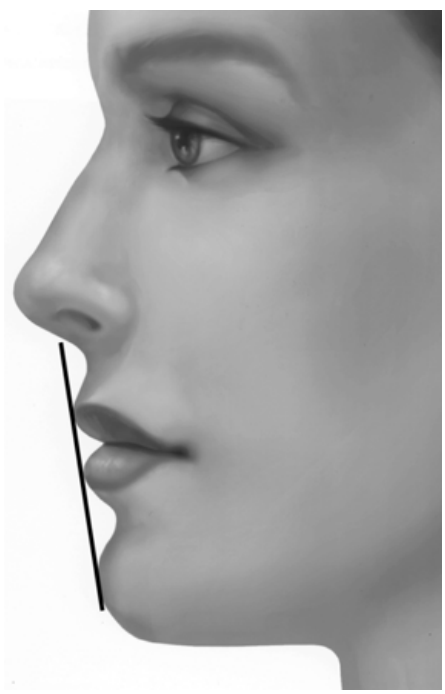

Figure 31–20 Some authors recommend that appropriate chin projection be determined by drawing an oblique line across the most projecting portions of the lips. Inferiorly, the line should touch the menton.

NASAL–BROW–FOREHEAD RELATIONSHIP

The shape of the forehead influences the perception of nasal appearance. There are essentially three fundamental forehead contours: protruding, flat, and sloping.[1] A forehead that slopes posteriorly from the brow to the hairline tends to exaggerate the appearance of nasal length and projection, whereas a flat, vertically oriented, or protruding forehead diminishes the appearance of nasal length. Similarly, the brow or frontal bar influences the perception of the nose (Fig. 31–21). Lowering the nasal dorsum and deprojecting the nose should be approached with caution in the patient with frontal bossing if the upper and middle third of the face are to be kept in harmony. Furthermore, a prominent brow alters our perception of the nasofrontal angle, making it appear deeper and more acute and giving the nose the appearance of greater projection.

PHOTOGRAPHY

High-quality photographs taken consistently with standard views are essential for comparing pre- and postoperative results, for teaching, and for medicolegal documentation, as well as to facilitate communication with the patient. Consistency is the key in taking adequate nasal photographs. Larrabee provided information regarding standardization of photographic equipment, background, magnification, lighting, and views, so that pre- and postoperative photographs are comparable.[9] For the rhinoplasty patient standard views include the frontal, both lateral, both oblique, and basal views. The sky or "bird's eye" view may be advantageous in some circumstances, such as in demonstration of external nasal deviation from the midline. In addition, a lateral photograph with the patient smiling may reveal aesthetic problems in the lower third of the nose that are not evident in

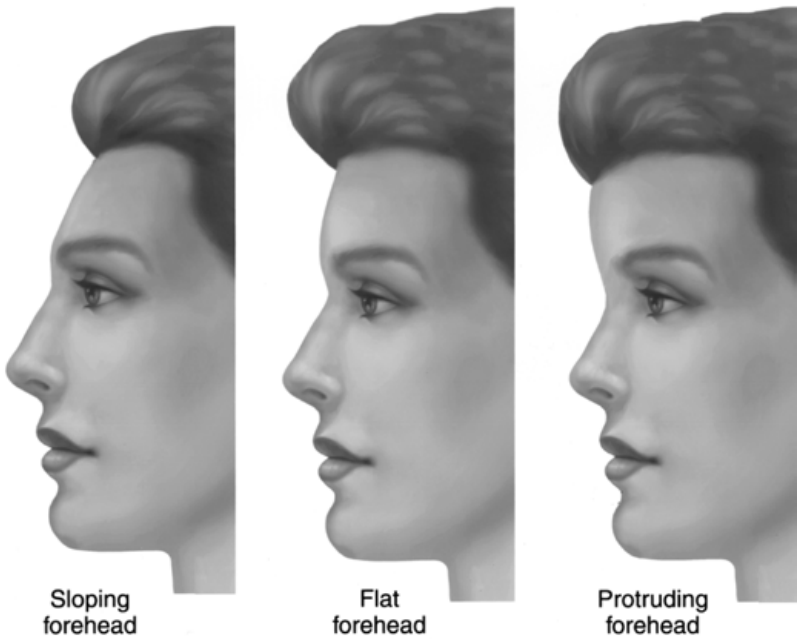

Figure 31–21 The forehead contour influences the perception of the nose. A retrusive forehead tends to accentuate the nose, whereas a prominent forehead diminishes its appearance as seen on these images in which the forehead contour is the only feature changed.

repose. Before the operation, the surgeon and patient should examine the photographs and discuss the desires and goals of the procedure.

COMPUTER ANALYSIS

Computer imaging systems that allow the surgeon to capture and alter the patient's image on the screen can enhance communication between surgeon and patient. Aesthetic concepts that are difficult to articulate can be easily visualized during office consultations. Imagers use video or digital cameras to display the patient's image on a monitor. Patient and surgeon can then discuss what is seen on the image in a more objective fashion. The image can be altered with various software programs to achieve the desired surgical results. The image may be printed on photographic paper or stored in a computer file for later retrieval in an effort to remind the surgeon or patient about the goals of surgery.

SUMMARY

Rhinoplasty more than any other operation in facial plastic surgery requires a thorough knowledge of facial anatomy and an artistic sense of aesthetics. An appreciation of facial proportions, measurements, and relationships and a keenly developed aesthetic judgment will assist the surgeon in preoperative planning and establishing the goals of surgery. The appropriate use of photography and computer imaging can be valuable tools in pre- and postoperative analysis, formulating surgical goals, and facilitating communication of aesthetic concepts between patient and surgeon.

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Chapter 32

Philosophy and Principles of Rhinoplasty

M. Eugene Tardy, Jr., Dean M. Toriumi, and David A. Hecht

Rhinoplasty is a continually evolving operation, but the fundamental philosophy and principles have not changed dramatically over recent years. Advances have been made in the refinement of rhinoplasty through a better understanding of nasal analysis, anatomy, function, and long-term postoperative healing. Novel surgical maneuvers and techniques have also been developed that improve the long-term results of rhinoplasty from both aesthetic and functional standpoints. Furthermore, technological advances in computer imaging and innovative surgical instrumentation have widened the armamentarium available to the surgeon performing rhinoplasty as well as other facial plastic procedures.

Aesthetic surgery of the nose is considered to be the most challenging, rewarding, and humbling of all facial plastic procedures. Every rhinoplasty operation presents the surgeon with a diversity of nasal anatomy, contours, and proportions, requiring a series of organized and interrelated surgical maneuvers tailored to each patient's anatomical and functional needs. The surgeon controls the operative event and must also become skilled at manipulating and controlling the dynamics of postoperative healing to attain optimal long-term aesthetic results. A necessary prerequisite is the skill to visualize the ultimate healed outcome while modifying nasal structures.

Such skills require many years of study and experience as the surgeon observes, analyzes, and modifies surgical results. With the improved methods of analysis and the increased popularity of open (external) rhinoplasty, young surgeons may be able to perform precise maneuvers under direct visualization. The key to self-education through experience is an accurate diagrammatic record keeping coupled with long-term patient follow-up and evaluation (Fig. 32–1).[1,2]

The unique anatomy of the nose is the critical factor influencing the final result of each individual rhinoplasty procedure. Variability in anatomy demands refined diagnostic skills to identify the infinite variety of problems encountered. The aesthetic judgment of the surgeon, guided by patient expectation, determines the surgical changes planned. No single procedure or technique will suffice to reconstruct every nose in an aesthetically pleasing fashion. Therefore, the surgeon must be skilled in many different approaches and maneuvers to handle the wide range of nasal anatomic combinations. The ability to identify correctable deformities and limitations inherent in each patient exists as the single most critical prerequisite to attainment of outstanding results on a consistent basis. Misguided attempts to create changes greater than the tissues will permit (overoperating) frequently result in aesthetic and functional complications resulting from overaggressive resection of supportive structures (Fig. 32–2).

NASAL ANATOMY

The nose can be separated into several anatomic components, including the covering skin, the bony pyramid (nasal bones, bony septum, and ascending process of the maxilla), the cartilaginous pyramid (upper lateral cartilages and cartilaginous septum), and the nasal tip (lower lateral cartilages) (Fig. 32–3A).[3] The nasal tip can be further broken down into the domal region, infratip lobule, alar sidewalls, and columella (Fig. 32–3B).

The nose has a rich arterial blood supply derived mainly from branches of the facial and superior labial arteries.[4] These arterial branches are accompanied by corresponding veins and lymphatics that run together in a plane within the superficial musculoaponeurotic system (SMAS) layer of the nose. This relationship of the nasal blood supply to the SMAS layer of the nose bears clinical importance.[5] By elevating the skin–soft tissue envelope off the nasal skeleton *below* the SMAS layer during rhinoplasty, maximal blood supply and SMAS layer cushioning will be preserved in the overlying skin–soft tissue envelope.

PATIENT EVALUATION

Throughout the entire evaluation process, ongoing analysis of the patient's motivations, expectations, and rapport with the surgeon is vital. This important information may help identify the problem patient with unrealistic expectations.[6] If the patient's anatomy suggests significant surgical limitations, surgical management should be planned only if outcome limitations are clearly understood and accepted by both patient and surgeon.

Careful examination of the nose and surrounding facial structures is critical before any decisions regarding the actual surgical plan can be made. The ideal nose differs for every patient and depends on facial features, the surgeon's sense of aesthetics, and the ability to surgically create the desired nasal shape.

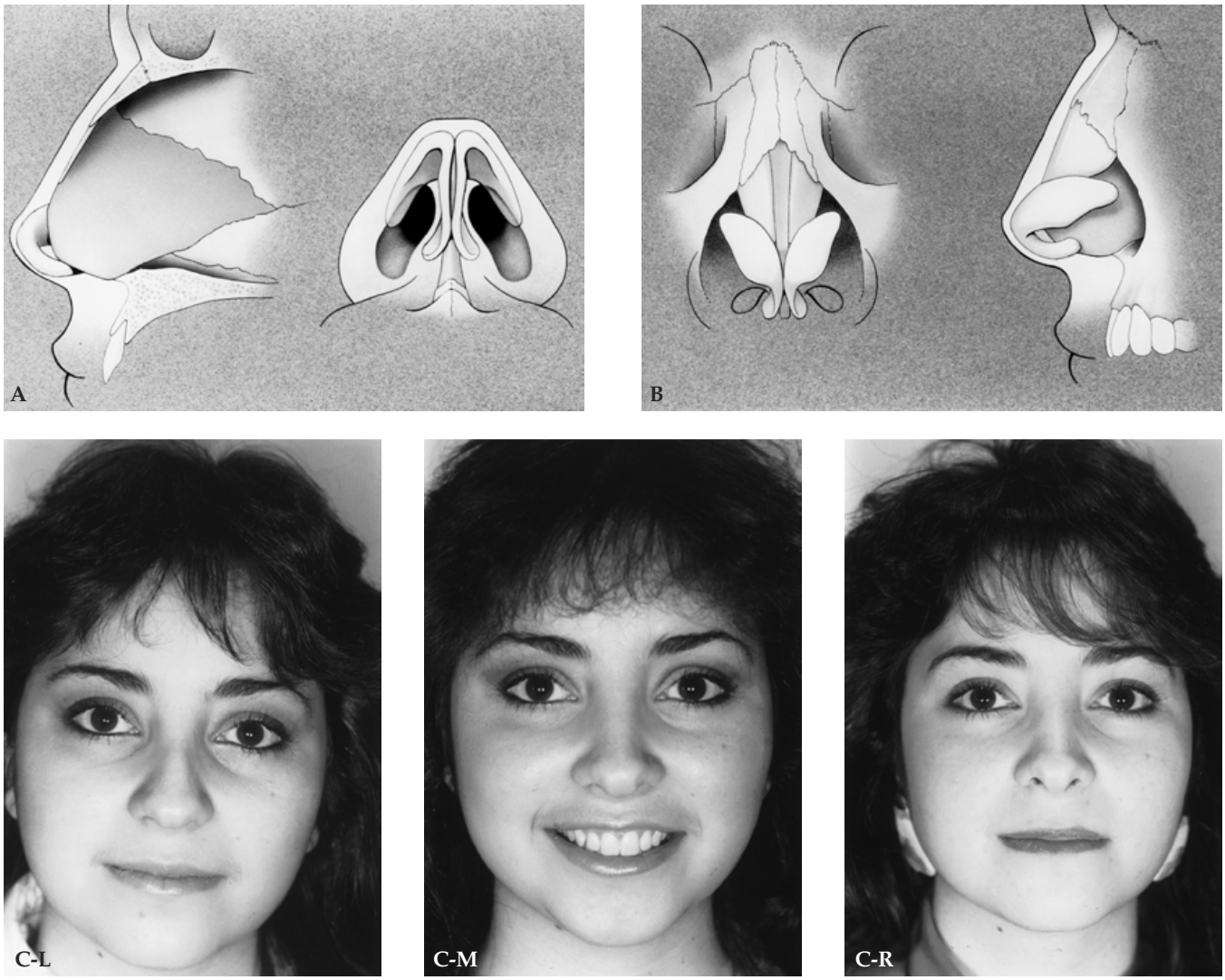


Figure 32–1 (A, B) Graphic charts used in visual record keeping of the techniques and maneuvers carried out during rhinoplasty. Comparison of this graphic record with the long-term outcome provides an instructive self-analysis of the usefulness of particular surgical techniques. Long-term follow-up of young girl who has undergone aesthetic septorhinoplasty (5 years). Column 1 illustrates the preoperative condition, column 2 the result at 1 year, and column 3 the final outcome at 5 years. Note the evolutionary progression of healing refinements over time. *(continues on next page)*

Balance and harmony of proportionate facial features are critical in determining the ideal nose for a particular face. For example, the degree of nasal projection that is appropriate for an individual patient may be influenced by the projection and shape of the chin and mandible. An overprojected nose may not appear to be as unsightly in a patient with a strong chin and mandible. However, an adequately projected nose may appear overprojected in a patient with an underprojected chin or retrognathia. This relationship can be exploited in the case of an overprojected nose with an underprojected chin. In these cases, moderate retroprojection of the nose can be performed and supplemented by chin augmentation. Nasal projection will not have to be reduced to a point where the structure and balance of the nose are compromised, yet the increased chin projection will balance even a slightly overprojected nose.

The thickness of the skin overlying the nasal structure is perhaps the most critical factor in achieving ideal results in rhinoplastic surgery. Skin of moderate thickness is ideal because it usually conforms to the underlying cartilage and bone; therefore, surgical changes made in the nasal skeleton (cartilage and bone) translate the desired soft tissue changes. In addition, nasal skin of moderate thickness possesses enough subcutaneous fibrofatty tissue to provide a satisfactory cushion over the nasal skeleton to hide small irregularities of the nasal dorsum or asymmetries of the lower lateral cartilages.

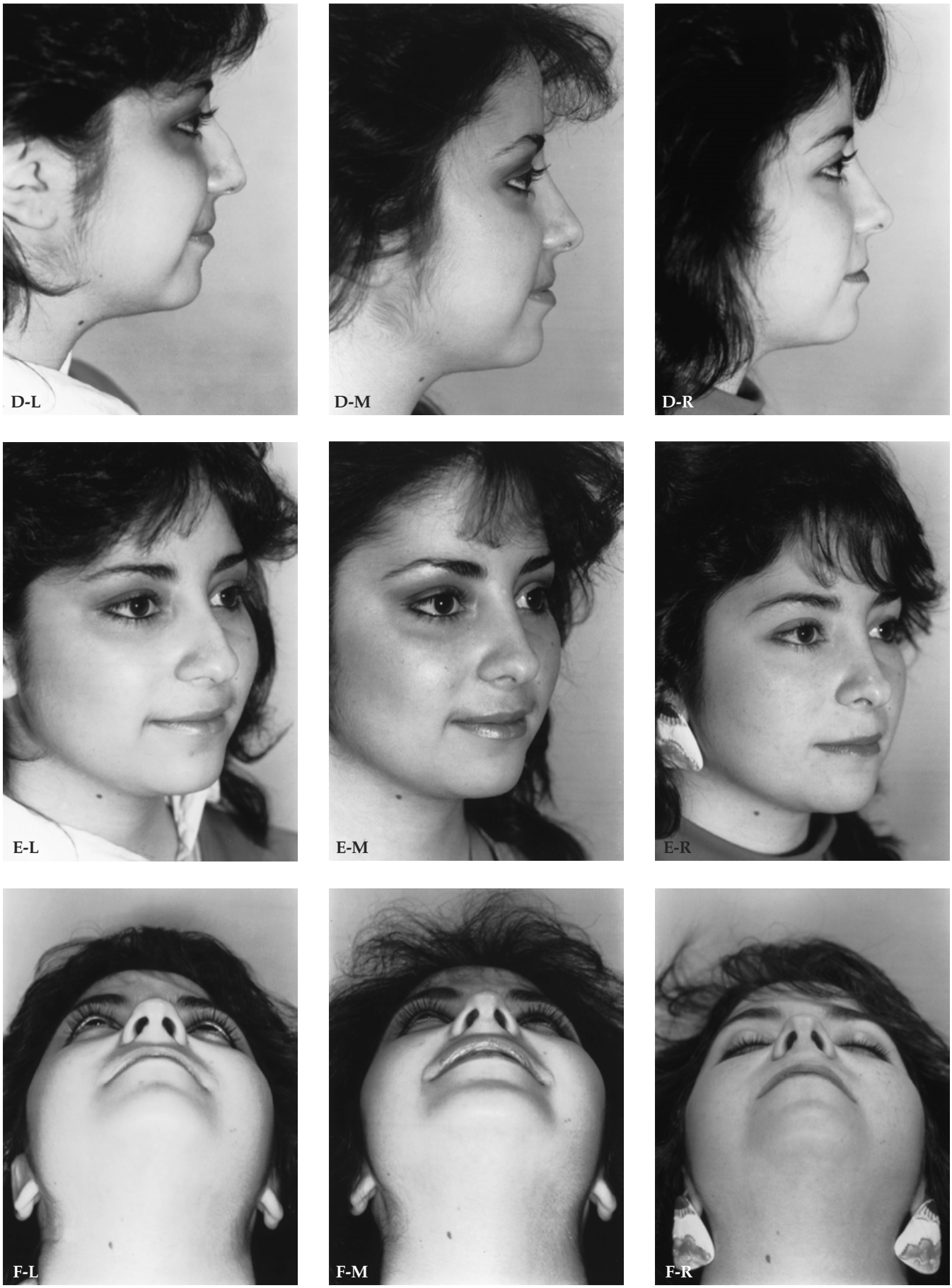


Figure 32–1 *(continued)*

Figure 32–2 Patient with iatrogenic overprojection of the tip several years following rhinoplasty surgery. **(A)** Inappropriate tip refinement technique was chosen, resulting in disproportion of the nose. Original operative record was unavailable. **(B)** Revision surgery consisted of exploration of the nasal tip with retropositioning of the overprojection phenomenon, intended to bring the nose into better balance.

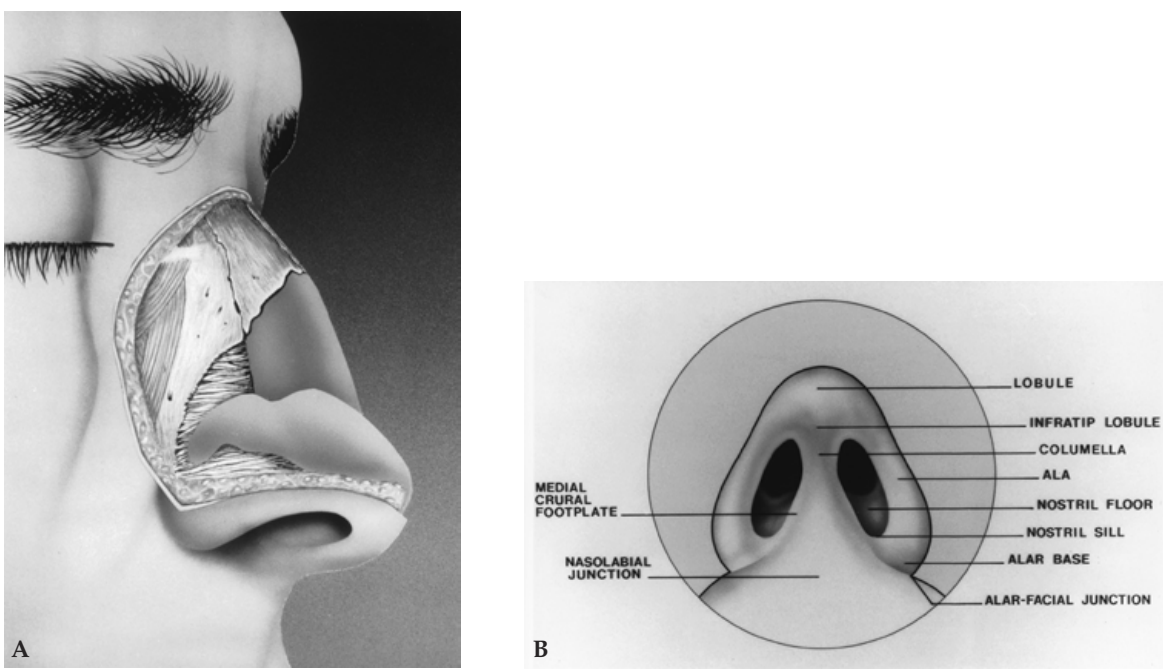


Figure 32–3 **(A)** Artist's rendering of the anatomical components of the nose. **(B)** The anatomy and topographic designations of the nasal base.

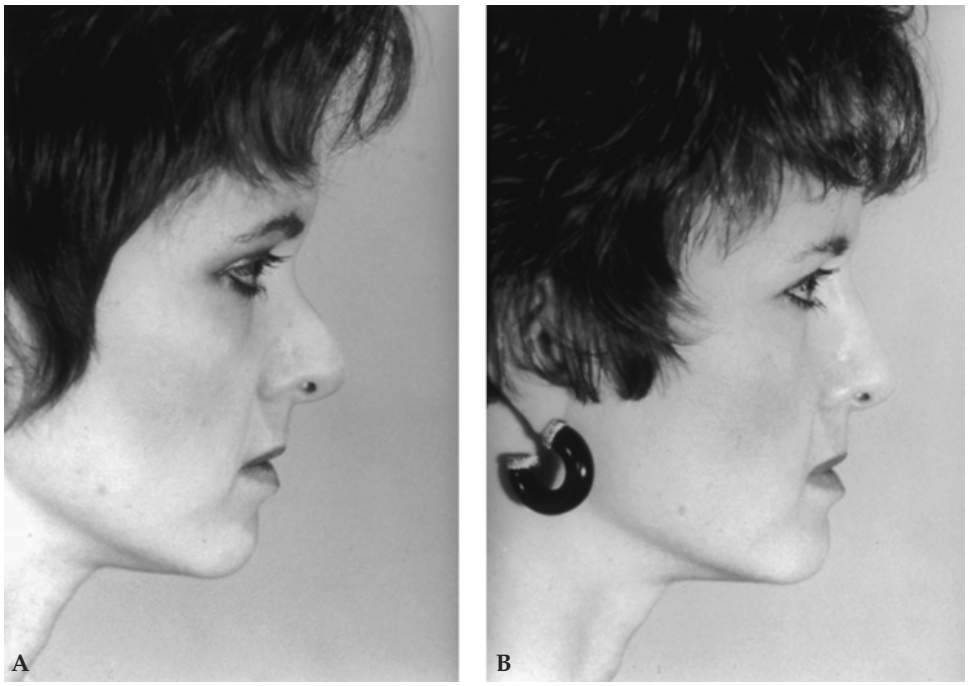


Figure 32–4 **(A)** Patient requesting revision rhinoplasty following overaggressive procedure carried out elsewhere. **(B)** Revision repair utilizing autogenous cartilage grafts to augment the overdeep bony dorsum and nasofrontal angle, with reduction of the soft tissue and cartilaginous pollybeak deformity.

Thick sebaceous skin tends to be inelastic, possessing a memory of its own. A nose with thick skin may suggest the temptation for aggressive changes in the shape of underlying cartilages to effect a change in soft tissue nasal contour. These aggressive maneuvers tend to weaken the support of the nasal skeleton, which may ultimately buckle and collapse under the forces of scar contracture. In some cases, the memory of the skin is so great that no matter what is done to the nasal skeleton, the skin will not drape, leaving a dead-space void. This void may become occupied by scar tissue producing an amorphous nasal tip and soft tissue pollybeak (Fig. 32–4).[7]

Extremely thin skin is often pale and freckled and must be recognized and respected for its inherent limitations. Although ideal for obtaining critical definition, thin skin with limited subcutaneous tissue provides almost no cushion to hide even the smallest skeletal irregularities or contour imperfections. Working with thin skin requires near-perfect surgery to achieve the desired result. These patients also tend to demonstrate undesirable progressive skin retraction and shrinkage over several years, rendering the nose potentially unnatural and angular.

Evaluation of the skin is performed by close inspection and by palpation in the form of gentle pinching of the overlying skin to see how it glides over the nasal skeleton. In the non-Caucasian nose, the skin is commonly so thick and the cartilages so weak that at times it may be difficult to even appreciate the cartilages. In revision cases, skin thickness may be deceiving because of dense scar tissue, obliterating what once was a well-defined, subcutaneous fibrofatty tissue plane.[8]

When examining the patient, it is essential to evaluate the inherent strength and support of the lower third of the nose by using fingertip depression to test tip recoil.[9] The tip of the nose is firmly depressed toward the upper lip and then released, allowing the tip to recoil (Fig. 32–5). This is a reliable

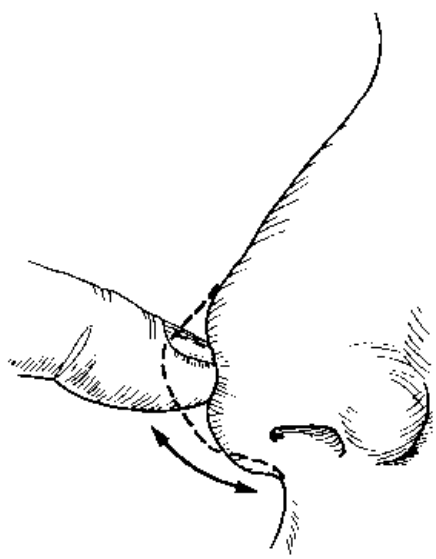


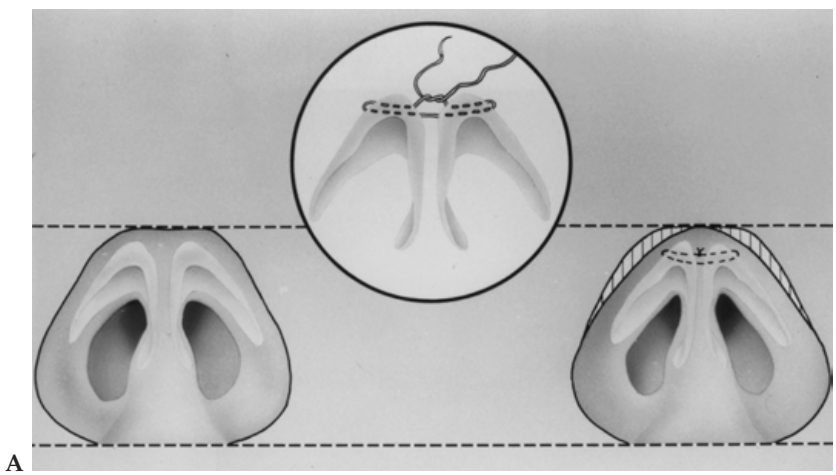
Figure 32–5 Tip recoil phenomenon demonstrated on nasal tip. A degree of resilience of the nasal tip supportive structures provides a reliable guide to the ability of the nasal tip to retain satisfactory support and projection following tip refinement procedures.

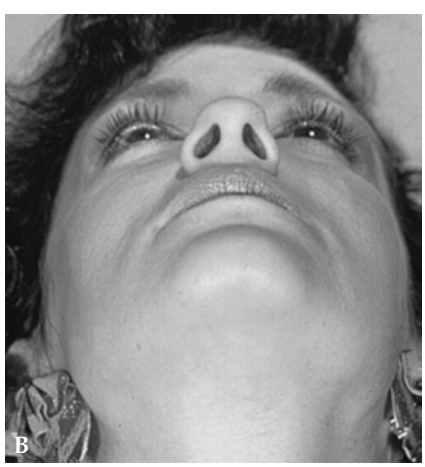
support test of the mobile lower third of the nose. A nose that lacks tip support probably has weak lower lateral cartilages that will not tolerate much loss of support through aggressive tissue excision, suggesting the addition of supportive struts to prevent postoperative loss of tip projection. If tip recoil is vigorous and the tip cartilages resist the force exerted by fingertip depression, reasonable surgical manipulation of the lower lateral cartilages can usually be performed without a significant loss of tip support. Palpation or ballottement of the lateral crura between two fingers can provide important information about the size, shape, and strength of the alar cartilages. Buckles or asymmetry of the lower lateral cartilages should be identified before surgery, because these findings may influence the manner in which the cartilages are manipulated. The domal region should be examined to determine the distance between the domes. Significant tip bifidity requires narrowing the interdomal distance to achieve refinement (Fig. 32–6). The relationship between the anterior septal angle and domes should also be evaluated.

The length and strength of the upper lateral cartilages should be compared with the length of the nasal bones. Short nasal bones are usually associated with longer upper lateral cartilages. Patients with short nasal bones tend to possess less support in the region of the internal nasal valve because the long upper lateral cartilages can collapse inward on inspiration (negative pressure).[10,11] This is particularly true if a sizable dorsal hump is removed, leaving the caudal margin of the upper lateral cartilages with even less support. The internal nasal valve is composed of the angle defined by the caudal margin of the upper lateral cartilages, the nasal septum, and the floor of the nose. If the caudal margin of the upper lateral cartilages is weakened, allowing it to collapse inward, the dimensions of the internal nasal valve can decrease dramatically. To prevent such problems, when a large dorsal hump is removed leaving long-flail upper lateral cartilages, spreader grafts can be positioned between the dorsal edge of the septum and the upper lateral cartilages to prevent their collapse and prevent overnarrowing of the nasal middle third, characterized by an "inverted-V" deformity.[11]

The columella and caudal margins of the septum can be palpated between the thumb and index finger to supply information about the relationship between these two structures. On occasion, the caudal septum may be twisted or the quadrangular cartilage overdeveloped, pushing the medial crura and columella inferiorly and creating a convex, overly prominent columella in relation to the alar rim (Fig. 32–7). Palpation in this region can also provide information about the anterior nasal spine and its relationship to the posterior septal angle.

The width and length of the columella and medial crura should be determined because of the support provided by this anatomic complex. Short medial crura usually require a cartilaginous strut to provide support and prevent postoperative loss of tip projection.[11] In the overprojecting nose, extremely long or flaring medial crura can be reduced in





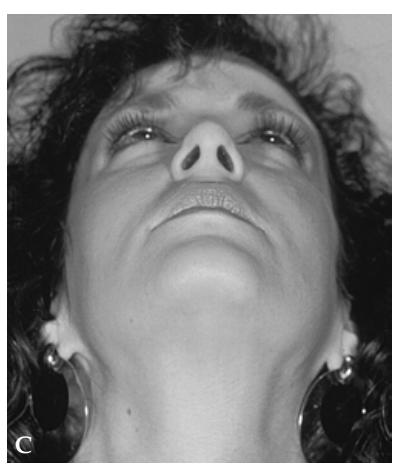


Figure 32–6 **(A)** Transdomal suture narrowing refinement of trapezoidal nasal tip creates improved triangularity and refinement without disturbing the integrity of the lower lateral cartilages. **(B)** Patient with broad amorphous tip prior to surgery. **(C)** Narrowing refinement 2 years following transdomal suture refinement.

Figure 32–7 **(A)** Patient with a large nose demonstrating overdevelopment and alar–columellar disproportion, as well as elongation of the caudal septum, creating a "hanging" infratip lobule phenomenon. **(B)** Correction involves reduction of the length of the quadrangular cartilage, excision of redundant vestibular skin, and shave-excision of the caudal margin of the medial and intermediate crura.

width and length to retroproject the lower third of the nose. Whether the tip–lip complex is tethered by an active musculus depressor septi nasi must also be determined.

A thorough intranasal examination before and after shrinkage of the mucosa of the septum and turbinates is an essential part of the initial examination. Shrinkage of the mucosa permits superior visualization of septal deviations and spurs along the floor of the nose. Identification of a deviated ethmoid plate is critical because it may be responsible for nasal obstruction after osteotomy and infracture of the bony sidewalls. Careful examination of the nasal valve region and turbinates is performed to determine if surgical reduction of the turbinates is required to improve overall nasal function. Finally, the surgeon must ensure that no septal perforations or synechiae exist.

The position and inclination of the nasofrontal and nasolabial angles must be carefully evaluated (Fig. 32–8). The nasofrontal angle can vary greatly from patient to patient. The deepest point of the nasofrontal angle is called *the sellion* and corresponds to the nasal starting point.[3] The nasal starting point in women should ideally be at or just below the level of the superior palpebral fold. In men, the nasal starting point should be at or just above the level of the superior palpebral fold. In some patients, the nasofrontal angle is blunted with a poorly defined nasal starting point. This can be due to a bony prominence in this region or a thick procerus muscle that tents across and blunts the nasofrontal angle. To correct this deformity, it may be necessary to excise bone or muscle to produce a well-defined nasal starting point.

An overly acute or retracted nasolabial angle can be effaced by placing cartilage plumping grafts at the columellar–labial junction. In more severe cases, such as is seen in non-Caucasian noses, larger premaxillary grafts can be positioned on the premaxilla through a sublabial incision to help bring out the acute nasolabial angle.[12]

The size and shape of the alae and alar base should also be examined, with assessment regarding how this shape may change with an increase or loss in nasal tip projection (Fig. 32–9). In some cases, alar base excisions may be necessary to provide harmony with the size and shape of the rest of the nose.

Finally, a functional assessment of the nose should be performed with an emphasis on dynamic forms of nasal airway obstruction, particularly the internal and external nasal valve regions. The internal nasal valve, as described previously, can be evaluated in two different ways. The Cottle maneuver is performed by retracting the cheek soft tissue and adjacent nasal wall laterally while the patient inspires through the nose. Alternatively, a blunt instrument (such as a nasal speculum or cerumen curette) can be inserted in the nose and used to directly displace the lateral nasal wall outward.[10] Both of these maneuvers result in decreased air flow resistance in the widened internal nasal valve region and are noted by the patient as conferring an improvement in nasal breathing. External nasal valve collapse is best evaluated from a basal view of the nose and manifests as collapse of the nostril margin (alar collapse) on nasal inspiration. It is important to evaluate and recognize nasal valve collapse because it is surgically correctable with the use of various grafting techniques.[10,11]

Figure 32–8 **(A)** Patient requesting rhinoplasty. **(B)** Postoperative view shown 5 years following surgery, demonstrating near-ideal configuration of the nose, nasofrontal angle, and nasolabial angle.

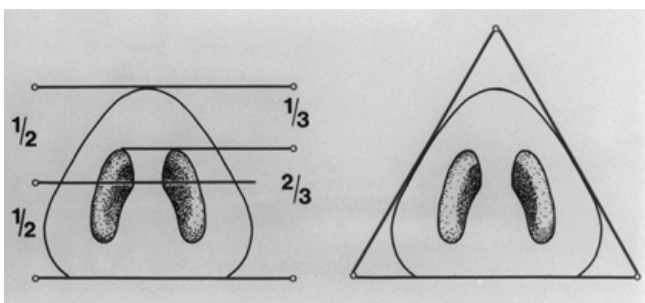


Figure 32–9 Ideal proportionate configuration of the nasal base.

PHOTOGRAPHIC AND COMPUTER IMAGING

Standard and uniform color photographs of the rhinoplasty patient, recorded before and after surgery, are important because they provide permanent records of the patient's deformity and how it has been corrected. The preoperative photographs are important guides to operative planning and execution. The entire set of preoperative and postoperative photographs provide a means of evaluating the progress of the patient, an invaluable teaching tool, and a vital medicolegal record.

Standard 35-mm color slides (Kodachrome or Ektachrome) in six standard head positions are preferred. Standard views in rhinoplasty photography include full frontal, right and left lateral, right and left oblique, and basal views (Fig. 32–10). Use of a standard 105-mm portrait lens with dual-flash strobe units and an overhead slave key flash provides high-quality shadow-free representations of the nose and surrounding facial features.[13] A light blue background works well because this color complements skin tones. The photographic technique used should remain constant from sitting to sitting to produce standardized and uniform photographic records.

Computer imaging can be useful in facilitating communication between the surgeon and the patient.[14] Oftentimes, patients have difficulty describing the nasal deformities of concern and expressing the changes they desire. This also provides an opportunity for the surgeon to demonstrate to a patient what changes are realistic and surgically attainable. The nasal profile view lends itself well to computer imaging manipulation because the flesh-colored nasal contour is contrasted sharply against a selected colored background. Furthermore, profile changes can be made in the chin region to demonstrate to the patient the importance of balance between nasal and chin projection. The frontal view is more difficult to manipulate on the computer than the profile view because the nose is contrasted against the flesh-colored background of the face. However, by shifting shadows on frontal view it is possible to effect changes in nasal appearance. Finally, it must be emphasized to the patient that the images produced by the computer serve as a guideline of the proposed changes and hold no guarantee of the final results.

Figure 32–10 Typical preoperative photographic views obtained for rhinoplasty planning and documentation. Additional close-up views are recorded when required.

ANESTHESIA

Rhinoplasty can be performed under general anesthesia or local anesthesia with intravenous sedation.[15] No matter what mode is used, the key to anesthesia is comfort, safety, and good communication between the surgeon and the anesthesia provider. The patient must be made as comfortable as possible without compromising oxygenation. Proper use of the local anesthetic agents (1% lidocaine with 1:100,000 epinephrine, freshly mixed) provides good anesthesia and limited bleeding. The surgeon must dissect within the correct tissue planes during the operation to prevent unnecessary bleeding, violation of muscle, or thinning of skin flaps. Dissection in proper nonvascular areolar tissue planes prevents bleeding, decreases postoperative edema, and reduces scar tissue formation.

Choice of injection site depends on the particular approach to the nose that is used. The smallest amount of local anesthesia possible should be used to prevent distortion of tissues.

PRINCIPLES IN SHAPING THE NASAL TIP

Shaping of the nasal tip is the most exacting aspect of nasal plastic surgery. The surgeon must modify the lower lateral cartilages with a symmetric surgical technique, factoring in the dynamics of healing. Furthermore, no single surgical technique can be used on all noses because of the endless anatomic tip variations encountered. The surgeon must devise a surgical plan based on factors such as skin thickness, strength and shape of the alar cartilages, domal angle anatomy, dorsal contour, length and width of the nose, tip–lip angulation, requirements for tip projection and rotation, and, most importantly, patient expectations.

A fundamental principle of tip surgery is that normal or ideal anatomic features of the tip should be preserved and abnormal features analyzed, exposed, and modified. Experienced nasal surgeons realize that radical excision of alar

cartilages and other tip support mechanisms frequently leads to loss of tip support, buckling, and an unnatural appearance. What may appear satisfactory immediately after surgery may heal poorly because of overaggressive tissue excision. The goal of rhinoplasty is to achieve a more favorable appearance without compromising nasal support. The philosophy of a graduated systematic anatomic approach to tip surgery is highly useful to achieve consistent long-term natural results.[13] Conservative reduction of the cephalic margin of the lateral crus, preserving at least 5 to 7 mm of complete strip of residual alar cartilage, is preferred. As the severity of the tip deformity becomes more profound, more aggressive techniques may be required (Fig. 32–11). These procedures may involve interruption of the lateral crural strip, resection of excess cartilage, followed by suture reconstitution of the divided edges. In cases where these more aggressive maneuvers are needed to produce a change, it is prudent to resect less cartilage and reconstitute all flail segments to control healing and use sutured-in-place columellar struts and sutured-in-place tip grafts to provide the desired shape.[16]

Tip reshaping techniques cannot be performed with success until the major and minor tip support mechanisms are recognized, respected, and preserved or at least reconstructed.[17] Postoperative loss of tip support and projection is one of the most common iatrogenic consequences of rhinoplasty surgery. This loss of support is usually secondary to the sacrifice of one or more tip support mechanisms.

In most patients the major tip support mechanisms include (1) the size, shape, and resilience of the medial and lateral crura, (2) the wrap-around attachment of the medial crural footplates to the caudal margin of the quadrangular cartilage, and (3) the connective tissue attachment of the cephalic margin of the alar cartilage to the caudal margin of the upper lateral cartilage (scroll or recurvature). Whenever possible, an attempt should be made to reconstruct these major support mechanisms when they are divided.

The minor tip support mechanisms, which in certain anatomic configurations may assume major importance as a support mechanism, include (1) the interdomal ligament, (2) the dorsal cartilaginous septum, (3) the membranous septum, (4) the sesamoid complex, (5) the skin and subcutaneous fibrofatty tissues, and (6) the nasal spine. On occasion, because of extreme anatomic variability, a minor tip support may assume the importance of one of the more major supports. In light of the importance of these support mechanisms, tip incisions, approaches, and techniques should be planned to preserve as many tip supports as possible.

In Caucasian patients, nasal tip projection is usually adequate, and attempts should be made to preserve that degree of tip projection. Unfortunately, many of the maneuvers used to correct profound tip anomalies actually weaken tip support and result in a postoperative loss in tip projection. Thus, columellar struts and tip grafts are recommended in selected patients to reestablish the preoperative level of tip projection.

The correct use of terminology is critical in communicating technical aspects of rhinoplasty procedures. The frequently misused terms *incision*, *approach*, and *technique* must be differentiated. An incision is a cut or the act of cutting to gain access to the underlying skeletal structures (in this case, bone and cartilage) of the nose. An approach is the specific anatomical dissection that provides surgical exposure of the skeletal structures, in this case consisting of procedures to

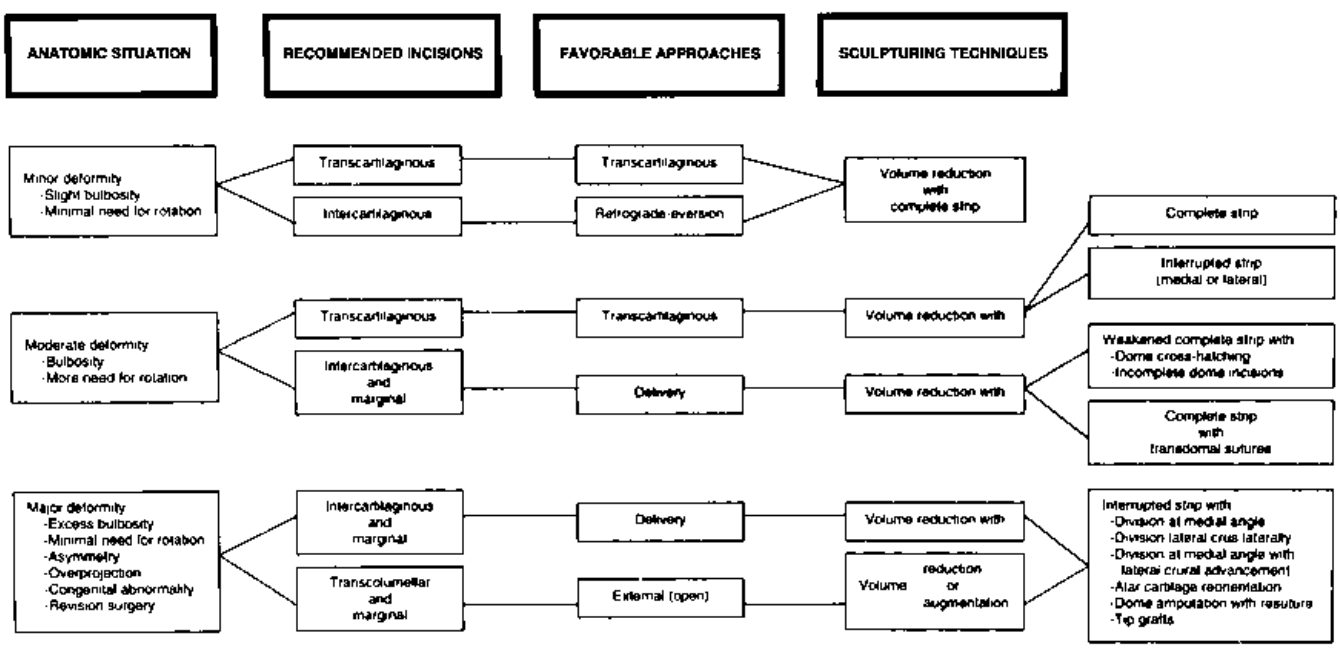


Figure 32–11 An operative algorithm is useful in selecting the incisions, approaches, and techniques used in nasal tip surgery. In every case, the patient's anatomy dictates the selection.

deliver the tip cartilages or to avoid complete delivery, by operating on the alar cartilages without removing them from their anatomic beds. A technique is the specific method of procedure and the details of the surgical operation (i.e., excision, reorientation, or reconstruction of the alar cartilages to produce a predicted change in the projection, size, shape, and definition of the nasal tip).

Before making any changes in the tip, the surgeon must determine if the tip requires (1) a change in projection, (2) a reduction in the volume of the alar cartilages, (3) cephalic rotation with an increase in the columellar inclination, or (4) a change in the shape or orientation of the alar cartilages. In patients requiring *limited* refinement of the nasal tip, conservative reduction in the volume of the cephalic margin of the lateral crus can be executed, preserving the majority of the lateral crus and maintaining a complete (uninterrupted) strip of alar cartilage. When properly used, this technique provides the subtle tip refinement and minimal rotation while conferring little risk of postoperative deformity secondary to loss of tip support.

As the nasal tip deformity increases in size and complexity, more aggressive techniques must be considered. The philosophy of the graduated, incremental anatomic approach to the nasal tip is useful. This approach implies that no routine tip procedure is used; instead, the appropriate incisions, approaches, and tip sculpturing techniques are selected based entirely on the analysis of the varying anatomy encountered.

SURGICAL APPROACHES TO THE TIP

Nondelivery Approaches

In many patients the surgeon may encounter favorable nasal tip anatomy, composed of minimal tip bulbosity, medium skin thickness, and tip–cartilage symmetry. In such individuals, conservative tip refinement can be performed using nondelivery approaches. Less dissection and tissue manipulation is required, thereby reducing the possibilities of surgical error, tip support loss, asymmetries, and unfavorable healing. Properly executed, nondelivery approaches permit the surgeon to control healing to a greater extent than more radical approaches (delivery) and techniques (dome division).

The transcartilaginous approach (Fig. 32–12) is the preferred nondelivery approach because of its simplicity; similar tip modifications can be accomplished through the retrograde approach (Fig. 32–13). These approaches are most effective in patients with limited nasal tip bulbosity that only requires modest volume reduction of the cephalic margin of the alar cartilages. Such noses have a favorable triangularity of the tip, manifested as an equilateral triangle on the basal view (Fig. 32–14). In the case of widely arched, bifid, or bulbous lower lateral cartilages, the domal region requires aggressive alterations that cannot be accomplished through a nondelivery approach.

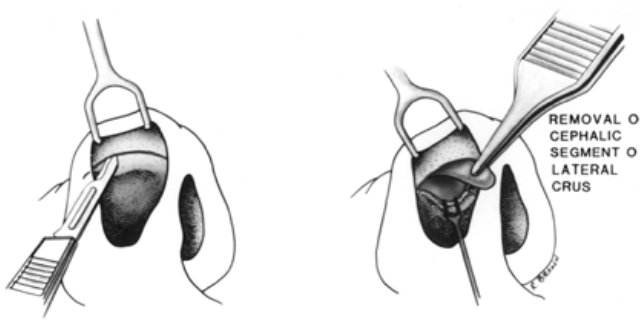


Figure 32–12 Nondelivery approach to the nasal tip cartilages via the cartilage splitting (transcartilaginous) approach.

Delivery Approaches

In the case of more severe tip deformities requiring alteration of alar cartilage shape or orientation, the alar cartilages may be effectively delivered through intercartilaginous and marginal incisions as chondrocutaneous flaps (Fig. 32–15). The basal view can provide important information in the determination of triangularity of the nasal tip. If the alar cartilages are widely arched and bulbous with flared nostrils, tip triangularity is unsatisfactory and a delivery approach may be necessary to correct these deformities. A highly useful and effective technique involves transcartilaginous suture narrowing of broad, widely arched domes through the delivery approach (Fig. 32–16).[18] For more radical tip narrowing and cephalic rotation, interrupted-strip techniques can be performed, almost always by reconstituting the strip with fine sutures. The surgical exposure provided by the delivery approach is superior to that of nondelivery approaches but involves more disturbance of normal tissues. The open (external) approach provides maximal exposure.

External Rhinoplasty Approach

The open or external rhinoplasty approach requires bilateral marginal incisions connected by a transcolumellar incision at the level of the midcolumella (Fig. 32–17). The visualization provided by the open approach is unparalleled, affording the surgeon diagnostic and technical capabilities unavailable

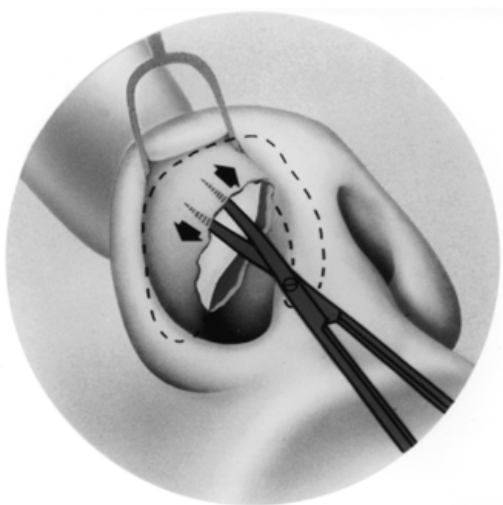


Figure 32–13 Alternative nondelivery approach to the nasal tip cartilages via a retrograde approach.

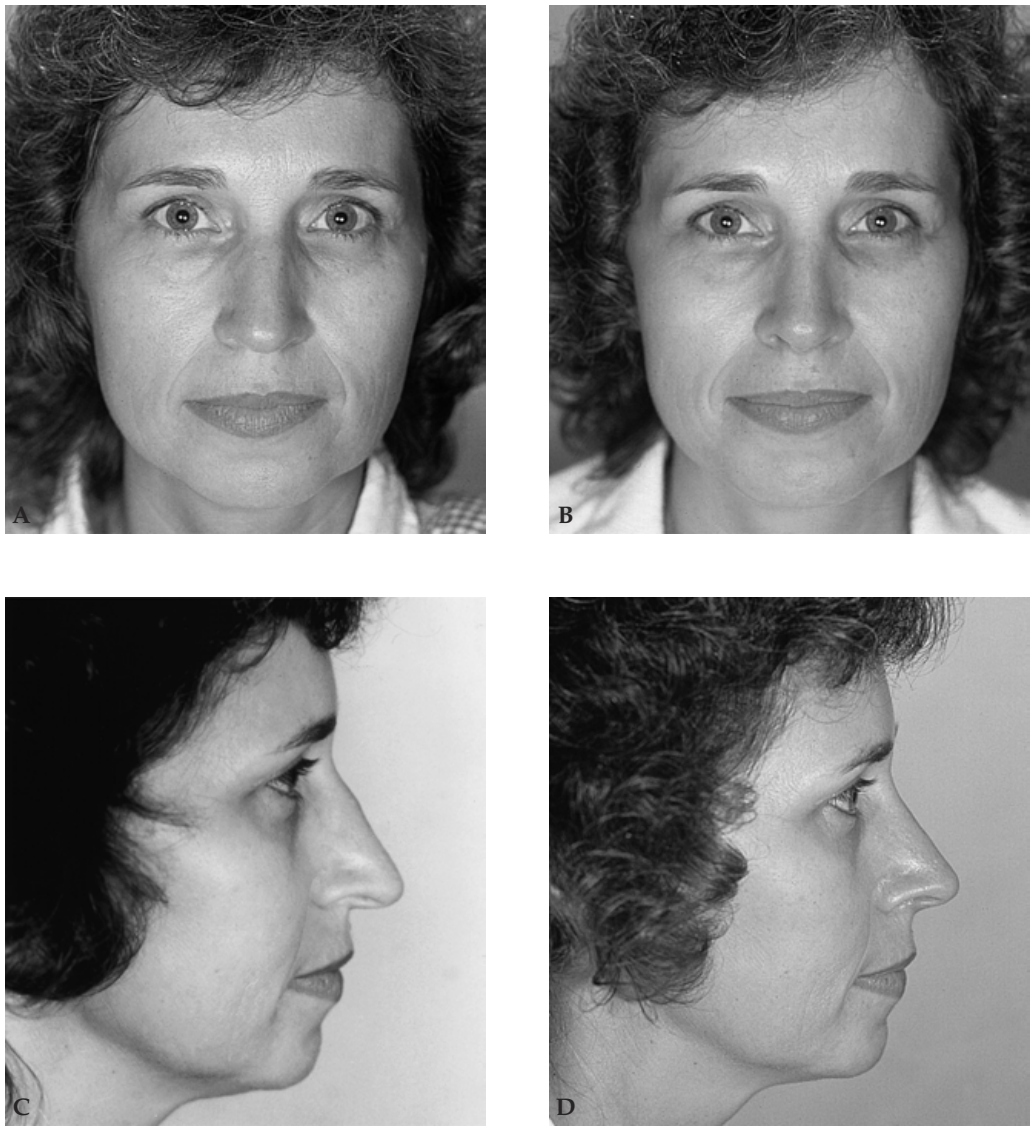


Figure 32–14 Two-year follow-up of patient operated utilizing a nondelivery cartilage splitting approach to the nose. Preoperative (column 1) and postoperative (column 2) condition.

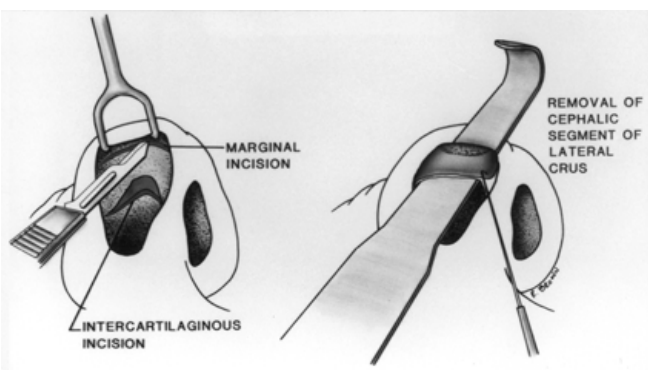


Figure 32–15 Delivery of the nasal tip cartilages via intercartilaginous incisions combined with marginal incisions, utilized to deliver the cartilages as chondrocutaneous flap for evaluation and tip refinement surgery.

through traditional endonasal approaches (Fig. 32–18). This approach appears aggressive; however, the means of exposing the nasal skeleton does not in itself divide any major support mechanisms. The transcolumellar scar is of negligible importance if it is closed using proper techniques of skin eversion and early suture removal.[19] Disadvantages of the open approach include an enlarged region of dissection with possible scar formation, prolonged nasal tip edema, and increased operating time. None of these disadvantages can be considered major problems for experienced surgeons; however, the diagnostic and technical virtues must be weighed with the potential disadvantages. Indications for the open approach include a nasal tip that is asymmetrical, markedly bulbous, severely overprojected or underprojected, or anatomically complex (revision or cleft noses, infantile nostrils).[19,20] Relative indications include a nose with thick skin, poor tip support, or large perforations. One of the most valuable uses of the open approach is for teach-

Figure 32–16 Nine-year follow-up of patient with bifid, trapezoidal, twisted, and overprojected tip, approached through a delivery procedure. **(A)** Preoperative view. **(B)** Volume reduction and transdomal suture refinement of the nasal tip resulted in an improved triangular configuration to the nasal tip. Bilateral alar reduction procedures were necessary to improve the flaring of the alae secondary to retropositioning of the overprojected tip.

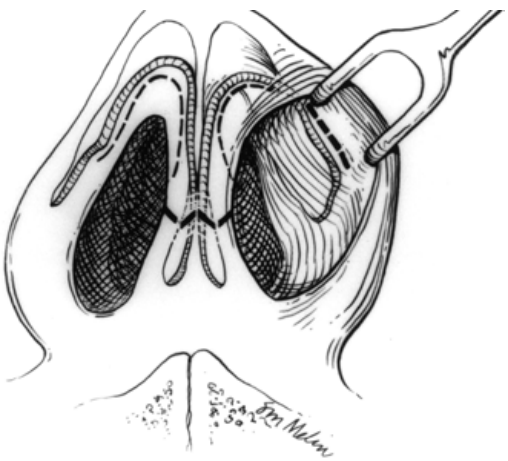


Figure 32–17 Open rhinoplasty approach to the nasal tip cartilages.

ing purposes. When subtle and conservative tip surgery is indicated by the patient's nasal contour, the open approach is unnecessary.

With the increased popularity of the open approach, techniques stressing a structurally sound nasal structure have been reemphasized. Open structure techniques may incorporate a sutured-in-place columellar strut, dome-binding sutures, and sutured-in-place tip graft. These basic maneuvers are more readily performed via the open approach to allow precise placement of struts and grafts, although in expert hands the closed approach can be preferable. The key to this technique is the precise control of tip shape, projection, and rotation, while preserving support and structure for long-term stability and control of healing.

ALAR CARTILAGE SHAPING TECHNIQUES

The choice of technique used to alter the shape and position of the alar cartilages should be based on the anatomy encountered, the patient's wishes, and the predicted result defined by the dynamics of long-term healing.

Management of the alar cartilages can be divided essentially into four major categories. Although technical variations, such as the actual amount of cartilage to be resected, can vary, the four major categories are (1) volume reduction with residual complete strip, (2) volume reduction with transdomal suturing, (3) volume reduction with interrupted and resutured strip, and (4) tip refinement without volume reduction.

Whenever the presenting anatomy permits, preservation of the complete strip is preferred to prevent loss of support and projection. When the domes are divided, resuturing of the cut ends of the alar cartilage preserves structure and support.

In some cases, the complete residual strip is altered with a dome-binding suture to effect reorientation of the domes, narrowing, or changes in projection. In rare cases, stiff cartilages may need to be weakened by gentle crosshatching.

In more severe deformities, the alar cartilages may require division to correct asymmetries or change projection. These maneuvers tend to produce healing in a less controlled fashion, with a greater tendency to asymmetry and deformity. In some cases, domal suturing is combined with dome division in an effort to stabilize the flail segments. Despite such suturing, the risk of asymmetric healing and loss of support is higher when the domes are divided and not reconstituted in a precise manner.

Tip Projection

Modification of the alar cartilages may require division of one or more of the major support mechanisms of the nose, resulting

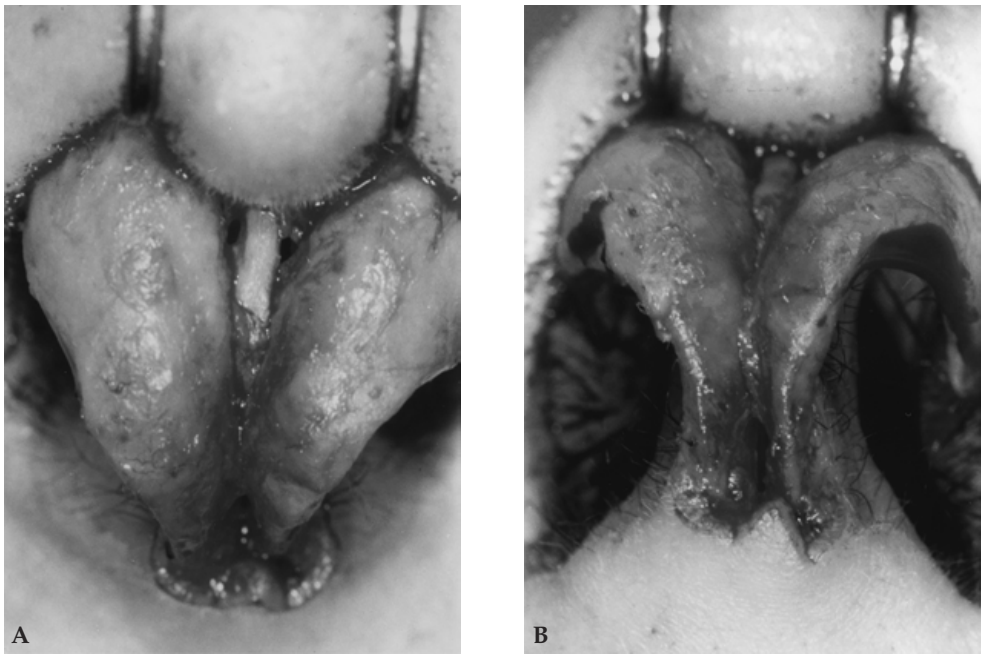


Figure 32–18 Substantial exposure and visualization of the precise anatomy of the nasal tip cartilages is afforded through the open approach. **(A)** Frontal view. **(B)** Basal view.

in a potential loss of tip projection. One of the keys to successful rhinoplasty is preservation of existent nasal tip projection by preservation of as many support mechanisms of the nose as possible.[21] Many of the maneuvers performed to carry out other aesthetic changes result in loss of tip projection. In the case of the overprojected nose, these changes are calculated and desirable. In other cases, nasal projection is appropriate or deficient, requiring special surgical techniques to increase tip projection. All involve reorientation of the alar cartilages or addition of cartilaginous struts or tip grafts to support or increase the projection of the nasal tip and infratip lobule. The surgeon should avoid decreasing dorsal height to compensate for an inadequately projected nasal tip. Examples of techniques used to enhance tip projection include transdomal suturing, lateral crural steal, tip grafting, and the use of a columellar strut. Most of these techniques are covered in detail elsewhere in this book.

Tip Rotation

Some patients have a need for rotation of the nasal tip complex (alar cartilages, columella, and alar base), whereas in others rotation must be prevented. The dynamics of healing and scar contracture play a significant role in tip rotation. The upturned, short, overrotated nose of years past has fortunately given way to a more natural look, preserving a strong dorsum with sufficient length to impart character and suitable proportions to the rest of the face (Fig. 32–19). The degree of tip rotation depends on several factors, the most important being nasal length. To understand tip rotation, it must be distinguished from tip projection. Certain tip rotation techniques may result in increased tip projection because tip rotation and projection are complementary to each other and control of one variable is related to the other. The surgeon can imagine the alar cartilages acting as a tripod, with the conjoined medial crura making up one leg and the lateral crus making up the other two legs of the tripod. Using this simplified concept, the surgeon can conceptualize how tip rotation and projection are closely related.[13] The surgeon can produce the illusion of tip rotation by angulating the infratip lobule in a cephalic direction or by blunting the nasolabial angle. Placement of tip grafts along the caudal surface of the medial and intermediate crura can increase tip rotation. Use of double-layer tip grafts can give the illusion of increased nasal length by lengthening the dorsal line of the nose (Fig. 32–20). Modifications of the tip–lip complex profile with autogenous cartilage grafts can provide the illusion of tip rotation and preserve the length of the nose.

Fundamentally, nasal tip rotation results from planned surgical modification of the alar cartilages, such as conservative excision of the cephalic margin of the lateral crus. Tip rotation can also be obtained by shortening the caudal septum, shortening the septum with a high transfixion incision, setting back the medial crura on the caudal septum, and interrupting and overlapping the residual complete strip (Figs. 32–21 and 32–22).[22] Because tip rotation is only one of the objectives of rhinoplasty, the technique that is chosen must not interfere with the other aspects of the operation.

Volume reduction of the alar cartilage produces a tissue void along the cephalic margin of the lateral crus and results in limited tip rotation, with possible valve collapse and supraalar pinching in the long term. By interrupting the lower lateral cartilages at the domes, upward scar contracture will increase tip rotation, with possible asymmetrical healing, loss of support, and overrotation. A reliable alternative involves resection of a segment of cartilage just lateral to the domes, followed by resuturing of the cut ends to reconstitute

Figure 32–19 Patient **(A)** before and **(B)** after rhinoplasty in which a strong, high dorsum was maintained.

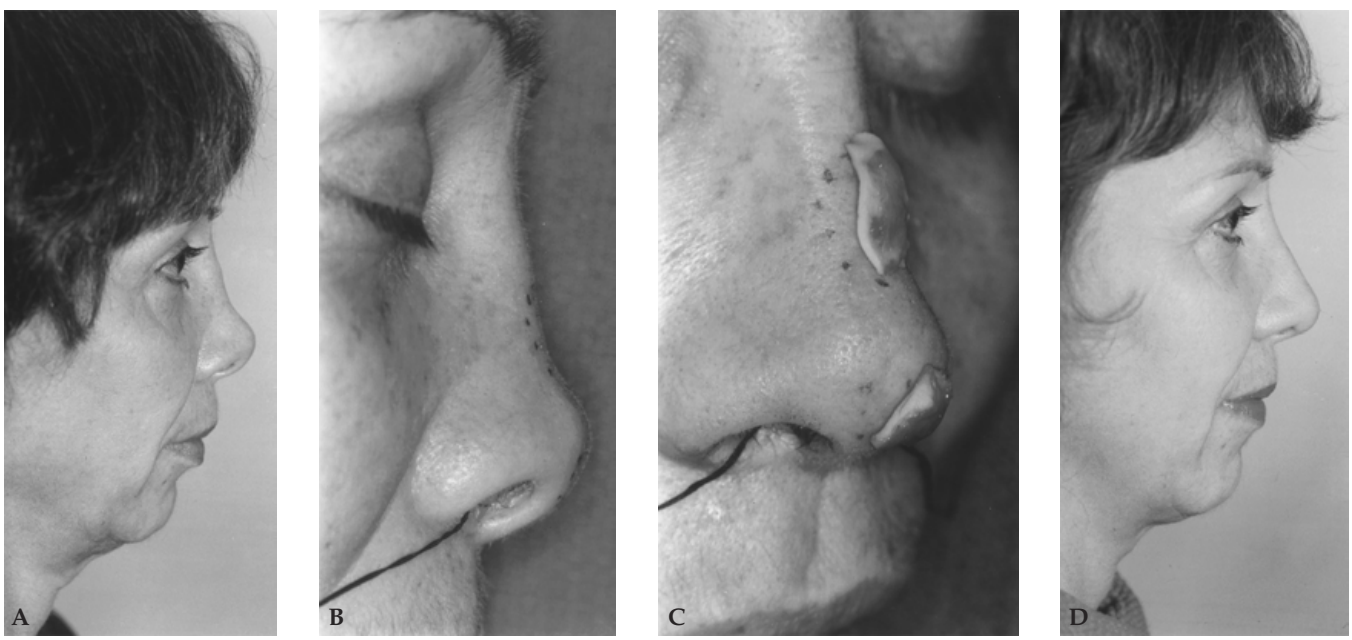


Figure 32–20 **(A, B)** Patient operated elsewhere in whom a saddle-nose deformity resulted, associated with marked overrotation of the nose. **(C, D)** Autogenous cartilage from the external ear implanted into the supratip area and infratip lobule was effective in elongating the nose, reducing the overrotated appearance, and creating a more aligned profile.

Figure 32–21 Patient with elongated, dependent nose in need of a profile alignment and cephalic rotation of the nasal tip. Tip rotation was accomplished by shortening of the caudal septum, excision of redundant vestibular skin, and lateral interruption of the residual complete strip with suture reconstitution as shown in Fig. 32–22.

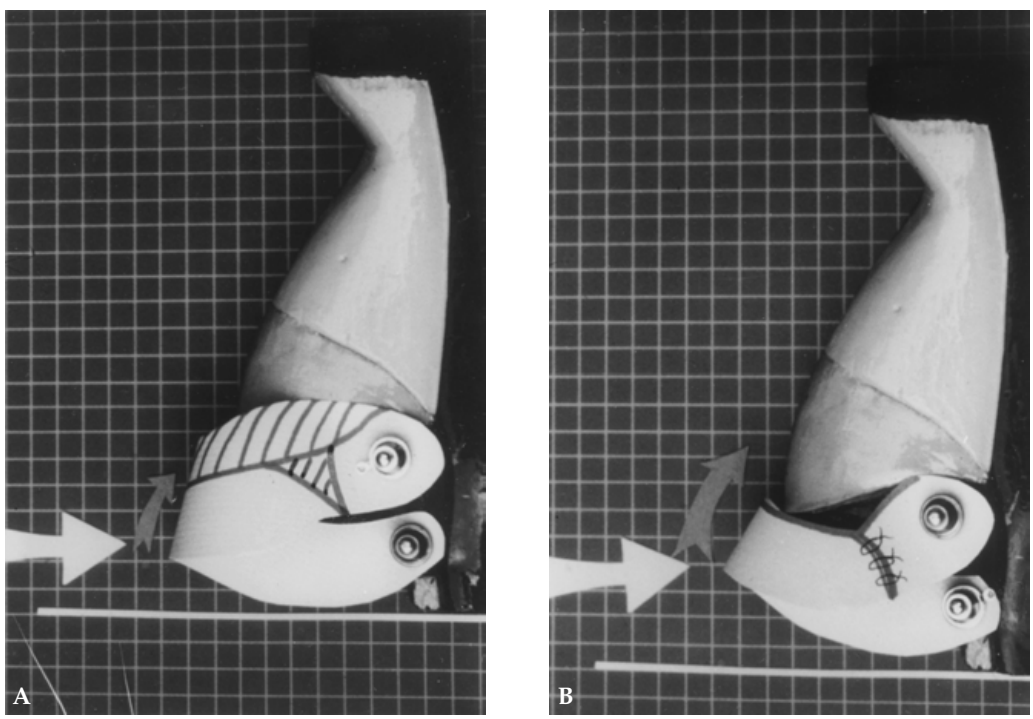


Figure 32–22 **(A)** Representation on teaching model of the extent of cephalic excision of lateral crus carried out with a representation of the interruption of the residual complete strip, demonstrating the triangular wedge excision preparatory to cephalic rotation. **(B)** Cephalic rotation of alar cartilage (and therefore nasal tip) subsequent to suture reconstitution of the interrupted strip to yield a reconstituted complete strip.

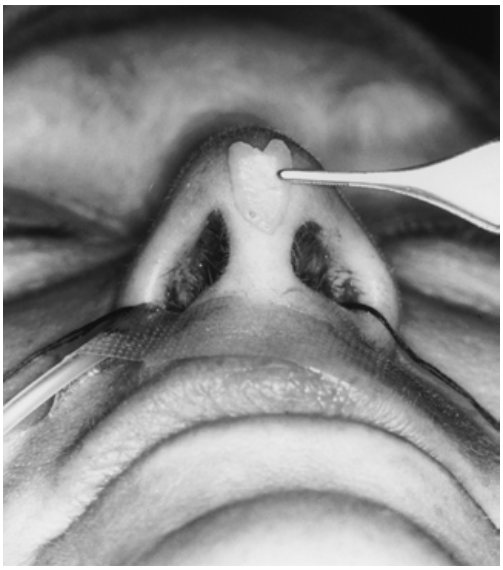


Figure 32–23 Nasal tip grafts, either sutured in place or positioned in precise pockets in the infratip lobule, are effective in providing contour and projection to the nasal tip.

the intact strip (Fig. 32–22B). Lateral interruption of the lower lateral cartilages with a lateral crural overlay reconstitution technique also produces tip rotation, with less of a chance of deformity in the domal region; however, the possibility of asymmetry and overrotation still exists if surgery is inexact. A columellar strut can be sutured between the medial crura to stabilize and support. Alternatively, the medial crura can be stabilized by a "set-back" fixation to the caudal septum. If necessary, a shield-shaped tip graft can be sutured to the caudal margin of the medial crura at a designated angulation to provide precisely the tip projection and rotation that are desired (Fig. 32–23).

Profile Alignment

The structures responsible for the nasal profile are the nasal bones, the cartilaginous septum, and the alar cartilages. All three structures must be carefully realigned to create a well-balanced, natural profile. The nasal dorsum remains strong, with a well-defined nasal starting point at or just below the level of the superior palpebral fold (slightly higher in a man is acceptable). The nasal starting point is defined by the deepest point of the nasofrontal angle or sellion. The dorsal line of the nose extends from the sellion to the tip-defining points. In women, this line should be straight or have a slight concavity. The dorsal line in men should be straight or have a slight convexity.

The extent of reduction or augmentation of the profile depends on the final position of the nasal tip; setting the projection of the tip at the beginning of the operative procedure is therefore recommended. Overreduction of the dorsum should be avoided because it produces a washed-out, infantile appearance on the frontal view, separating the eyes inadequately and reflecting desired light reflexes poorly. A strong dorsum provides good shadowing along the nasal walls,

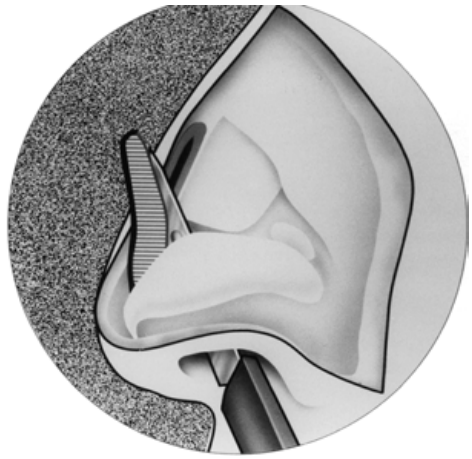


Figure 32–24 Incremental sharp-knife reduction of the cartilaginous dorsum.

giving the appearance of dorsal height. A slight supratip depression should exist at the junction between the tip and dorsum. Preservation of a supratip depression depends on strong support of the lower third of the nose.

Surgical access to the dorsum is gained through a transcartilaginous or intercartilaginous incision or an open approach. The plane of dissection over the dorsum should be just intimate to the perichondrium of the cartilaginous vault and just beneath the periosteum of the bony vault. The dorsal hump can be removed en bloc or incrementally, depending on the surgeon's preference (Fig. 32–24).[12,23] A sharp Rubin osteotome can be used to remove the bony dorsum, extending the excision to the nasofrontal angle (Fig. 32–25). A common error is to overresect thinner nasal bone near the rhinion and underresect the thicker bone near the nasofrontal angle.

In patients with a poorly defined nasofrontal angle resulting from bony excess, special excision of the thick frontal bone may be necessary to deepen this angle. A 2-mm

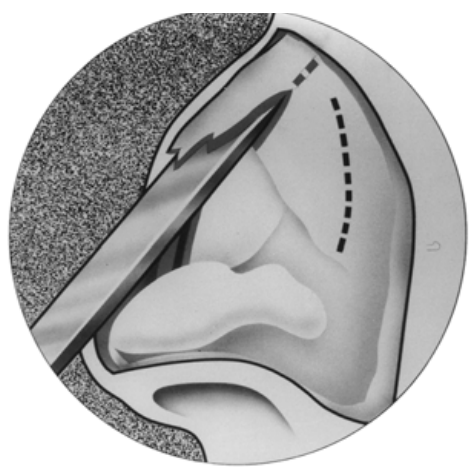


Figure 32–25 Excision of the bony profile utilizing a thin, sharp, Rubin osteotome.

Figure 32–26 When deepening of the nasofrontal angle is indicated, the precise site of the angle break is created by driving a 2-mm osteotome transcutaneously into the nasal bony root, scoring the bone with several perforations to ensure the exact site of its eventual cephalic removal.

straight osteotome can be inserted transcutaneously to precisely define the upper margin of the resection (Fig. 32–26).[17] Then, a Rubin osteotome can be directed cephalically, completing hump removal at the point where the bone was scored with the 2-mm osteotome.

Any small irregularities can be corrected using traditional tungsten-carbide rasps or the newer powered instrumentation (Rhinobur, Xomed, Jacksonville, FL).[24] The powered instrument consists of a bur partially encased by a sheath that provides protection and suction. This bur allows precise modification of limited areas of the nasal dorsum while sparing unnecessary trauma to surrounding tissues. Fine tuning of the profile can then be accomplished with small dorsal grafts, radix grafts, soft tissue resection in the supratip region, and plumping grafts for the nasolabial angle. A new method of camouflaging dorsal contour irregularities or raising dorsal nasal height involves the use of a thin sheet of acellular dermal allograft, such as AlloDerm (LifeCell Corp., The Woodlands, TX). As healing occurs, this allograft is replaced by a layer of scar tissue that maintains the desired contour alterations.

Narrowing the Bony Pyramid

After dorsal hump removal, the bony and cartilaginous pyramids must be narrowed to restore the normal frontal appearance to the operated nose. The bony lateral walls must be completely mobilized and moved medially, avoiding greenstick fractures. To facilitate high-low-high lateral osteotomies and control the exact site of fracture, medial oblique osteotomies

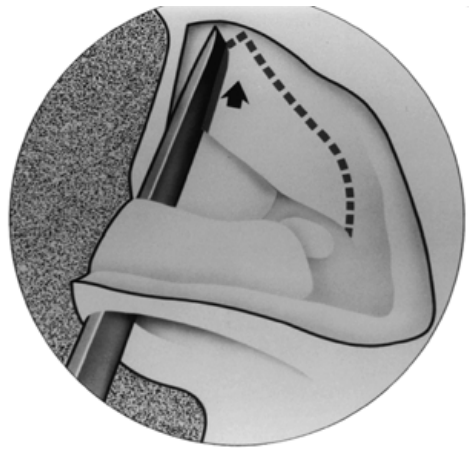


Figure 32–27 In the majority of patients, medial oblique osteotomies, directed 15 to 20 degrees from midline, are useful in siting the exact position of the eventual back-fracture created by the low, curved, lateral osteotomy.

angled laterally at 15 to 20 degrees from the vertical midline are preferred (Fig. 32–27). This medial fracture provides control for the exact site of back-fracture in the lateral bony sidewall. A 2- to 3-mm sharp microosteotome is ideal for the medial oblique osteotomies.[17]

The low lateral curved osteotomy is started at the piriform aperture at or just above the inferior turbinate. A 2- to 3-mm microosteotome is recommended. The osteotome should be driven toward the base of the maxilla, curving up along the nasal maxillary junction to encounter the previously created small medial oblique osteotomy via a controlled back-fracture (Fig. 32–28). Immediate pressure is applied to prevent bleeding and ecchymosis.

If alar base reduction is indicated, the appropriate geometrical excision is carried out as the final maneuver. All inci-

Figure 32–28 The low, curved, lateral osteotomy is created with 2- or 3-mm microosteotomes. The osteotome is driven cephalically in a curvilinear direction to encounter the exact site of the back-fracture created when the lateral osteotomy meets the medial oblique osteotomy site.

sions are suture-repaired, the nose is taped and splinted, and the procedure is completed.

POSTOPERATIVE CONSIDERATIONS

Patients should be given a postoperative instruction sheet, which guides their postoperative activities and care. Any nasal packing should be removed as soon as possible. If an open rhinoplasty approach was used, sutures from the columellar incision should be removed within 5 to 7 days. Care should be taken during cast removal at 5 to 7 days to present hematoma by avoiding elevating the skin off the underlying structures. Patients and their families must clearly understand that at least a year must pass before the near-final result of the surgery can be observed (Fig. 32–29). In many patients, changes will continue for a lifetime.

Figure 32–29 Patient with severely twisted nose and nasal airway blockade. Postoperative result is shown 1 year and 7 years following surgery. Note the evolutionary healing changes that occur with the passage of time. *(continues on next page)*

Figure 32–29 *continued*

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Chapter 33

Open Rhinoplasty

Peter A. Adamson and Henry Huang

HISTORY OF OPEN RHINOPLASTY

Open, or external, rhinoplasty is not a new operation. Circa 600 BC the Sushruta Ayurveda described external nasal surgery being performed in India.[1] One of the more interesting open rhinoplasty patients was Jacques Joseph's first case of reduction rhinoplasty. Widely published photographs usually show the patient's profile—in fact, he had a full-length midline nasal incision made to remove skin and underlying tissue.[1] In 1920, Gillies degloved the nasal tip using an "elephant trunk incision" that was placed in the inferior columella. The modem era of open rhinoplasty began in 1934 when Rethi described a high transcolumellar incision to expose the tip alone.[2] Sercer, in Zagreb, Yugoslavia, performed nasal decortication by extending the exposure to include the entire nasal pyramid in 1956.[3] Padovan was a student of Sercer who used the external exposure to include an external approach to septoplasty.[4] He introduced his technique in New York at the First International Symposium of the American Academy of Facial Plastic and Reconstructive Surgery in 1970, and the era of open rhinoplasty in North America began. The technique has stirred controversy and until the last decade was promoted mainly by a few advocates. Goodman in Toronto[5–11] is generally recognized as the first North American to embrace the technique, followed by Anderson,[12] Wright,[13] and others. Today open rhinoplasty is a well-recognized and accepted approach to rhinoplasty in North America. It is being taught widely in residency and postgraduate programs and has achieved a respected position as a unique approach. Now, almost 60 years since its modern-day origins in Europe, renewed interest in the technique is also being seen there.

PREOPERATIVE ASSESSMENT

At the initial consultation a complete history is taken and a head and neck examination is done with specific emphasis placed on functional and aesthetic nasal diagnosis. The patient's wishes are determined; approximation of the goals of surgery are drawn for the patient using Polaroid photographs or computer imaging. The patient is educated regarding realistic expectations by viewing a variety of preoperative and postoperative rhinoplasty results. The possibility of minor postoperative asymmetries is stressed. Surgical protocols and risks are outlined. The patient is given literature to read before the second consultation. Computerized nasal air flow studies and medical photographs are arranged. Allergy testing is recommended if indicated, so that medical and surgical management of nasal function can be addressed. At the second consultation all questions are answered, and specific surgical goals are defined. Accurate rendering of the aesthetic goals are drawn on 5 × 7 black and white photographs or the computer imager and reviewed with the patient. The results of computerized nasal airflow studies and other appropriate tests are discussed. The position of the external scar is drawn on the consent form and initialed by the patient. A rhinoplasty assessment sheet is completed, and a written surgical plan is formulated.

ANESTHESIA

Most rhinoplasty patients are treated on an outpatient basis using general or neuroleptic anesthesia with an anesthesiologist in attendance. Methylprednisolone (Solu-Medrol), 125 mg, has been used in the past to reduce swelling. After review of the literature it was felt that dogmatic usage of corticosteroid may not be necessarily warranted. Thus we have discontinued its use for approximately 2 years without any qualitative increase in postoperative swelling. Cefazolin (Ancef), 1 g is given intravenously for bacterial prophylaxis. Patients allergic to Ancef are given clindamycin, 300 mg, intravenously. Cocaine 5% packs are placed for several minutes before injection of the nasal mucosa in patients undergoing local anesthesia. This is usually omitted for patients given general anesthesia. Local infiltration anesthesia of the entire external and internal nose is carried out with lidocaine (Xylocaine), 1%, with epinephrine (Adrenalin), 1:100,000, mixed in equal parts with bupivacaine (Marcaine), 0.5%, with epinephrine, 1:200,000. This provides long-acting anesthesia with a satisfactory vasoconstrictive effect. About 15 mL is required.

SCAR ANALYSIS

Some surgeons, primarily those not performing the open technique, have cited the columellar scar as a major disadvantage of the procedure. There is unanimity among those who frequently use the technique that the resultant scar is almost negligible and should be given minor consideration in the choice of surgical approach.[14] A recent study of patients undergoing cosmetic open rhinoplasty revealed a subjective dissatisfaction rate of 1%

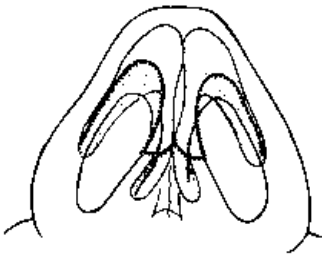

Figure 33–1 Open rhinoplasty incision. The transverse midcolumellar incision should be placed above the medial crural feet and extend around to meet the vertical marginal incision at a right angle.

and objective unsatisfactory scar rate of 2%.[14] These rates could be higher with inexperienced or less meticulous surgeons. The first step in obtaining an ideal scar is incision planning. The preferred open rhinoplasty incision is a transverse midcolumellar gullwing-shaped incision (Fig. 33–1). It should curve around the caudal margin of the medial crus to meet the marginal incision at right angles. The marginal incision is frequently placed slightly behind the true caudal margin of the medial crus because this allows the columellar flap to be slightly wider and allows it to curve more gracefully around the caudal concavity of the medial crus. It is therefore easier to suture the marginal incision evenly and to camouflage the marginal incision. Care is taken to place the incision above the medial crura, especially in blacks and Asians who may have short medial crura. This prevents postoperative transverse columellar notching, which can occur with wound contraction. The columellar flap should be kept as thick as possible and one should avoid traumatizing the medial crural cartilages with its elevation. The flap should be handled carefully with skin hooks, and cautery of the flap should be avoided. The area of greatest potential for an unfavorable scar is the junction of the transverse columellar and vertical marginal incisions. The natural forces of contraction associated with wound healing tend to cause a trapdoor effect of the columellar flap. This can be minimized by undermining the inferior columellar skin before closure and by placing the angle suture full thickness in the inferior columellar skin and only partial thickness in the angle of the columellar flap because this tends to be thicker as a result of edema. A single simple inverted 6-0 polyglycolic acid suture may be placed intradermally in the central columella to decrease tension. Simple 5-0 nylon or fast-absorbing gut everting sutures are used for skin. In cases where significant deprojection of the tip has been carried out, the columellar flap may be slightly long. If not shortened 1 or 2 mm, it could result in a mild hanging columella effect. Conversely, in hypoprojected tips that have had medialization of the medial crura or tip grafts placed to increase projection, the columellar flap may appear relatively short on closure. Closure tension can be decreased by bilaterally extending the vertical marginal incision inferiorly. This allows development of an inferior columellar advancement flap. If this potential problem is recognized preoperatively, another option is to make a V-shaped incision primarily and close in a V-to-Y fashion to increase columellar length. The gullwing incision heals with a better aesthetic scar than V-shaped, staircase, or straight transverse incisions.

SURGICAL TECHNIQUE

Incision and exposure

The transverse columellar incision is made initially with a no. 11 blade. It is joined with a vertical marginal incision made superficially, so as not to incise the underlying crus, from the soft tissue triangle to the junction of the two incisions. The columellar flap is freed up with scissors dissection up to the angle. Blunt and sharp scissors dissection is carried superolaterally over the dome and down along the lower lateral crus, continuing the marginal incision laterally as dorsal exposure is achieved. This technique usually is faster than making a marginal incision and then elevating the dorsal skin before joining up the lateral marginal and medial marginal incisions. However, this latter technique is occasionally required in cases of severe scarring or unusual lobular configurations that make scissors dissection over the domes difficult. Elevation of dorsal skin can be performed as in the closed technique in primary rhinoplasty. In cases of severe scarring, unknown deformities, or thin skin, it can be made under direct vision with scissors or knife dissection. Occasionally brisk bleeding occurs from the inferior columellar artery or from branches of the facial artery in the region of the pyriform aperture. This usually subsides spontaneously but may be treated with bipolar cautery under direct vision if necessary. The dorsal skin is elevated in a submucoperichondrial and submucoperiosteal plane to diminish bleeding and tissue trauma. The extent of elevation is as minimal as possible, but that which will allow appropriate surgical maneuvers and postoperative skin redrapage.

Septoplasty

Septoplasty is usually performed first to correct functional problems and obtain any cartilage that may be necessary for grafting. The anterior septal angle is easily identified, and soft tissue is removed from between the medial crura down to the premaxilla. This provides excellent exposure of the caudal septum and allows the columella to be narrowed. This is especially helpful if a columellar strut is to be placed because struts widen the columella inferiorly. If nasolabial augmentation is required, this soft tissue may be retained as a flap based inferiorly and turned on itself to provide additional nasolabial angle augmentation.[15] It is secured with a through-and-through premaxillary transfixion suture. Beginning at the anterior septal angle, complete submucoperichondrial and submucoperiosteal septal flaps are elevated bilaterally. The upper lateral cartilages are separated from the septum such that the nasal dorsum and septum are "ouvert au ciel" (open to the sky). This affords a superb undistorted exposure that is not available with any closed technique (Fig. 33–2). Standard and more aggressive septoplasty techniques can be effected through this greater exposure. However, the view is more anterosuperior than that seen in closed techniques and may require some orientation adjustment in the mind's eye. Certain deformities may be corrected with greater ease and assurance with the open approach.

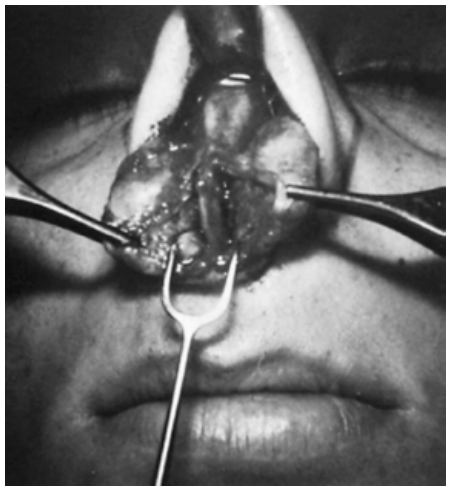

Figure 33–2 Open rhinoplasty exposure. With elevation of the tip and dorsal skin, superb exposure of the entire nasal structure is obtained. Separation of upper lateral cartilages from the septum provides a direct and undistorted view of the entire septum.

Posterior Spurs and Deflections

Posterior spurs and deflections can be assessed and surgically treated from a closer perspective. This is particularly true of the high subradix deviation that can be a cause of residual dorsal curvature if not corrected. These are treated primarily by vertical shaving of the dorsal septal cartilage followed by careful mobilization of the ethmoid plate to the midline, taking care not to fracture the plate superiorly. Severe deflections may require disarticulation of the bony and cartilaginous dorsal strut, mobilization to the midline, and fixation with upper lateral cartilage-septal transfixion sutures.

Dorsal Septal Curvatures

Dorsal septal curvatures are frequently the cause of middle third dorsal deformities. They are easily overlooked and difficult to assess, more so with the closed than with the open approach. Direct visualization of the dorsal septum without instrumentation distortion is possible. The following maneuvers can be applied as necessary: (1) Castellate by incising the dorsal strut vertically from above and below. This maintains cartilage integrity but decreases its spring. (2) Upper lateral cartilage-septal transfixion sutures can be strategically placed to correct minor curvatures and secure the middle third of the nose. (3) Cartilage spreader grafts can be placed on the concave side of the septum medial to the upper lateral cartilage to camouflage a concavity, increase support to the upper lateral cartilage, or broaden the nasal dorsum. In many cases, bilateral spreader grafts are required for a secure reconstruction.

Caudal Strut Deflection

The open approach offers additional exposure over the closed approach to the caudal septal strut, but its primary advantage is the undistorted view it provides of the caudal septum. This allows better diagnosis of any residual deformities. During standard septoplasty, cartilage excisions change the tensions in the quadrilateral cartilage. This may cause curvatures and deflections in the caudal septal strut that may not have been appreciated preoperatively. Excision of the posterior aspect of the caudal strut allows it to swing to the midline to rest in the maxillary groove. Incisions to break the cartilaginous spring and scoring to effect curvature are easily performed. The effect of these maneuvers can be assessed immediately without instrumentation distortion.

Severe Septal Deformities

If the caudal septum is so severely deflected that it cannot be straightened with the techniques mentioned, the septum can be removed in toto, the severe deformity excised, and the septum replaced back to front and resecured to the upper lateral cartilages.[16] Iatrogenic or traumatic cartilaginous-bony disarticulations of the septum can be secured similarly.

Septal Perforation

The open approach offers substantially improved access to surgically repair septal perforations. Perforations that are not causing bleeding, crusting with nasal obstruction, or whistling may not need closure. Symptomatic perforations up to 3 cm may be closed by the development of superior and inferior septal mucosal advancement flaps. Larger perforations may require other techniques and are associated with a significant risk of failure except in experienced hands.

Related Septal Conditions

Other conditions related to the nasal septum may require treatment. The following conditions are treated similarly regardless of whether the approach is open or closed.

Synechiae

Synechiae are incised and an allograft spacer, such as Surgicel gauze or a Silastic stent, is placed and secured.

Vestibular Stenosis

Vestibular stenosis is more common after closed approaches; the risk increases with the number of vestibular incisions used and the number of procedures performed. It is noteworthy that in the open approach the only internal incision is the marginal incision, and thus stenosis is rarely seen after open rhinoplasty. The most consistently effective technique used is to incise the stenotic scar and to rongeur down the anterorinferior pyriform margin. The anterior 1 cm of the inferior turbinate is also excised. A full-thickness postauricular skin graft, usually about 15 $\times$ 10 mm, is sutured into the floor and lateral wall of the vestibule in the vestibular defect. An alar-facial groove rhinotomy incision is made to improve exposure if required. Surgicel gauze is placed for 5 days for graft support. Further stenting with molded Silastic or cotton gauze for up to 3 months is occasionally indicated.

Mucosal Problems

Submucosal electrocautery of the inferior turbinate along with gentle outfracturing is carried out in allergic patients. If there has been preoperative nasal obstruction confirmed with nasal air flow studies and associated hypertrophy of the inferior

turbinates, the anterior 1 cm of the inferior turbinate is resected. This has been shown objectively to improve nasal air flow.[17]

Completing the Septoplasty

The septoplasty is completed with plain gut transfixion sutures to appose the septal mucosal flaps and an inferior horizontal flap drainage incision to prevent hematoma formation. If the caudal septal strut has been freed up posteriorly at the maxillary crest, it is resecured with transfixion sutures of 4-0 polyglycolic acid (Vicryl or Dexon). In cases where open rhinoplasty is indicated primarily for a tip deformity but the nasal septum and nasal dorsum are relatively true, some[18] prefer to perform an open rhinoplasty alone or in combination with a closed septoplasty. In this case the columellar flap and dorsal skin are elevated and tip work carried out above the level of the nasal septum and caudal to the membranous septum without dividing the tissues between the medial crura or developing septocolumellar mucosal flaps from above. In doing so the preoperative structural integrity of the columella is maintained intact. This obviates the necessity for a supporting columellar strut but does not allow satisfactory management of many columellar or premaxillary deformities.

Nasal Base

The nasal base is usually managed before the nasal dorsum. In this way, the desired projection and rotation can be produced, and the nasal dorsum can subsequently be reduced or augmented to provide a pleasing profile. Occasionally a high dorsum produces a tension tip deformity by pulling the tip up and increasing the nasolabial angle. This requires reduction before nasal tip surgery to reduce its distorting effect on tip dynamics. The tripod concept of tip dynamics is applied to produce the desired changes in nasal length, projection, and rotation. These concepts apply equally well in closed or open approaches, but the superb exposure of the open approach enables more accurate diagnosis and definitive, undistorted, bimanual correction of nasal base deformities. Standard rhinoplasty maneuvers are first performed on the medial crura, lateral crura, nasal lobule, and columella.

Medial Crura

Soft tissue excision between the medial crura produces a slight degree of columellar narrowing and gives wide and direct access to the premaxilla. The medial crural feet can be shortened to decrease projection or incised and bunched to decrease their inferior flare. Excessive crural curves can be improved with incision or scoring techniques, and the medial crura can be secured to each other with 6-0 nylon buried sutures.

Lower Lateral Crura

In most reduction rhinoplasties the cephalic margin of the superior aspect of the lower lateral cartilage is excised to refine or narrow the nasal lobule. The advantage of the open approach is the degree of exactness with which deformities can be seen and the correct amount of cartilage excised. Frequently, one finds quite marked asymmetry of the lower lateral cartilages on viewing them in situ despite a relatively symmetrical tip in external appearance. More importantly, symmetrical amounts of cartilage can be retained. Excision of the cephalic margin of the inferior aspect of the lower lateral cartilage produces some rotation and in bulbous noses a refinement of the lateral supratip region. The delicate scroll can be protected and vestibular incisions avoided. It should be emphasized that excessive cartilage excision does not further refine the lobule but rather weakens the lateral crus to such a degree that deformities, such as alar valve pinching, bossing, and knuckling, may develop. Usually a minimum of 6 to 8 mm, and frequently more, of lower lateral crus is retained. This is especially true in thick-skinned patients who require strong cartilage support to prevent tip ptosis and thin-skinned patients in whom cartilage deformities are easily seen. The hinge area, or junction of the lower lateral crus with the sesamoid cartilage, can be seen especially well from above in the open approach. Accurate dissection and resection of the hinge can be carried out to produce tip rotation and deprojection (or retrodisplacement). By keeping such incisions well lateral in the more substantial tissues of the alae, the risk of vestibular and valve deformities can be minimized.

Lobule Refinement

In most rhinoplasties, refinement usually refers to narrowing of the lobule. The simple maneuvers to obtain this—cartilage excision, scoring, morselization, and suturing—can all be done reasonably well with the closed technique. In all cases, though, the open approach offers an undistorted view of the tip cartilages. As lobule reconstruction becomes more intricate, the value of the open approach increases. This is especially true if vertical crural division or onlay grafts are required.

Vertical Crural Division

Vertical divisions of the medial or lower lateral crura can be most useful to change projection and rotation, narrow a broad domal vault, and correct lobular asymmetries. The side with the greatest deformity is treated first. Vestibular skin is freed from the crura, and the appropriate site is chosen for division. If cartilage is severely deformed, it may require excision; otherwise the cartilage is incised, overlapped, and secured with transfixion sutures of 6-0 nylon. Further scoring and 6-0 nylon sutures are used as necessary to obtain maximal symmetry. This may take the form of single dome unit sutures that create a more acute angle between the medial and lateral crura. Also, double dome unit sutures may be utilized to draw the domal units medially on each side, thereby narrowing the lobule. Diagnostic acumen, cartilage manipulation, and final assessment of these maneuvers all are enhanced with the open approach.[19,20]

Onlay Grafts

The open approach is ideally suited for lobular and alar grafting. Autologous septal or conchal cartilage is preferred. In some cases, Mersilene surgical polymer mesh or expanded polytetrafluoroethylene (e-PTFE or Gore-Tex) in small amounts has been used successfully. Infratip onlay grafts can be used to increase tip projection, improve definition, camouflage asymmetries, lengthen the nose, and give a degree of apparent counterrotation. They are usually secured with

6-0 nylon sutures, although tissue glue is an alternative. Final sculpting of the graft is deferred until it has been secured to obtain ideal proportions. Similarly, cartilage onlay grafts can be transfixed with 4-0 plain gut through the lower lateral cartilage. They are used to increase structural support in cases of previous overresection or for correction of alar concavities and rim retraction.[21] There are a variety of shapes, sizes, and techniques from which to choose.[22]

Columella Refinement

Considerations included in columellar refinement follow.

Premaxillary Augmentation or Reduction

Nasolabial augmentation is most frequently required after iatrogenic shortening of the posterior aspect of the caudal septum or excision of the premaxillary spine. A premaxillary pocket can be developed easily from above, and implant material can be inserted under direct vision. Care should be taken not to enter the labial sulcus and to restrict dissection to the bony–soft tissue plane to retain a substantial soft tissue pocket. In the past, sculpted Silastic block measuring about $10 \times 8 \times 6$ mm, shaped in a pyramidal fashion with all sharp edges shaved down, or rolled surgical polymer mesh (Mersilene) have been used with relative success. Autologous cartilage is satisfactory, although the volume available is usually not sufficient to produce any significant change. The columellar soft tissue flap already described may give an additional small degree of correction. If greater volume filling is required, our preference today would be e-PTFE (Gore-Tex) with needle punctures to encourage tissue ingrowth and stabilization. Relative contraindications include patients with short upper lips or those with upper dentures—the superior portion of the denture in the midline should be drilled down before placement of the implant to prevent contact ulceration and extrusion. Premaxillary deepening is easily performed by excising soft tissue and bone to deepen or narrow the premaxillary spine. The wide exposure achieved is much superior to that achievable with closed techniques.

Columellar Struts and Battens

An autologous cartilage columellar strut may be placed between the medial crura to lengthen or strengthen them and thereby achieve support for the nasal tip. By varying the angle of its placement in the inferior columella, the strut can also be used to augment the nasolabial angle or increase columellar show. These struts are placed just above the premaxillary spine under direct vision and secured with transfixion sutures of 4-0 polyglycolic acid through both medial crura and the strut and the membranous septum. The strut is left long for easier handling and then shortened below the level of the nostrils so as to prevent any infratip lobular asymmetries. It is important to note the length of the caudal septum before placing a columellar strut. It is frequently necessary to shorten the caudal septum so that the columellar strut will not excessively lengthen the septum and cause a hanging-columella effect. In noses with long septums the excised portion of the caudal septum may be ideal as the columellar strut itself. One should also ensure that the columellar strut extends to but not beyond the nasal spine. If it extends beyond the nasal spine, it may flip from one side to another or simply remain on only one side of the spine. A disadvantage of the open approach is the loss of tip support provided by the medial crura if the medial crura are completely separated. In most of these cases a strut is desirable to maintain tip support. A columellar batten is a nonsupporting onlay graft used to augment columellar show or camouflage columellar asymmetries. Autologous cartilage, secured with 6-0 nylon buried transfixion sutures to the medial crura, is preferred. If an onlay tip graft is also required, this is sculpted so that the tip graft extends the full length of the columella and obviates the necessity for a separate columellar batten. The open approach offers a significant advantage in securing and accurately sculpting such grafts.

Hanging Columella

A hanging columella can be caused by several anatomic deformities, either individually or in combination. Excision of a prominent medial crural caudal margin or vertical cartilage division to decrease a broad domal vault is facilitated by the open approach. However, excision of a bulky membranous septum or shortening of the caudal septum is done as easily with the closed approach. It is of interest that a fusiform excision of a prominent membranous septum can be carried out at the same time as an open rhinoplasty. However, it needs to be recognized that this diminishes blood flow to the medial crura and columella solely through its superior and inferior aspects. Caution is advised.

Dorsum

Almost every procedure on the dorsum can be performed more easily because of the improved exposure of the open approach. One difficulty, especially for the novice open rhinoplasty surgeon, is assessment of the nasal dorsum. With the closed technique, the surgeon develops a definite feel to the dorsal profile. With the open approach, this feel is still used but is of a different nature because the dorsal skin must be replaced and maintained in position with forceps while the dorsum is assessed. However, with experience the improved visualization and development of a new sense of feel allows excellent dorsal results to be achieved. The nasofrontal angle can be deepened with a nasofrontal osteotome much as in a closed approach. An otologic burr or cartilage shaver can be used where greater reductions are desired. Diamond rasps are used to lower the dorsum because they give a more secure and refined result than osteotomes. Septal cartilage is lowered with angled scissors. Localized dorsal prominences are easily assessed under direct vision to determine whether they are bony or cartilaginous, and the desired mode of removal is selected. Fading, abbreviated medial osteotomies are performed under direct vision. This decreases the incidence of bone chips and rocker deformities. Low lateral osteotomies are carried out through separate pyriform margin incisions after elevation of the periosteum internally and externally. These are done no differently than in closed rhinoplasty. Double osteotomies, consisting of a low and an intermediate lateral osteotomy, may be indicated if the bony pyramid extends lateral to a line dropped vertically from the medial canthus. They can also decrease a broadly vaulted bony pyramid or correct a severe unilateral bony pyramid convexity. The higher (intermediate)

lateral osteotomy should be placed 3 to 5 mm above the lower lateral osteotomy and kept low enough that a substantial nasal bone plate will be retained. The periosteum may be minimally elevated, but as much periosteum as possible should be kept intact to support the nasal bones. The lower lateral osteotomy is then completed, and gentle infracturing is performed. Outfracturing is usually omitted. Caution is advised in patients with short or brittle nasal bones or in those with a low nasal bridge because an increased risk of collapse or eggshelling of the bones exists. Should this occur, support the bones with Surgicel packing. The relative positions of the nasal bones and upper lateral cartilages with respect to the septum may be altered with osteotomies. Therefore, final refinement of the dorsum is deferred until the osteotomies are completed. Open rhinoplasty lends itself well to the following techniques used to achieve an ideal dorsal configuration.

Dorsal Irregularities

Small irregularities of the septal or upper lateral cartilages can be trimmed under direct vision. Small curvatures in the upper lateral cartilages, or collapsing upper lateral cartilages, can be secured across the midline with a 4-0 polyglycolic acid transfixion suture. Such suturing can also close open-roof deformities and provide added stability to the middle third of the nose. Cartilage or bone irregularities at the bony-cartilaginous junction can be accurately excised or small cartilage grafts placed to fill areas of bone chips or open-roof deformities.

Spreader Grafts

Autologous cartilage spreader grafts, measuring between 10 and 15 mm in length by 2 mm in vertical height by 1 to 2.0 mm in width, can be placed between the dorsal aspect of the nasal septum and the upper lateral cartilages, or even extended up between the nasal bones if indicated. These are functionally useful to open up the nasal valve, especially in cases of previous overresection of the vertical height of the upper lateral cartilages causing nasal valve collapse.[23] The middle third, and to a lesser extent the upper third, of the dorsum can be widened in cases of previous overresection. A unilateral middle third dorsal concavity caused by a septal curve or upper lateral cartilage deformity may be corrected by placement of a spreader graft along the concave side. These are secured with two transfixion sutures of 4-0 polyglycolic acid through the upper lateral cartilages and septum. By not placing the sutures over the dorsum, but rather through the septal cartilage on both passes, further refinement of the dorsum is possible after suturing.

Dorsal Augmentation

If only minimal dorsal augmentation is required, deprojection of the nasal tip or elevation of the nasal dorsum by placing transfixion sutures through the upper lateral cartilages may suffice. Autologous material should always be the material of choice for dorsal augmentation. However, certain limitations may arise, such as donor site morbidity, availability of material, partial resorption, warpage, concern about irregularities, and an unnatural sensation. Polyamide mesh (Mersilene) has been used by the senior author with reasonable success, but not without some resorption. Currently, our best results have been obtained with bivalved layered e-PTFE (vascular Gore-Tex). The implant is customized by stacking as many layers as needed and transfixing the implant through and through with 4-0 polyglycolic acid sutures. Needle punctures are placed through the material to encourage tissue ingrowth and stability. Smaller cartilage grafts for localized deformities are secured with transcutaneous transfixion sutures following accurate placement. The sutures are removed in four days. Both intraoperative intravenous antibiotic and antibiotic irrigation coverage are given. The open approach is beneficial to exactly position and secure the implant. Also, the open approach minimizes implant exposure to nasal mucosal incisions and consequent potential infection. Such implants can be used to augment upper lateral cartilage concavities and dorsal depressions. However, it can be more difficult to assess the dorsal profile in the open approach. It is also not possible to develop as exact a pocket in the dorsum as one might in a closed approach for a localized deformity. These are not significant disadvantages.

Pollybeak

Pollybeak deformity is a relatively common unfavorable postoperative event and one that haunts the experienced and inexperienced rhinoplasty surgeon. The variability of both postoperative tip deprojection and skin contraction over the dorsum determines that the degree of intraoperative lowering or augmentation of the nasal dorsum is always an estimate. The tendency for pollybeak to form is represented by the following equation:

$$PB = BHR/CHR + TLLC/LSMC + STDS + ST$$

where PB is tendency for pollybeak, BHR is bony hump removal, CHR is cartilaginous hump removal, TLLC is thrust of the lower lateral cartilage, LSMC is length and strength of the medial crus, STDS is supratip dead space, and ST is skin thickness.[24] About 70% of patients with pollybeak require only soft tissue or cartilage excision for correction, whereas about 30% require grafting procedures.[25] Tip ptosis is usually caused by a combination of weakened support from the medial crural cartilages and the thrusting force of the lower lateral cartilages that have been left long. The dorsal nasal skin is thin in the middle third and thicker in the nasofrontal and supratip regions. Slower contraction of the supratip skin allows scar tissue to form in the potential supratip deadspace, resulting in a soft tissue pollybeak. This is especially true in thick-skinned patients. If the bony hump is overresected and the cartilaginous hump is left high, a prominent pollybeak may result. Management depends on diagnosis of the cause of the deformity—cartilaginous, soft tissue, or both. Cartilaginous pollybeaks are revised by lowering the cartilaginous supratip and placing a medial crural columellar strut to maintain tip projection. The superior bony dorsum occasionally requires grafting. Soft tissue pollybeaks are treated by excising the redundant supratip scar and subcutaneous tissue and scoring the undersurface of the supratip skin for better redrapage. The supratip dead space is obliterated by apposing the mucosal flaps with a transfixion suture. A columellar strut is placed if tip support is required. Triamcinolone acetonide (Kenalog) 10 to 40 mg/cm^3 is injected into the subcutaneous supratip as early as 3 weeks after surgery if soft tissue pollybeak formation is suspected. This can be repeated at 3-week

intervals for several injections if required. The dorsal supratip skin is taped nightly for the first 6 postoperative weeks to encourage better skin redrapage.

Soft Tissue Refinement

Skin Management

Skin is the most significant factor affecting the final aesthetic result for the experienced rhinoplasty surgeon. Thick-skinned patients require a longer time for skin contraction, especially in the supratip. Additional lowering of the supratip dorsal cartilage may be necessary in such cases to prevent a soft tissue pollybeak. Sebaceous skin and older skin with less elasticity may also take longer to settle and may do so with more variable results. It may be beneficial to excise subcutaneous tissue from the supratip region and lightly cross-hatch the undersurface of the dorsal skin with a no. 15 blade. This thins the skin and renders it more pliable, both of which enhance redrapage. Care must be taken not to compromise the dermal-subdermal vascular plexus. Postoperative triamcinolone acetonide injections are more frequently required in such patients. Such injections are omitted if autologous or synthetic implants have been used. Such patients must be cautioned preoperatively that the more highly structured and refined nose may be difficult, if not impossible, to achieve for them. Conversely, thin-skinned patients redrape more quickly and completely—so much so that small irregularities may be rendered visible. Attention must be paid to achieving exceptionally fine sculpting of the bone and cartilage profile in such patients. Autologous cartilage or polyglycolic acid surgical polymer mesh may assist in camouflaging larger irregularities, just as autologous cartilage tip grafts may improve lobular refinement. Fine irregularities may be improved by laying a thin layer of Gelfoam, AlloDerm, or 4-0 polyglycolic acid mesh along the dorsum; this possibly facilitates a thin layer of fibrosis to form, smoothing out the irregularities.

Columellar Scar

It is rarely necessary to refine the columellar scar of a previous open rhinoplasty.[14] The most likely deformity is a small irregularity at the junction of the horizontal and vertical components of the columellar incision. This is best treated with light dermabrasion or laser resurfacing. In revision open rhinoplasties, the original incision may be used without excising the initial scar.

Alar Advancement

Alar narrowing is considered if the ala extends lateral to the perpendicular dropped from the medial canthus, the equilateral triangular proportions of the nasal base are lacking because of increased width of the alae, or the nasal base proportions are proportionately large for the nose. Alar refinement is particularly common when large noses are reduced and nasal tip deprojection causes flaring of the alae. A variety of nasal sill and alar excisions have been used.[26] The inner and outer circumference of the alae are assessed, and an appropriate resection from the nostril circumference and alar length is effected. This excision is usually best made in the sill because this retains the curvilinear anatomic circumference of the nostril and ala and prevents notching of the sill. A generous back-cut placed just above the alar facial groove allows the ala to be advanced and rotated as a flap. If the lateral alar wall is too long, causing rounding of the ala, a wedge is excised above the alar facial groove to shorten alar length. The incision is closed meticulously with 5-0 nylon or fast-absorbing gut sutures, with special care taken to evert the sill incision. This technique narrows the nasal base, decreases nostril size, and alters the nostril axis.

Alar Hooding

Alar hooding repair is assessed after tip rotation and columella position is optimized. On lateral view, hooding appears as a curvilinear ptosis of the middle and posterior alar margin. Correction of this deformity may be effected by placing a fusiform wedge excision in the caudal margin of the alar rim. This is then closed with 5-0 nylon interrupted sutures.

Displaced Alar Cartilages

The lower lateral cartilages may displace into the nasal vestibule when the hinge of the lower lateral cartilage is incised or if there is poor placement of marginal incision sutures. This can cause nasal obstruction or aesthetic complaints. The marginal incision should be reopened, a pocket made for the caudal margin of the lower lateral cartilage, and minimal cartilage trimming carried out if necessary. Meticulous suture closure then usually corrects this cartilage in-flare. A single Z-plasty effectively rotates cheek skin immediately lateral to the nasal wall into the sill in cases of previous excessive nasal sill excision. Fortunately, this is rarely required.

Closure

The marginal incisions are closed with 4-0 chromic gut sutures around to the angle. A 6-0 polyglycolic acid suture may be used in the central columellar flap dermal closure. Simple 5-0 nylon or fast-absorbing gut sutures are used for the horizontal and vertical components of the columellar incision as already described. Septal stents of exposed x-ray film or Silastic sheeting are secured with transfixion sutures of 4-0 polyglycolic acid (Vicryl). Turbinate surgery is carried out if indicated. Surgicel pledgets are placed in the nasal vestibule at the osteotomy incision sites. A small plaster of Paris cast, metallic splint, or thermoplastic splint is applied.

POSTOPERATIVE CARE

The Surgicel pledgets are removed on day 1, and the nose is debrided. Columellar and alar sutures are removed on day 4, with the exception of stay sutures at the transverse columellar-vertical marginal incision junction. These are removed at day 7 along with the septal stent and nasal cast. The patient is advised to perform nasal exercises for an additional 5 weeks. These consist of light pressure placed evenly on the nasal bones with the index fingers on a regular basis to

maintain narrowing and straightening of the nasal dorsum. Patients are advised to avoid active exercise for 3 weeks and contact sports for 6 weeks.

RESULTS

Approximately 71% of our cases of open rhinoplasty were primary, 23% revisions of a procedure performed by another physician, and 6% personal revisions (Figs. 33–3 to 33–6). Complications consisted of minor infections, suture extrusion, minor septal perforations that healed spontaneously, a premaxillary Silastic removal, and postoperative nasal obstruction. This constituted a 6.3% complication rate.[27] Patients with unsatisfactory results, that is, failure to achieve a desired aesthetic goal, composed 5.7% of our patients. These complaints consisted of cartilaginous and soft tissue polly-beak, tip fullness, dorsal sloop, dorsal curve, broad dorsum, and widened alar base. It is to be noted that graft slippage or extrusion has been almost negligible. Excessive bleeding has

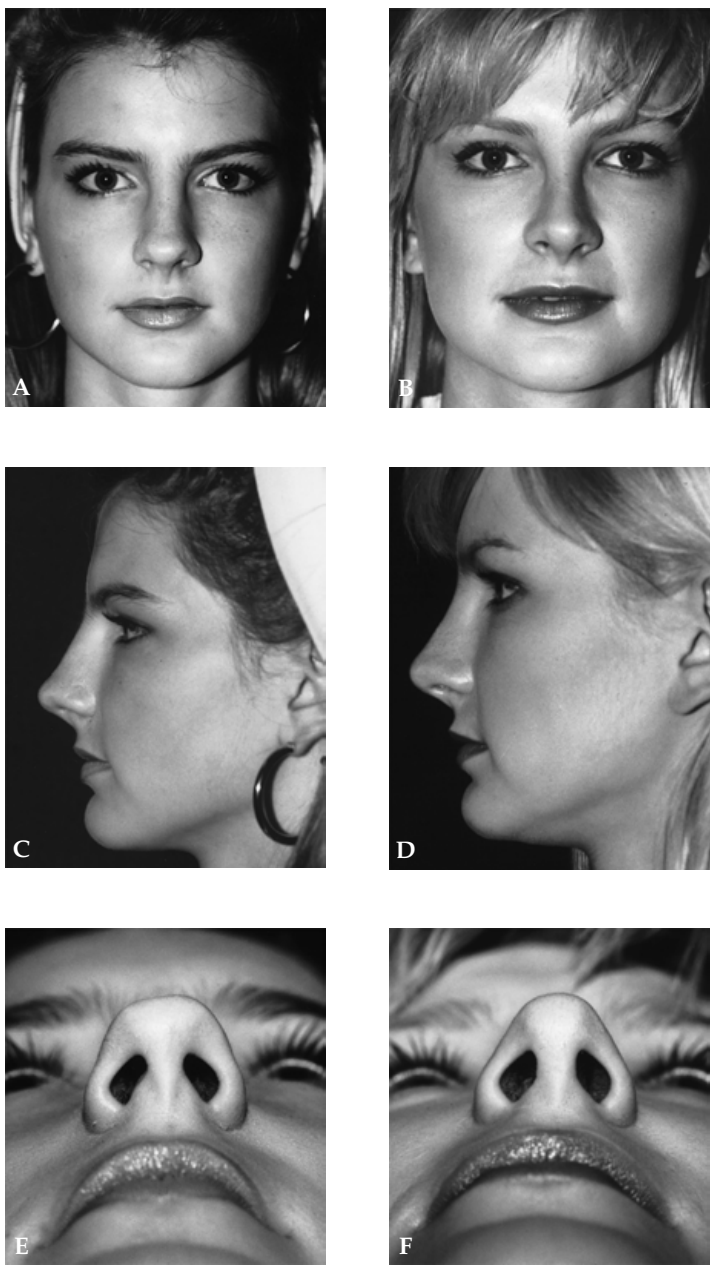

Figure 33–3 Cosmetic open rhinoplasty. **(A, C, E)** A 16-year-old girl with a broad nasal tip. **(B, D, F)** The 2-year postoperative results after conservative incision of the cephalic margin of lower lateral cartilages, freeing of vestibular skin, and tip refinement with 6-0 nylon cartilage transfixion sutures. Conservative septoplasty and dorsal refinement were also carried out.

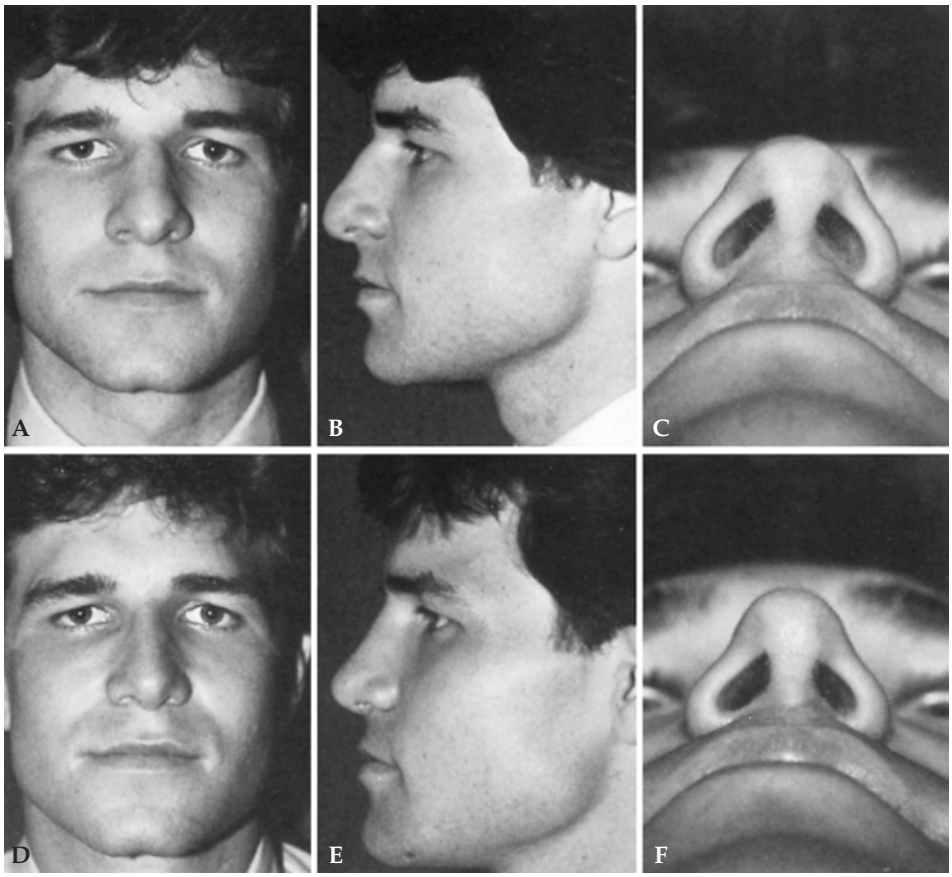

Figure 33–4 **(A–C)** A 21-year-old man with nasal obstruction, bulbous tip, mild hanging columella, and dorsal hump. **(D–F)** The 3-year postoperative result after conservative septoplasty with a swinging door for the caudal strut and shortening of the caudal septum. The medial crural feet were incised to allow bunching, and the hinge area of the lower lateral cartilage was excised for rotation and retrodisplacement. The cephalic lower lateral cartilage was trimmed for nasal tip narrowing and rotation. Domes of the lower lateral cartilage were scored and medialized with transfixion nylon sutures. A columellar strut was placed. The bony and cartilaginous dorsum was lowered and osteotomies performed for narrowing. Alar base narrowing and a wedge from the alar facial groove was performed to narrow the base and decrease alar flaring.

also not been a problem; the average blood loss is between 50 and 100 mL, often less if local anesthesia is used. The risk of an unsatisfactory scar is 1% if reasonable attention is paid to planning, executing, and closing the incision.

SUMMARY

Open rhinoplasty is generally well accepted in North America. Many surgeons expound on its advantages for the difficult nose. If the procedure has definite advantages for the difficult nose, rhinoplasty surgeons must also ask themselves why it may not be beneficial in the average or even in the good nose to achieve superior results. It has been shown by many authors, including ourselves, that the scar is really a nonissue in most cases. Perhaps the time has come to put aside many of the transparent arguments about the negative aspects of the scar of open rhinoplasty and discuss the merits and disadvantages of the technique based on achievable surgical results alone. The knowledgeable surgeon rapidly concludes that the open rhinoplasty approach is frequently the preferred approach to achieve consistently good and reproducible results. Furthermore, it is an educational approach in itself, with both novice and experienced rhinoplasty surgeons enhancing their diagnostic and therapeutic rhinoplasty skills.

Advantages

The real advantage of open rhinoplasty, the one from which all the other stated advantages accrue, is improved surgical exposure. This is especially true with respect to the premaxillary spine, caudal septum, dorsal and anterior septum, lobule, and superior dorsum. An unparalleled diagnosis of the underlying anatomy resulting in the external deformity can be made via the open approach. Sutures can be placed, grafts exactly trimmed, and asymmetries corrected without distor-

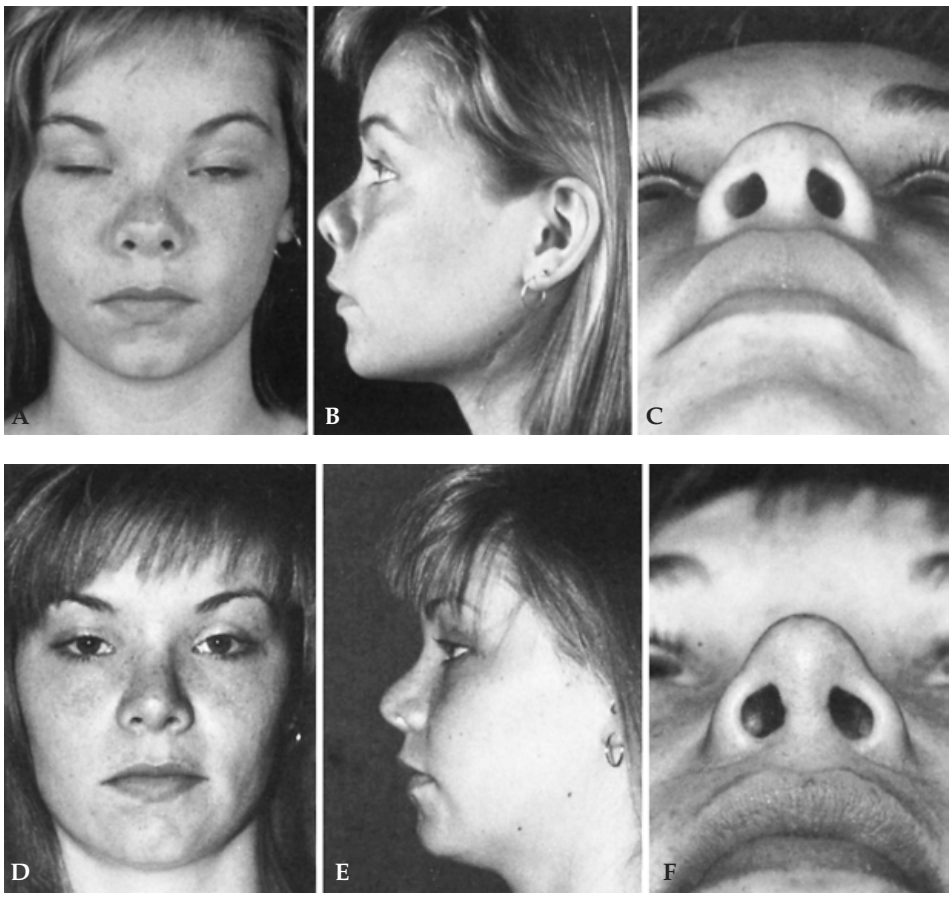

Figure 33–5 Reconstructive open rhinoplasty. A 16-year-old girl had trauma at age 6 followed by a septal hematoma and necrosis of septum. L-shaped Silastic implant was placed for nasal collapse at age 14. The patient wished her nose narrowed and overrotation improved. The first revision procedure resulted in infection of the implant and subsequent removal. **(A to C)** Preoperative status with Silastic implant in place. **(D–F)** The 3-year postoperative result after a second revision procedure to correct the severe dorsal sloop and overrotation that occurred after removal of the Silastic implant. Tip reconstruction included placement of a conchal cartilage lobule and columellar batten with an autoallograft of Mersilene surgical polymer mesh from a right postauricular pocket overlaid to form a double tip and columellar onlay graft. A columellar strut supported the medial crura. A second Mersilene surgical polymer autoallograft was placed along the dorsum. Marginal incisions were extended inferiorly in the columella to create an inferior columellar advancement flap to allow closure without tension. Medial and lateral osteotomies were completed. Bilateral alar advancement-rotation flaps narrowed the alar base.

tion of surrounding tissues. Scar tissue and redundant subcutaneous tissue are more easily excised. The valve region can be well protected, and the absence of incisions in the intercartilaginous region helps prevent later obstructive problems by avoiding interruption of one of the tip support mechanisms or scarring.[28]

Disadvantages

Disadvantages of open rhinoplasty include increased operating time; this is due to the more meticulous closure required and the likelihood that the surgeon will spend more time correcting deformities that are more easily seen. Concerns regarding the viability of the columellar flap should be minimal if reasonable surgical technique is maintained. Assessment of the dorsal profile is different and may be more difficult initially, but with experience assessment becomes as accurate as with the closed technique. Similarly, supratip settling may vary from that seen with closed techniques, but in time it approaches that of the closed technique. A significant caveat is that those initially performing the open approach must not create unattainable and unrealistic expectations. The approach only ensures a good exposure to correct nasal deformities—improved results occur only if appropriate rhinoplasty techniques are used and surgical experience accrued. This is true of any surgical procedure.

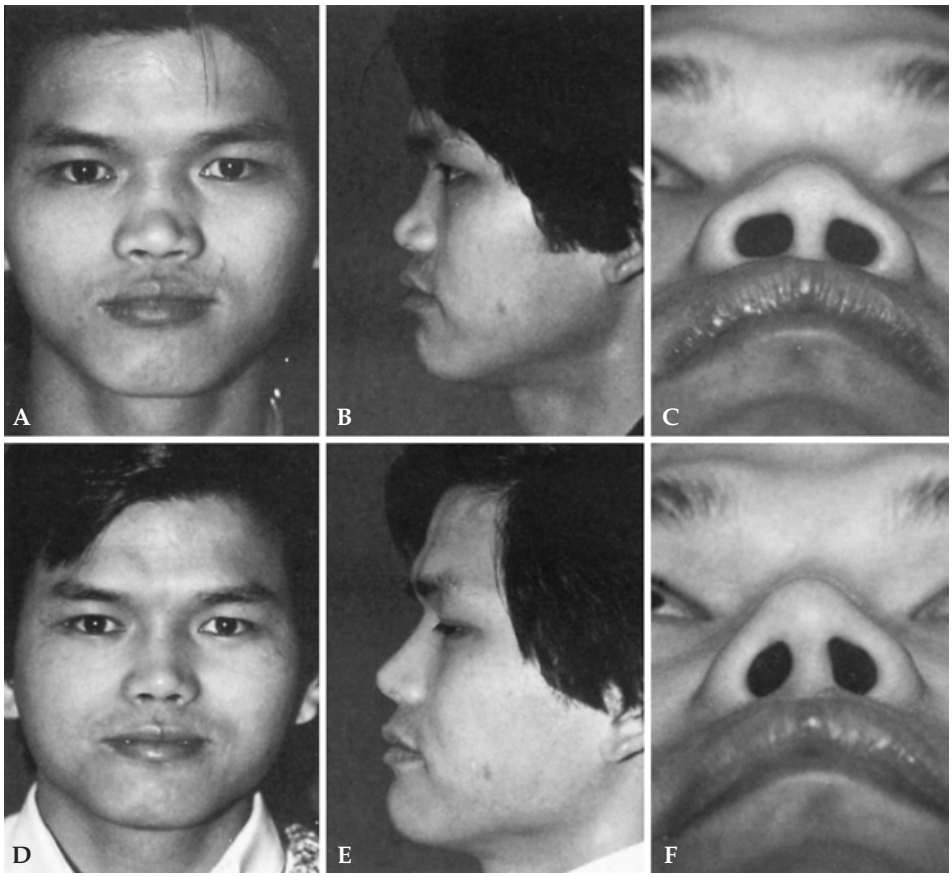

Figure 33–6 Augmentation, revision open rhinoplasty. **(A–C)** A 23-year-old man had two previous septorhinoplasties and was seen with nasal obstruction, tip hypoprojection, columellar retraction resulting from septal shortening, middle third collapse, and low dorsal profile. **(D–F)** A 2-year postoperative result after conservative excision of the cephalic lower lateral cartilage and incision at the hinge for slight rotation. A columellar strut was placed for support and premaxillary Silastic block for augmentation. A conchal cartilage lobule and columellar batten graft were placed for tip projection and refinement. Mersilene surgical polymeric mesh augmented the dorsum and bilateral alar advancement rotation flaps, and wedge excision of the alar facial groove was used to narrow the base and decrease alar flaring.

Indications

It is recognized that each rhinoplasty surgeon has a different surgical experience and therefore will have unique indications for using the open technique. The open rhinoplasty technique is recommended for all rhinoplasties unless: (1) an accurate preoperative diagnosis can be made, and (2) the surgeon, within his or her personal experience, believes the desired result can be obtained with the closed approach. It can be used for cosmetic and reconstructive rhinoplasties and for both the good nose and the bad nose. Open rhinoplasty has opened new vistas for rhinoplasty surgeons and offers solutions for many challenging functional and cosmetic nasal deformities.

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Chapter 34

Management of the Bony Nasal Vault

Sam P. Mostafapour, Craig S. Murakami, and Wayne F. Larrabee, Jr.

Correction of deformities of the bony nasal vault presents a challenge to the rhinoplastic surgeon. In many cases, suboptimal clinical results may result from inadequate or inappropriate mobilization of the nasal bony-cartilaginous framework. Furthermore, postoperative complications, such as significant reduction of the nasal airway, may occur. A number of techniques are available to appropriately mobilize and reposition the bony nasal vault. Herein we review our experience with a variety of techniques and consider some special situations.

ANATOMY

Requisite to the use of the techniques described below is an understanding of the bony anatomy of the nose and its relation to the external nasal contour. The external contour of the upper third of the nose is defined by the two sidewalls, the dorsum, and the nasofrontal angle. A number of terms used to describe the anatomy of the bony nasal vault warrant review.[1] The *nasion* is the bony junction between the frontal and nasal bones. The *nasofrontal angle* is the external landmark identifying the deepest or most posterior portion of the nasal dorsum and may lie several millimeters inferior to the nasion. The osseocartilaginous junction of the nasal bones inferior to the superior edge of the upper lateral cartilages is the *rhinion*. The sidewalls are formed by the nasal bones themselves and the frontal process of the maxilla. The nasal bones are thin inferiorly and become thick superiorly.[1,2] This is demonstrated by transillumination of the skull (Fig. 34–1). The variable thickness of the bony structures of the nose has implications for osteotomy placement, as discussed later in the chapter.

The relationship of the soft tissue envelope to the bony nasal vault must not be overlooked. This soft tissue varies in thickness over the nasal bones. As shown in Figure 34–2, the nasal skin is thicker superiorly and inferiorly and quite thin over the central nasal rhinion.[1] Thus, surgery on the nasal profile must compensate for this to avoid a "saddle-nose" appearance. For example, a slight hump must be left at the bony rhinion if a straight soft tissue profile is desired.

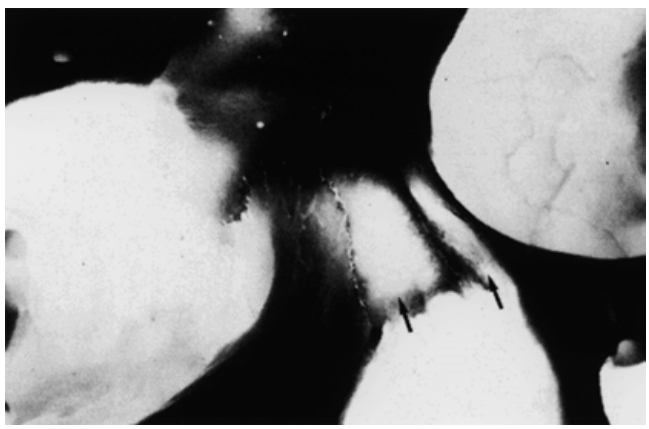

Figure 34–1 Transillumination of the skull reveals the thinner aspect of the nasal bones, which are mobilized with osteotomies in rhinoplasty (*arrows*). Osteotomies that are carried into the thicker bone of the maxilla or frontal bone are ineffective or result in inappropriate fracture sites. (Adapted from Larrabee WF Jr. Open rhinoplasty and the upper third of the nose. *Fac Plast Surg Clin North Am* 1993;1(1):24.)

BASIC SURGICAL TECHNIQUES

Hump Reduction

The soft tissue envelope is elevated from the bony-cartilaginous framework up to the level of the nasofrontal angle (via incisions described elsewhere in this text; Fig. 34–3). Care is taken to undermine conservatively and yet widely enough to permit adequate hump reduction and subsequent skin redraping. Although adequate exposure is obtained to perform the desired reduction or refinement of the profile, as much soft tissue support is preserved as possible. Either an osteotome or a rasp can be used to lower the dorsum, depending on the surgeon's experience and preference. In general, an osteotome may be used for larger humps and a rasp for smaller reductions and refinements. To remove larger humps, a conservative correction is performed with a

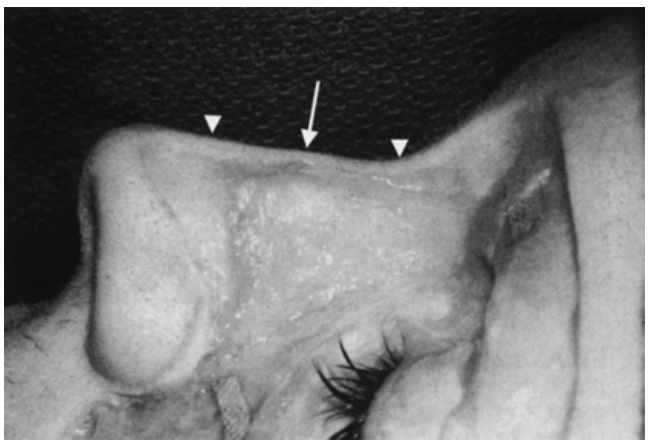

Figure 34–2 Skin thickness of the nasal dorsum. The nasal thickness varies greatly from patient to patient but in general is thicker in the supratip and nasion areas (*arrowheads*). Reduction of the bony/cartilaginous framework in rhinoplasty must allow for variations in the thickness of the soft tissue/skin envelope. To maintain a straight soft tissue profile, the framework must maintain a slight hump at the rhinion (*arrow*). (Adapted from Larrabee WF Jr., Makielski KH. *Surgical Anatomy of the Face*. New York: Raven Press; 1993:164.)

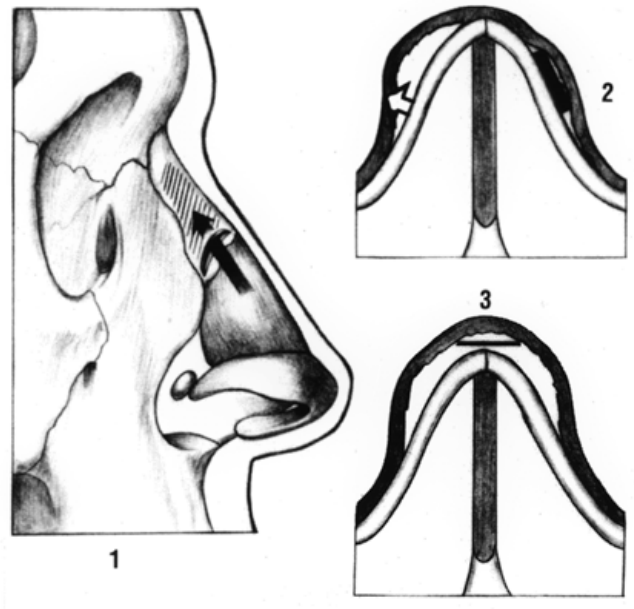

Figure 34–3 Elevation of the periosteal flap begins with (1) sharp dissection a few millimeters above the caudal end of the nasal bones, followed by the development of pockets bilaterally (2) and the connection of these pockets in the midline with sharp dissection (3). (Adapted from Larrabee WF Jr. Open rhinoplasty and the upper third of the nose. *Fac Plast Surg Clin North Am* 1993;1(1):26.)

double-guarded osteotome (Fig. 34–4). Refinements are then made with a tungsten carbide pull rasp. The rasp is angled slightly obliquely off the midline to avoid avulsing the upper lateral cartilages from the undersurface of the nasal bones.

Osteotomies

Jacques Joseph was one of the first surgeons to promote osteotomy.[3] The path of his osteotomy extended from the inferior piriform aperture up into the nasal process of the frontal bone. The mobilization of the nasal bones by Joseph and other early rhinoplastic surgeons resulted in a high rate of nasal airway compromise postoperatively. The recognition that preservation of the periosteum and lateral suspensory ligaments of the lower lateral cartilage helped to lower the incidence of postoperative airway compromise has been an important positive technical modification.[4–6] Thus, modern techniques of osteotomy have evolved to take into account the effects of bony repositioning on functional as well as aesthetic outcome.

In performing nasal osteotomies, the surgeon's aesthetic objectives are to (1) close an open nasal vault; (2) straighten a deviated nasal dorsum; or (3) narrow the nasal sidewalls. From a functional standpoint, the surgeon must consider the possible effects of the osteotomy on the patient's nasal airway. Each patient's nasal architecture is unique. In general, an osteotomy should be limited to the thinner aspect of the nasal sidewall. The average thickness of the nasal sidewall

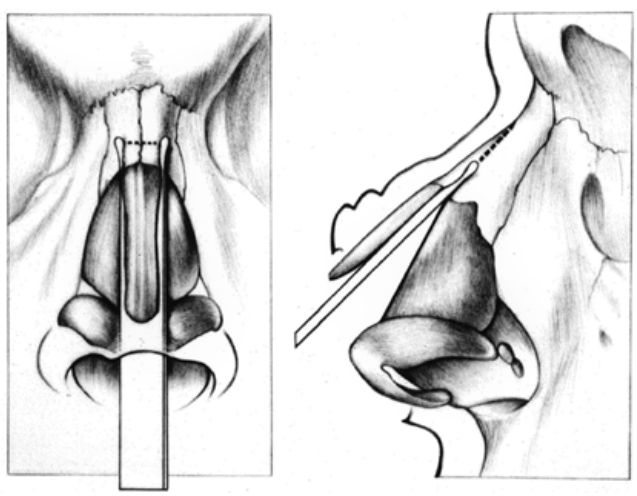

Figure 34–4 The cartilaginous dorsum to be removed is incised sharply and left attached to the nasal bones. After elevation of the periosteum, a double-guarded osteotome is used to complete the hump removal. Care is used to follow the planned profile superiorly to the nasion and to avoid canting the osteotome to the right or left. The hump removal is done conservatively with fine adjustments made with the rasp. (Adapted from Larrabee WF Jr. Open rhinoplasty and the upper third of the nose. *Fac Plast Surg Clin North Am* 1993;1(1):28.)

along the osteotomy path is 2.5 mm.[7] Commonly used osteotomy techniques include the lateral osteotomy, performed either with a perforation or linear technique; the medial osteotomy; the superior osteotomy; and the intermediate osteotomy.

The Lateral Osteotomy

Lateral osteotomies are performed to close an open dorsum (open roof) and to narrow or straighten the nasal pyramid. There are two basic techniques: the linear (single-cut) technique and the perforating technique. With the linear technique, the osteotome is used to make a bony cut along the nasal facial groove (Fig. 34–5). The most widely accepted path of the osteotomy follows a high (anterior), low (posterior), high (anterior) pathway. The course of the lateral osteotomy begins at the level of the attachment of the inferior turbinate. A small triangle of bone at the pyriform aperture is left intact to preserve the lateral attachments of the suspensory ligaments. This helps to preserve the nasal airway. Next, the osteotomy is continued along the nasal facial groove until it curves superiorly and anteriorly into the thinner aspect of the nasal bone at the level of the inferior orbit. The cut is then terminated at the level of the medial canthus. If it is carried higher into the thicker bone of the nasofrontal suture a rocker deformity may result, in which infracture of the nasal bone results in protrusion at the superior fracture site.[8]

The superior back-fracture can be created by turning the osteotome, applying digital pressure, or using a percutaneous transverse superior osteotomy. In the latter technique, a small cutaneous puncture is created with a 2-mm osteotome midway between the nasal dorsum and the medial canthal region. Through this site, the same osteotome is used to create three or four small perforations, allowing mobilization of the nasal bone without disrupting the overlying periosteal support.

The perforating technique can also be used to create a lateral osteotomy. A small series of perforations are placed along the desired fracture site using a transnasal or transcutaneous approach. The perforating intranasal osteotomy can also be used to "push out" the nasal bones that have been medially displaced by previous trauma or surgery. The objective is to move the nasal sidewall laterally. The perforating osteotomy is preferred in difficult cases, such as revision rhinoplasty or posttraumatic nasal surgery, where maintenance of structural support is critical. Cadaveric studies have demonstrated preservation of considerably more periosteal support with the perforating technique in comparison with the linear technique.[9,10] Noses that are extremely deviated or those that have thick nasal sidewalls are more appropriately treated with a linear osteotomy.[11]

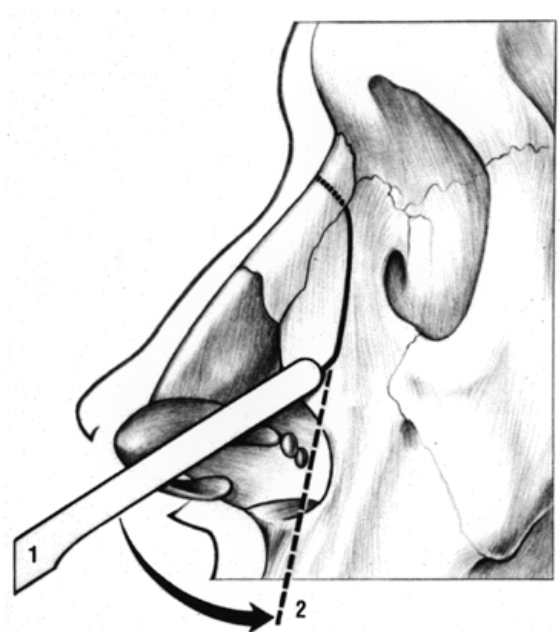

Figure 34–5 The lateral osteotomy is begun at the anterior end of the inferior turbinate and is first made perpendicular to the face of the pyriform aperture (position 1). After this cut, the osteotomy is carried in a curved fashion toward the medial canthal area (position 2). (Adapted from Larrabee WR Jr. Open rhinoplasty and the upper third of the nose. *Fac Plast Surg Clin North Am* 1993;1(1):30.)

The Medial Osteotomy

Medial osteotomies are performed when needed to mobilize the nasal sidewalls. They are often used to correct the deviated nose or to narrow the wide nose without a hump. Medial osteotomies are performed in an angulated fashion between the nasal bone and septum and are carried superiorly to meet the superior osteotomy site or back-fractured site (Fig. 34–6). In the severely deviated or wide nose, medial osteotomies can be considered essential. However, in cases where less correction is required, they may actually cause bony irregularities and should be used judiciously.

The Intermediate Osteotomy

The primary uses of the intermediate osteotomy are to (1) narrow the extremely wide nose that has good height (bilateral osteotomy); (2) correct the deviated nose with one sidewall much longer than the other; and (3) straighten a markedly convex nasal bone.[11,12] The intermediate osteotomy is made parallel to the lateral osteotomy somewhere along the midportion of the nasal sidewall. The exact medial/lateral placement of the osteotomy along the lateral nasal wall may vary depending on the surgical goals. In a closed rhinoplasty, it is usually performed via an intercartilaginous incision with a small osteotome (e.g., 3 mm) and carried cephalad to the superior fracture site. Through the open rhinoplasty approach it can be performed with more precision. The intermediate osteotomy is performed before the lateral osteotomy, as the intermediate cut cannot be made easily after the bone is mobilized laterally. Soft tissue should be left attached to the nasal bone for added support.

POSTOPERATIVE MANAGEMENT

Osteotomy causes mild to moderate soft tissue swelling and, in addition, may cause ecchymosis and periorbital edema. Postoperative edema can be greatly reduced by the application of cold compresses and by elevation of the head to 30 degrees during the first 24 hours after surgery. Perioperative antibiotics may be used. Nasal packing, if used, is removed in

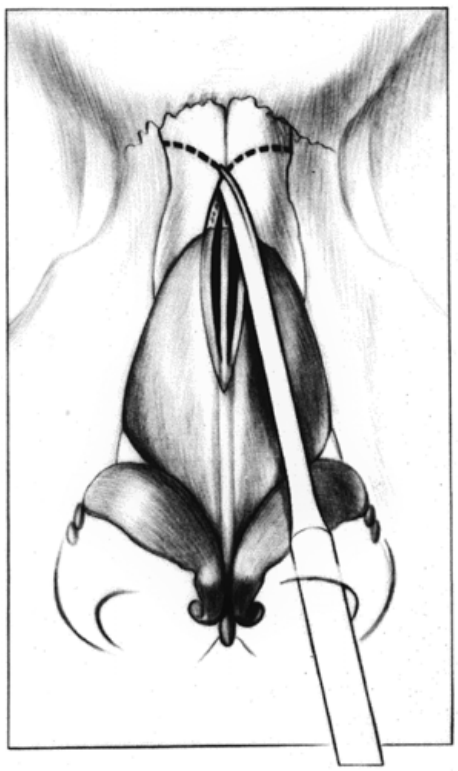

Figure 34–6 Medial osteotomies are not done routinely but are performed when necessary, such as in the extremely wide or deviated nose. Either a straight or a curved osteotome creates a controlled cut at the transition to the thicker frontal bone. (Adapted from Larrabee WF Jr. Open rhinoplasty and the upper third of the nose. *Fac Plast Surg Clin North Am* 1993;1(1):29.)

24 hours, and nasal casts or surgical splints are removed after 1 week. Some surgeons encourage nasal exercises, in which the patient places a finger on either side of the nose and exerts moderate inward pressure to prevent displacement of the newly medialized osteotomized bony pyramid.

SPECIAL CONSIDERATIONS

The Extremely Deviated Nose

The previous osteotomies may be used in combination to correct any given anatomic deformity of the bony nasal pyramid. For example, in the posttraumatic or longstanding severely crooked nose, it is important to completely mobilize the segments of the bony pyramid to avoid persistent postoperative deviations. In this situation, the osteotomies are performed sequentially beginning on the side opposite the deviation (e.g., for a pyramid displaced to the left, begin with the right lateral osteotomy). Note that this is similar to turning the pages of an open book, with the nasal walls and septum simulating the pages (Fig. 34–7). This allows creation of a space in which to realign the deviation.

Wide Nose

Removal of a significant hump from the wide nose may result in a wide open dorsum. Standard osteotomies may allow the nasal bones to be moved to close the open roof. Debris or residual wedges of bone or cartilage may persist at the junction of the nasal bone and septum. This must be removed prior to closure. In some cases, when nasal height is appropriate and the nasal bones are extremely wide or convex, bilateral intermediate osteotomies may be necessary to obtain adequate narrowing.[11]

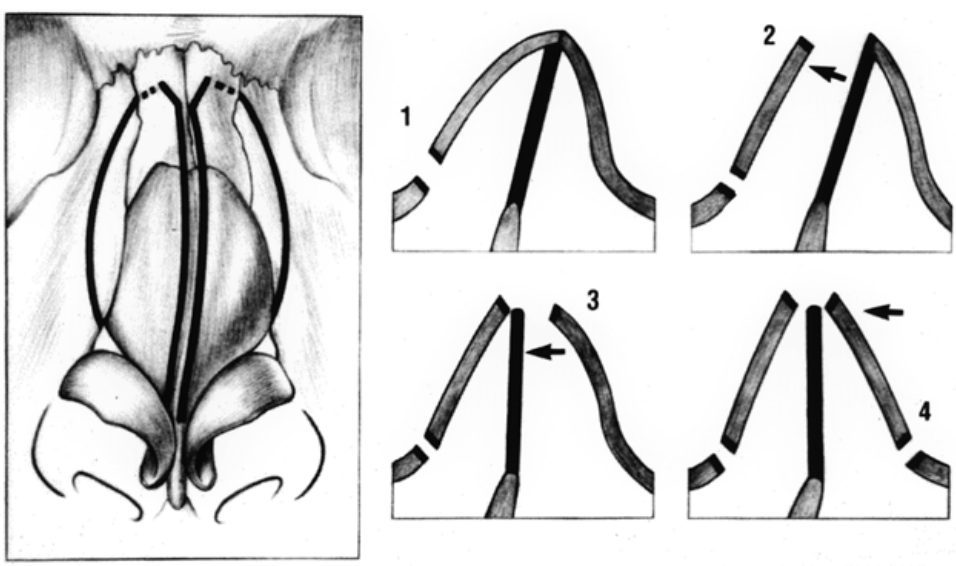

Figure 34–7 To correct a deviated nose, sequential osteotomies are performed in a fashion similar to opening a book. (Adapted from Larrabee WF Jr. Open rhinoplasty and the upper third of the nose. *Fac Plast Surg Clin North Am* 1993;1(1):33.)

Short Nasal Bones

Preoperative evaluation of the patient should include assessment of the length of the nasal bones and the composition of the nasal hump (bone versus cartilage). Patients with short nasal bones, as determined by palpation, often have a primarily cartilaginous hump. In this case, the surgeon must avoid both overmobilization of the nasal bones with osteotomies and overresection of the dorsal nasal bones with a rasp or osteotome. The dorsal hump can sometimes be lowered without osteotomies. A perforating osteotomy may be used to preserve maximal soft tissue support. In these cases, a greenstick fracture superiorly is desirable as it also avoids overmobilization of the delicate, short nasal bones.

SUMMARY

A systematic approach must be used when addressing the deviated nasal pyramid. This includes precise preoperative and intraoperative anatomic analysis of the bony deformity. A thorough understanding of the various techniques available to address these deformities allows the surgeon to address the deviated pyramid most appropriately and with optimal postoperative outcome.

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Chapter 35

Management of the Middle Vault

Ira D. Papel

Management of the middle vault in rhinoplasty was for many years considered little more than removal of a hump deformity. The traditional reduction rhinoplasty often included sharp resection of the middle vault apex (cartilage and mucosa) with little regard to nasal function or long-term sequelae. In the 1980s, surgeons began to describe long-term complications of this approach[1] and modified rhinoplasty techniques to avoid these problems. Reconstructive rhinoplasty techniques were also developed to repair damaged middle vaults. Nasal valve pathology is often overlooked as a source of nasal obstruction. Many surgeons concentrate on the septum, turbinates, and presence of mucosal abnormalities before considering the lateral nasal wall as a problem. Although it is important to rule out inflammatory, immunologic, septal, and other abnormalities in the nose, it is also important to consider the internal and external nasal valves in a differential diagnosis. In this chapter we will describe these techniques and identify patients who are at risk of middle-vault pathology in rhinoplasty.

MIDDLE-VAULT ANATOMY

Beneath the nasal skin and soft tissue, the middle vault is composed of the paired upper lateral cartilages and attached mucosa. At the cephalic end the upper lateral cartilages are fused with the nasal bones, inserting just under the caudal end of the bones. Medially the cartilages fuse with the cartilaginous septum, the caudal end separating from the septum and lying fairly mobile. The caudal end of the upper lateral cartilages may have a recurvature or scroll that has attachments to the lower lateral cartilages. Laterally the upper lateral cartilages approach the pyriform apertures, fusing with dense fibrous tissue. Mucosa is tightly attached to the internal surface of the cartilages and is continuous with the lining of the septum and lateral nasal wall (Fig. 35–1).

The caudal margin of the upper lateral cartilage, the septum, the floor of the nose, and possibly the anterior head of the inferior turbinate define the internal nasal valve. This is generally regarded as the narrowest point of air flow through the nose. The angle between the septum and the upper lateral cartilage has a normal range of 10 to 20 degrees, and narrowing of this angle due to trauma, surgery, or disease can cause significant nasal obstructive symptoms. The nasal valve has a cross-sectional area of 55 to 83 mm^2 and represents the narrowest area of the nasal passage. The nasal valve is the site of greatest nasal resistance[2] (Fig. 35–2).

SIGNIFICANCE OF MIDDLE VAULT ANATOMY IN RHINOPLASTY

Rhinoplastic surgeons must be able to evaluate and address the middle-vault region to provide acceptable functional and cosmetic results. Many patients present with a wide middle vault and internal nasal valve where hump reduction and narrowing of the internal valve do not cause later problems. This is particularly true in the African American population. However, the surgeon, must be able to identify patients in whom further narrowing is ill advised. In addition, repair of the incompetent internal nasal valve, with appropriate nasal width, must be part of the rhinoplastic surgeon's capabilities.

Hump reduction is probably the most common maneuver in rhinoplasty. In traditional hump reduction surgery, the cartilaginous hump is excised as a block with the underlying mucosa. This separates the upper lateral cartilages from the natural attachment to the septum and usually interrupts the continuity of the mucoperichondrium. This leads to inferomedial collapse of the upper lateral cartilages, which is worse if the mucosa is also severed.[3] This may not be apparent immediately after rhinoplasty but may present gradually over a period of years, with tell-tale deformities. The capacity of the middle vault to withstand the inward pressure of inspiration may be reduced. Chronic nasal obstruction due to valve narrowing may develop gradually or be apparent immediately. There are other conditions that may precipitate internal nasal valve obstruction. Facial paralysis can lead to ptosis of the lateral nasal soft tissues and narrowing of the valve, causing symptomatic obstruction. Cancer resection of the lower two thirds of the nose may lead to scar contraction and distortion of the valve. Senile tip ptosis can also cause significant narrowing and congestion (Fig. 35–3).

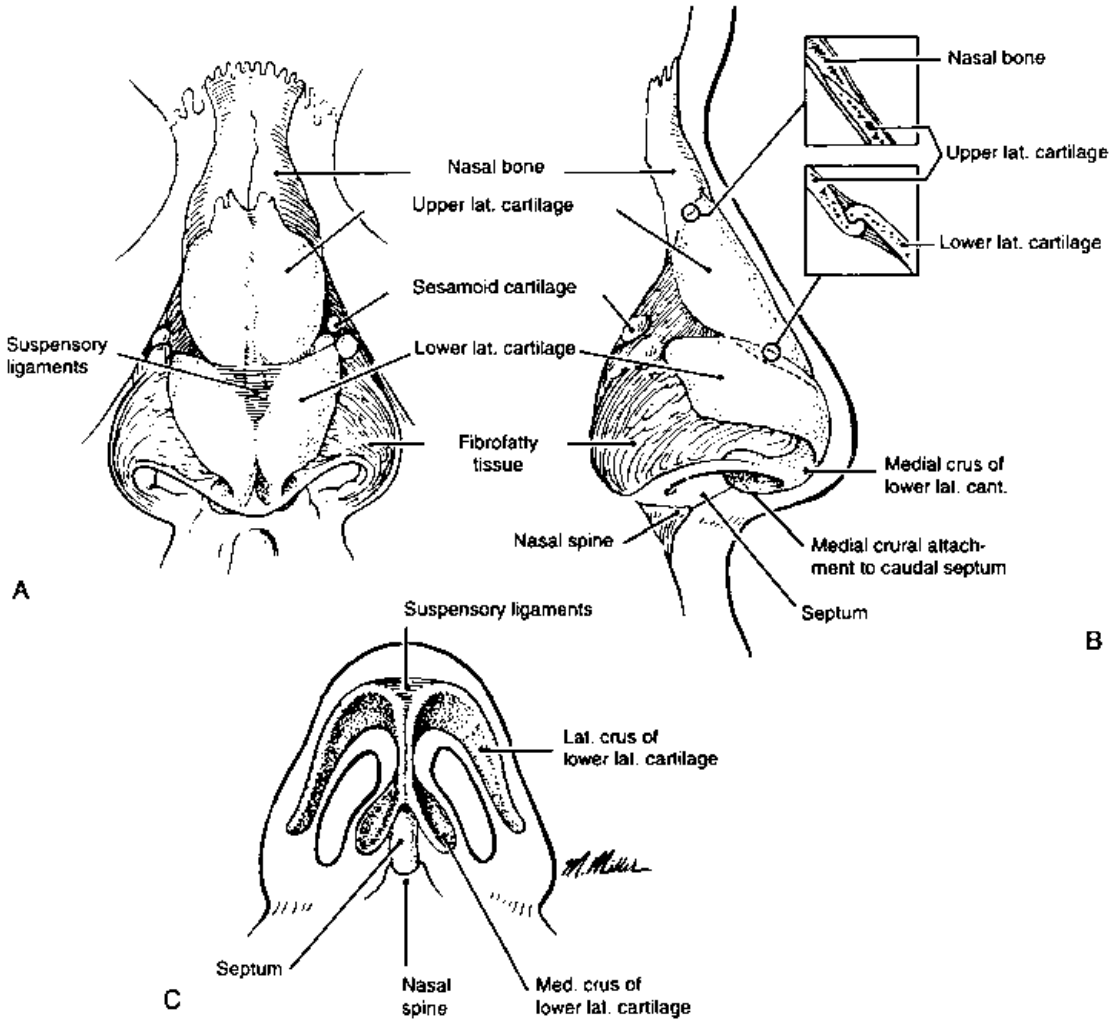

Figure 35–1 Nasal cartilage anatomy, with relationship of upper lateral cartilage to other structures.

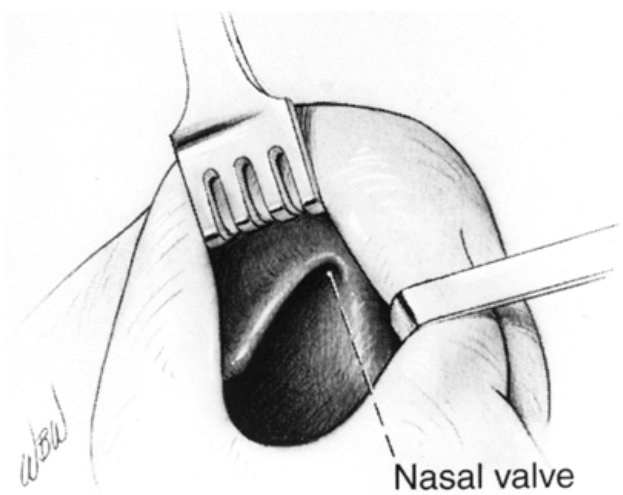

Figure 35–2 Clinical appearance of internal nasal valve, which is the narrowest cross-section of the nasal airway.

Figure 35–3 Appearance of patient after rhinoplasty with narrowing of the middle vault causing nasal obstruction.

RISK FACTORS IN RHINOPLASTY

Several risk factors have been identified as predisposing to middle-vault problems in rhinoplasty.[4] Not recognizing these warning signs may inadvertently result in physical signs, such as inverted-V deformity, middle-vault collapse on inspiration, overly narrow radix line, dorsal asymmetry, and eventual nasal obstruction.

The inverted-V deformity has been recognized as the classic sign of middle-vault pathology following rhinoplasty. The cause seems to be posterior displacement of the nasal bones and upper lateral cartilages after osteotomies, combined with overresection or posterior displacement of the upper lateral cartilages. If dorsal reduction involves mucosal interruption or detachment of soft tissue over the nasal bones and upper lateral cartilages, these structures have little to support them after osteotomy.[5]

Specific risk factors associated with middle-vault postoperative problems include short nasal bones, long and weak upper lateral cartilages, thin skin, tall and narrow noses, and previous trauma or surgery.[6]

PREVENTION OF MIDDLE-VAULT PROBLEMS

Proper preoperative evaluation and planning can prevent most middle-vault complications. This allows preventive rhinoplastic techniques to be employed and improves functional and aesthetic results. These techniques include preservation of middle-vault support structures, judicious use of spreader grafts, use of conservative osteotomies, and replacement of cartilage support in revision rhinoplasty cases. Every rhinoplasty patient deserves individual assessment and operative planning. Many middle-vault characteristics may not be appreciated on the initial physical examination. Good-quality photographs can be invaluable in preoperative evaluation and should be studied prior to surgery.

Toriumi and Johnson[4] have demonstrated that preservation of the middle-vault mucosa helps to minimize posterior displacement of the upper lateral cartilages during hump removal. This mucosal bridge between the septum and upper lateral cartilages can be preserved by the creation of junction tunnels under the attachment area of the septum and upper lateral cartilage. Preserving this mucosa also helps to maintain a blood-free surgical field.

When performing dorsal reduction a conservative resection should be done. Maintenance of a strong dorsal line is usually desirable for both aesthetic and functional reasons. In a patient with dorsal convexity and a narrow vault, it may be necessary to reduce the dorsum minimally, widen the middle vault with spreader grafts, and increase tip projection to achieve nasal harmony.

A common postoperative problem is overnarrowing of the nose due to medial displacement of the nasal bones after aggressive complete osteotomies. Although many rhinoplasty patients desire a narrower nose, narrowing can be excessive and detrimental to both aesthetics and function. By maintaining the soft tissue attachments of the nasal bones and upper lateral cartilages, excessive medial and posterior displacement can be prevented. Internal splinting can also prevent excessive narrowing in the early postoperative period.

CORRECTION OF MIDDLE-VAULT PATHOLOGY

Surgical correction of middle-vault problems can be preventive or corrective. When the risk factors identified are present, preventive action may be required. In a revision rhinoplasty multiple modalities may be utilized. These techniques may include cartilage grafts, precise structural realignment, and fixation of nasal valve structures.

Spreader grafts are probably the most common corrective modality used for middle vault rehabilitation. First described by Sheen and Sheen,[7] these are rectangular cartilage grafts placed between the junctions of the upper lateral cartilages and septum to widen the nasal valve. These cartilage grafts not only lateralize the upper lateral cartilages but add rigidity to the middle vault to resist inward motion on inspiration. They can be placed either through open or closed rhinoplasty techniques, but are easier to stabilize with direct sutures via the open approach. Septal cartilage is the most frequently used grafting material, but auricular cartilage may be used if septum is not available. Spreader grafts can also be utilized for aesthetic purposes. For patients with unilateral middle-vault depressions due to congenital, traumatic, or iatrogenic causes, a single spreader graft can elevate and lateralize the upper lateral cartilage and restore symmetry.

The surgical technique for placement of spreader grafts varies with the surgical approach. Sheen and Sheen[7] and Constantian and Clardy[8] describe placing the grafts in precise submucoperichondrial tunnels along the dorsal edge of the septum without separation of the existing upper lateral cartilages from the septum. This is accomplished through a closed rhinoplasty approach.

In many revision rhinoplasty cases involving middle-vault pathology, separation of the septum and upper lateral cartilages has occurred due to hump removal. There is usually fibrous tissue instead of a fusion of cartilage at the internal nasal valve. Therefore, preservation of the mucoperichondrium and creation of a pocket for the graft placement through an open approach is usually preferred. If the upper lateral cartilages are fused with the septum, sharp dissection from the internal side with an elevator will preserve the mucoperichondrial flap attachments and preserve stability. At times the upper lateral cartilages may have been almost completely resected. In this situation, conchal cartilage grafts may be necessary to provide lateral support in addition to spreader grafts. The grafts are carved, aligned, and fixed in position with 5-0 PDS (Polydiaxonone, Ethicon, Sommerville, NJ) mattress sutures. Most spreader grafts are 1.5 to 2.5 cm in length and 1 to 3 mm in width. In general, the grafts should run along the dorsal septum from below the bony–cartilaginous junction to the anterior septal angle. In severe cases the grafts may be layered to provide additional bulk. Grafts of unequal width may be used to accommodate asymmetries in the middle vault. Spreader grafts may also be used as internal stents to help straighten a caudal septal deflection. The technique of spreader graft placement and fixation is demonstrated in Figs. 35–4 to 35–7. Placement of a 30-gauge needle through the cartilage complex makes placement of the sutures much easier (Fig. 35–8).

Grafts that are wide at the end may lateralize the caudal portion of the upper lateral cartilages, creating fullness in the lateral supratip area. Releasing the lateral crura from

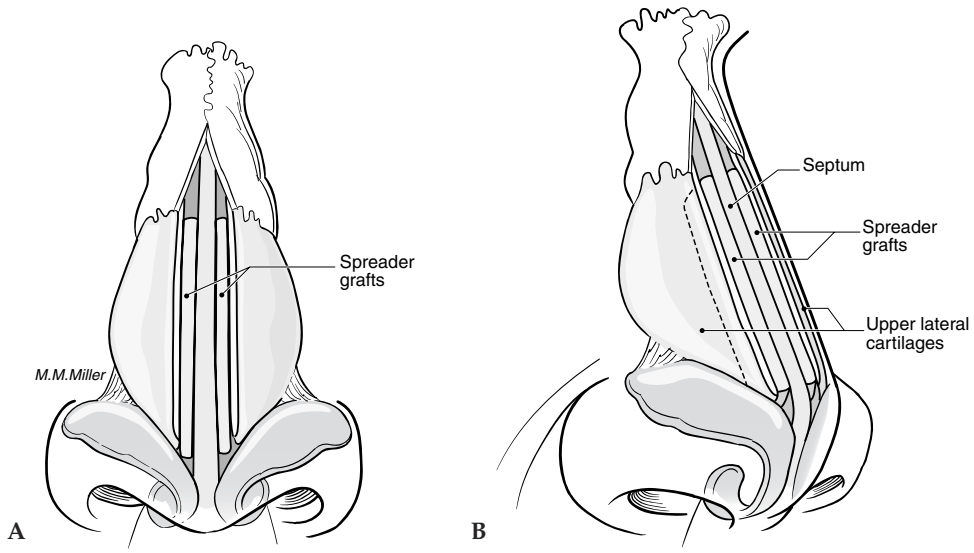

Figure 35–4 Ideal placement of spreader grafts between septum and upper lateral cartilages.

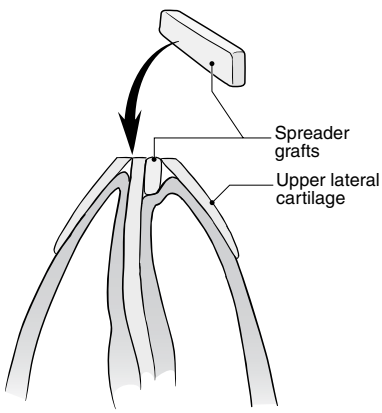

Figure 35–5 Placement of spreader graft lateralizes and elevates the upper lateral cartilage widening the middle vault.

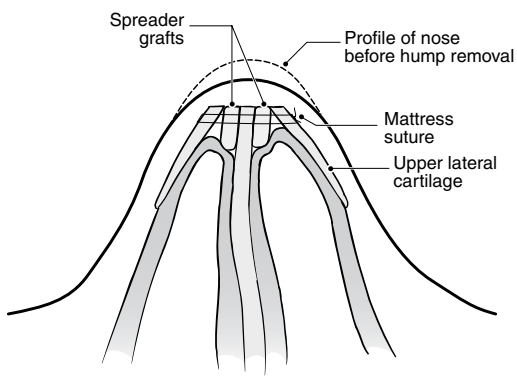

Figure 35–6 Spreader grafts in place and fixed with mattress sutures. The original dorsal height is identified.

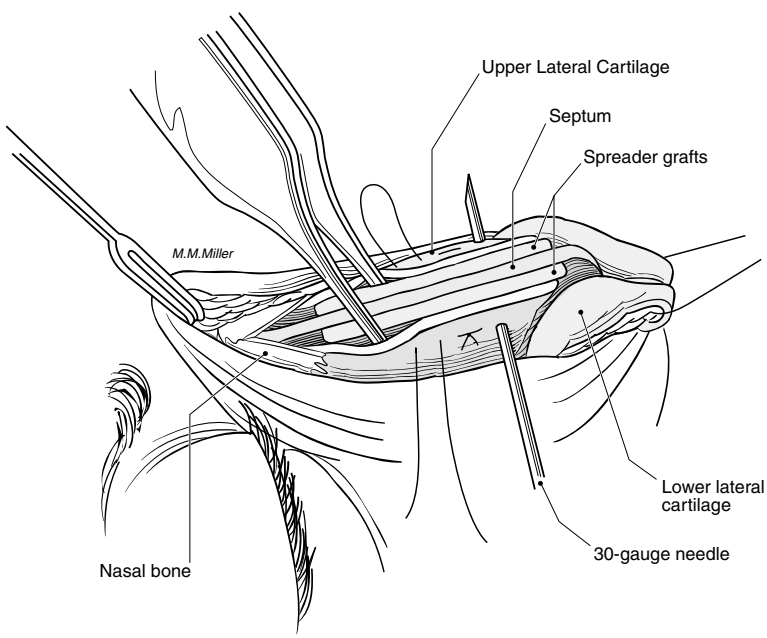

Figure 35–7 Demonstration of mattress suture technique for fixation of spreader grafts.

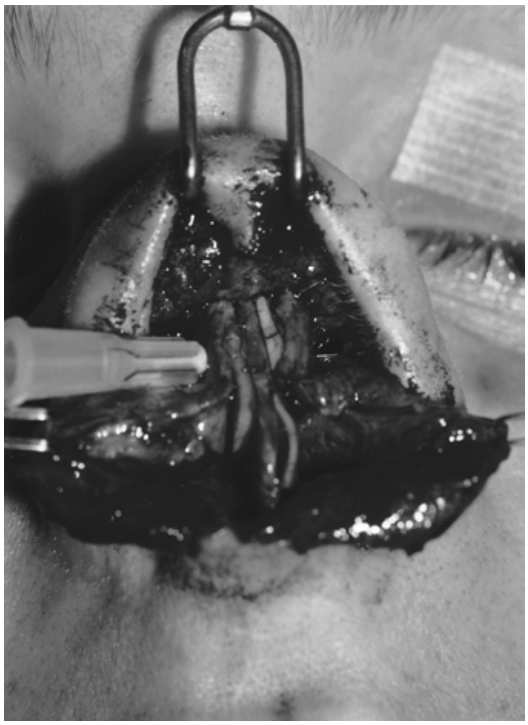

Figure 35–8 Temporary placement of a 30-gauge needle fixes grafts and makes placement of mattress sutures technically easier.

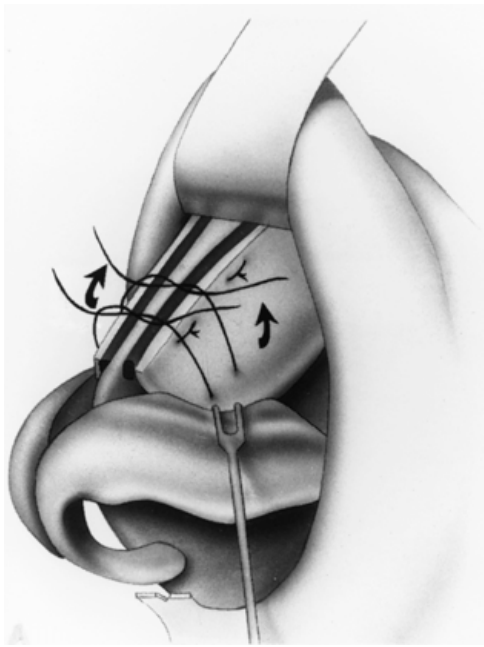

Figure 35–9 Flaring suture can be used to cause further widening of the middle vault when combined with spreader grafts. (From Park SS. Treatment of the internal nasal valve. *Fac Plast Clin North Am* 1999;7:333–345. With permission.)

the scroll area allows for free motion, some overlap, and prevents distortion. In some cases it may be advisable to place a graft of crushed cartilage over the dorsum and spreader grafts to smooth the profile. AlloDerm (LifeCell Corp., Branchburg, New Jersey) may also be used for this purpose.

In an effort to further support the nasal valve, Schlosser and Park[9] described the use of flaring sutures to improve the cross-sectional area of the internal nasal valves. The additional treatment here is a 5-0 nylon clear mattress suture that spans the upper lateral cartilages and the nasal dorsum horizontally. Tightening the suture increases the angle of the nasal valve, theoretically improving nasal function. Park's study indicated that flaring sutures used concomitantly with spreader grafts increase air flow more than spreader grafts alone[10] (Fig. 35–9).

Patients with saddle-nose defects may have middle-vault collapse with no support for the soft tissue. Fixated of a dorsal graft may help support the inferior soft tissues and stabilize the nasal valve. The use of cranial bone grafts combined with lag-screw fixation has been very helpful in these patients.[11] The cranial bone can serve as an anchor for reconstructive grafts and provide vertical height to the middle vault[12] (Fig. 35–10).

Nasal obstruction in rhinoplasty may have multiple causes. The middle vault may present with congenital, traumatic, or iatrogenic pathology that must be addressed during rhinoplasty. Specific physical signs and symptoms should alert the surgeon that middle-vault intervention is necessary to prevent unwanted sequelae later. This will lead to better functional and aesthetic rhinoplasty results.

Figure 35–10 Cranial bone grafts can be used for dorsal reconstruction and provision of middle-vault support.

PATIENT EXAMPLE

The patient shown in Fig. 35–11 presented with a history of previous rhinoplasty and increasing nasal obstruction for 10 years. The symptoms had gotten progressively worse and were not relieved by multiple medications. Examination revealed internal valve collapse bilaterally, with physical

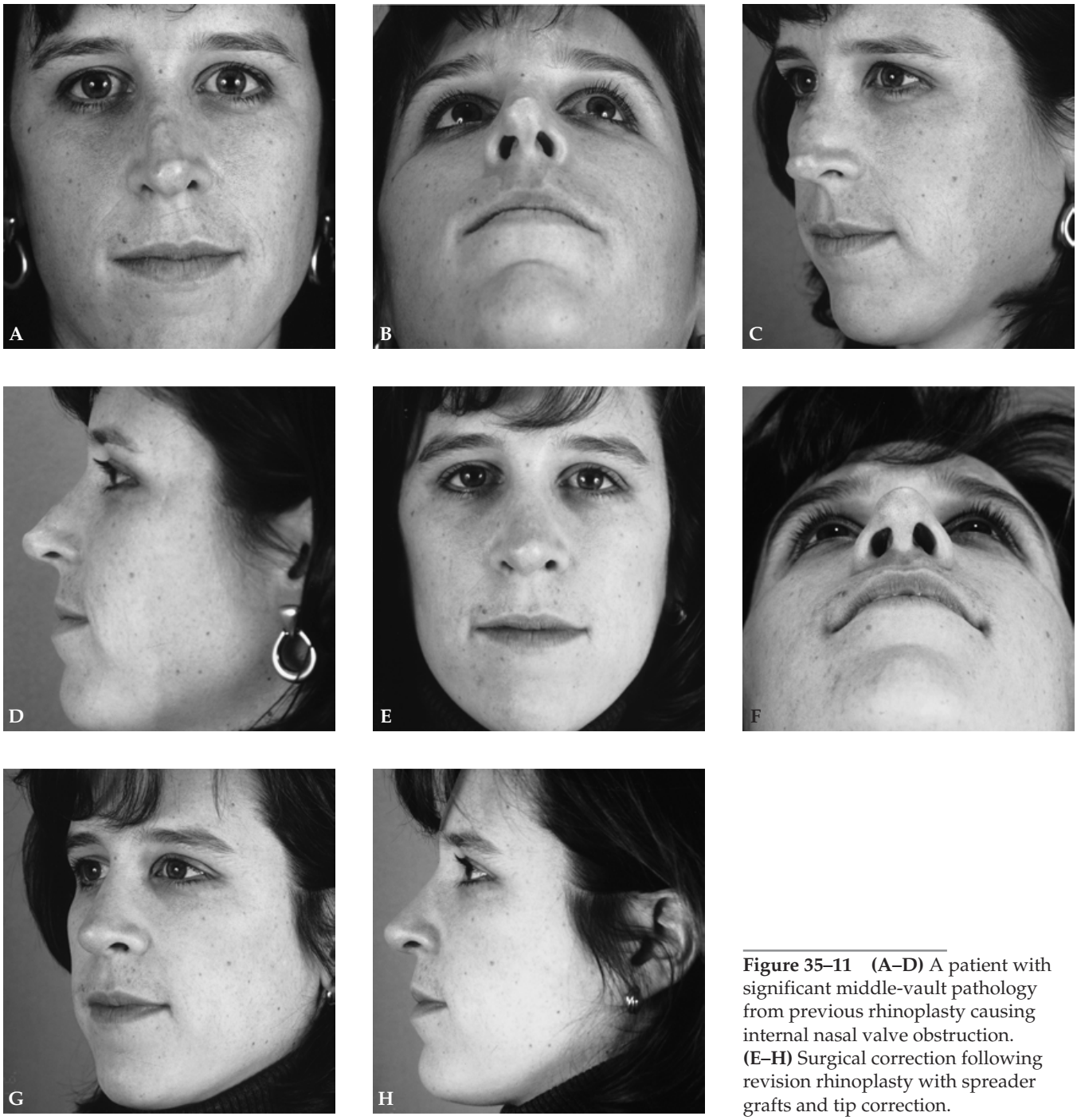

Figure 35–11 **(A–D)** A patient with significant middle-vault pathology from previous rhinoplasty causing internal nasal valve obstruction. **(E–H)** Surgical correction following revision rhinoplasty with spreader grafts and tip correction.

evidence of significant upper lateral cartilage resection. The residual middle-vault cartilage was inferomedially displaced, causing narrowing of the middle vault. The cartilage edges and bone were also irregular and asymmetric. The lower lateral cartilages were also asymmetric with a bossa on the right. The preoperative condition is exhibited in Fig. 11A–D.

This patient underwent an open rhinoplasty procedure with use of spreader grafts, reduction of tip projection, interdomal sutures, columellar strut, and smoothing of the dorsal bone. The 2-year postoperative photographs are shown in Fig. 11E–H. The middle vault is more symmetrical and has appropriate width for function and cosmesis.

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Chapter 36

Surgery of the Nasal Tip: Intranasal Approach

Gilbert J. Nolst Trenité

Nasal tip surgery is the most challenging part of rhinoplastic surgery. In the great variety of procedures for nasal tip surgery and individual differences in tip anatomy, a systematic rational approach as advocated by Tardy is obligatory (Table 36–1). Of the three basic approaches—non delivery, delivery, and the external approach—the external approach is the most traumatic. Nevertheless, that approach has gained enormous popularity over the past decade. The possibility of accessing the anatomical deformities by direct inspection of the nasal cartilaginous and bony framework, and much easier bimanual sculpturing under direct vision, has stimulated in particular less experienced surgeons to choose this approach. One should keep in mind that the less the surgical trauma the more predictable the long-term outcome will be.

In modern rhinoplasty, the basic philosophy is to use the least traumatic approach that will enable us to apply the appropriate techniques to correct the specific deformities. In this chapter, the less traumatic approaches (nondelivery and delivery) will be emphasized.

ANALYSES

Before analyzing the typical nasal deformity, the surgeon should consider other major aesthetic components in the facial complex—forehead, eyes, lips, and chin—so as to create harmony and balance between these components. Aesthetic parameters of the nasal tip are:

In frontal view (Fig. 36–1):

- Tip defining points
- Width of the tip

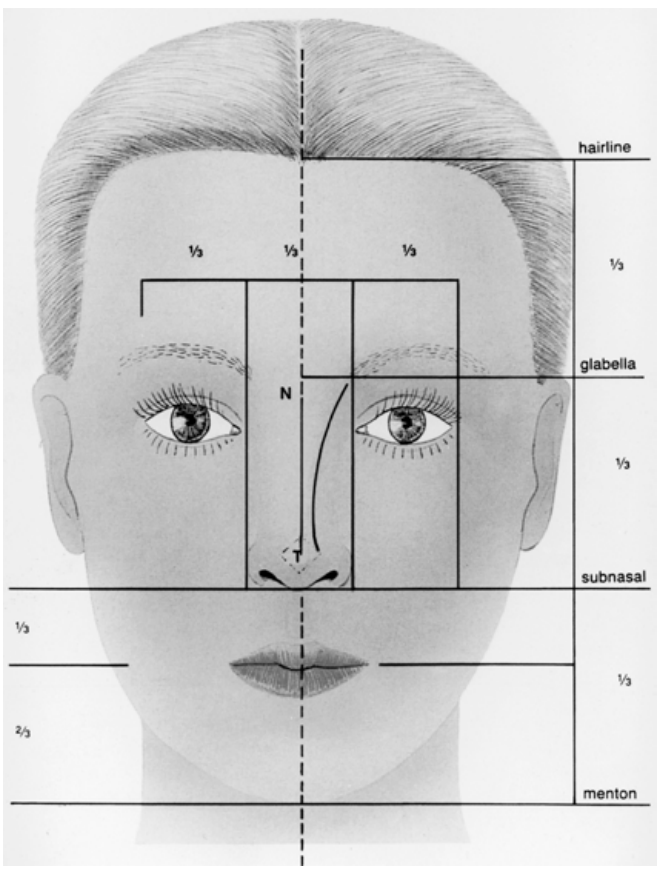


Figure 36–1 Frontal view of the face divided into aesthetic proportions (equal thirds) with a gently curving unbroken line from the supraorbital ridge along the lateral border of the dorsum to the tip-defining point on the same side.

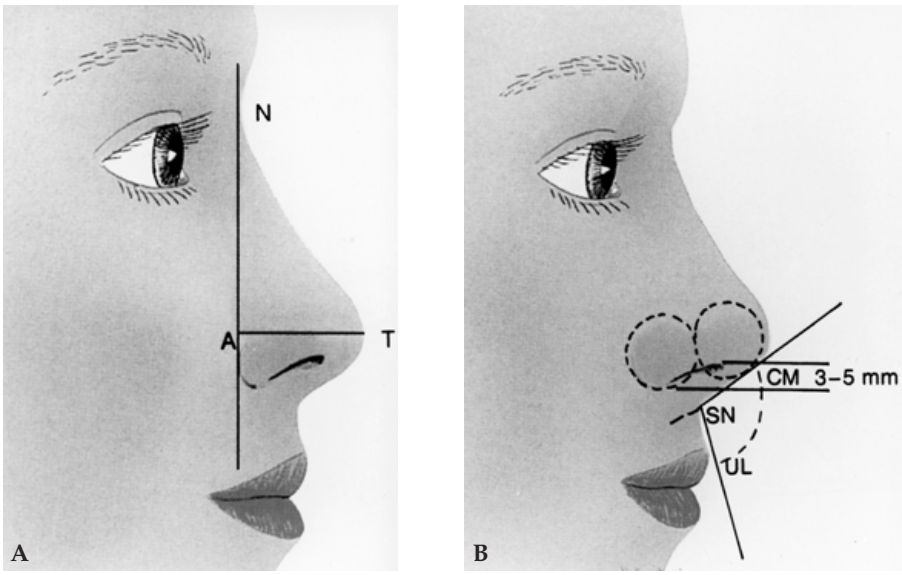


Figure 36–2 **(A)** The ratio TA/TN as a measure for tip projection. **(B)** The nasolabial angle (CM-SN-UL), the ratio between ala and lobule and extension of the columella below the nares (3 to 5 mm).

In lateral view (Fig. 36–2):

- Tip projection
- Nasolabial angle
- Ratio between ala and lobule
- Extension of the columella below the nares
- Columella double break

In basal view (Fig. 36–3):

- Equilateral triangle of the tip
- Lobular, intermediate, and basal part of the columella
- Nostril shape and lateral alar side walls
- Columella base

With these aesthetic guidelines in mind, the surgeon should assess and document the tip deformities (shape, projection, and rotation) (Fig. 36–5A). Furthermore standardized photographic documentation (at least six standard views) is obligatory. The quality of the skin (thickness, elasticity, and pathologic conditions), evaluation of the tip support (tip recoil; Fig. 36–4), and shape, size, and thickness of the alar cartilage play an important role in assessment of the surgical possibilities. Taking into account the desires of the patient and the information obtained by examination (inspection and palpation), the physician should devise a well-documented operative plan (Fig. 36–5B) and discuss it with the patient during a second consultation.

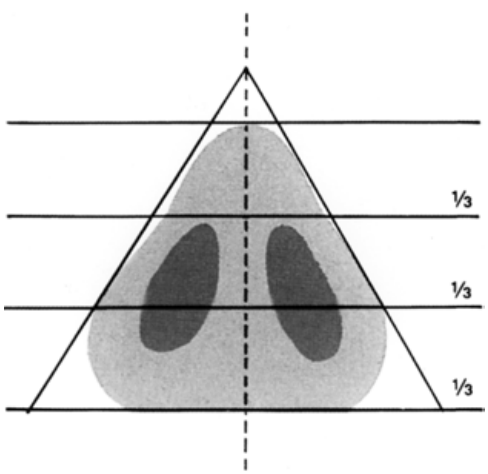


Figure 36–3 Basal view of the nose, which should have approximately the form of an equilateral triangle with the lobular, intermediate, and basal parts of the columella as three equal segments.

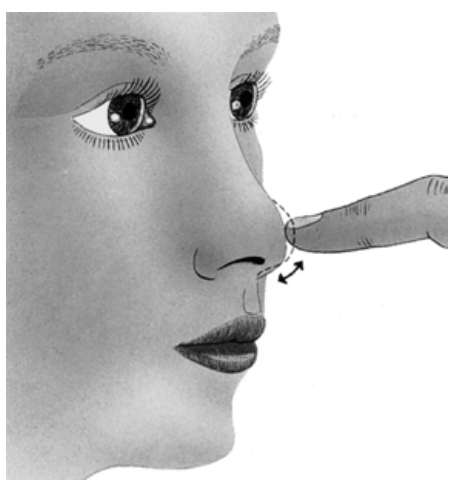


Figure 36–4 Tip recoil.

SEPTO-RHINOPLASTY ASSESSMENT FORM

born ... ☐ male ☐ female

Septo-rhinoplasty:
Type: ☐ primary ☐ functional ☐ revision ☐ aesthetic ☐ non-caucasion ☐ both ☐ cleft lip

Septum, valve and turbinates

Septum pathol.
☐ deviation
area 1 2 3 4 5 L
area 1 2 3 4 5 R
☐ perforation
diam. ... cm.
☐ cartilage loss
area 1 2 3 4 5
☐ other

Turbinate pathol.

	atroph.	hypertr.	other
inf. →	☐	☐	☐
med. →	☐	☐	☐

Valve pathol.
☐ too narrow
☐ too wide
☐ other

Tip columella, vestibulum and ala

Tip pathol.
☐ bulbous
☐ bifid
☐ asym.
☐ overproj.
☐ underproj.

Tip recoil
weak →1→2→3→4→5 strong

Columella pathol.
☐ retracted
☐ deviated
☐ broadened
☐ other

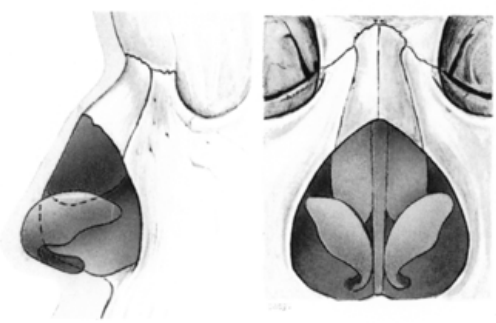
Vestibulum pathol.
☐ stenosis
☐ other

Alar pathol.
☐ insuff. ☐ flaring ☐ other

Osseo-cartilaginous vault

Skin qual.
thin →1→2→3→4→5 thick

Vault pathol.
☐ deviated
☐ cartil. ☐ bony ☐ both
☐ irregular
☐ cartil. ☐ bony ☐ both
☐ saddle
☐ cartil. ☐ bony ☐ both
☐ hump
☐ tension nose



Rhinometry
☐ acoustic
☐ mano

Photography
☐ standard
☐ other

Anesthesia: ☐ local
☐ iv analgesia
☐ general

☐ day care
☐ hospitalization

☐ pre-assessment

Expected operation time .....

Operation date .....

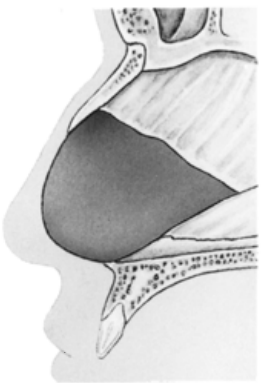
Figure 36–5 **(A)** Septorhinoplasty assessment form.

SEPTO-RHINOPLASTY OPERATION FORM

Name ... born ... ☐ male ☐ female
pat. reg. nr. .....
operating date ..... anaesthesia: ☐ local ☐ i.v. ☐ general

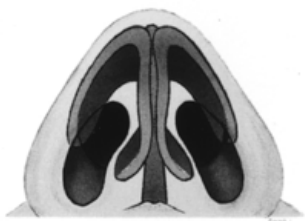
Approach

☐ endonasal
☐ delivery
☐ open



Incisions

☐ hemitransf.
☐ Killian
☐ part. transf.
☐ compl. transf.
☐ marginal
☐ rim
☐ intercartil.
☐ transcartil.
☐ V-Y procedure
☐ Z-plasty
☐ broken columella

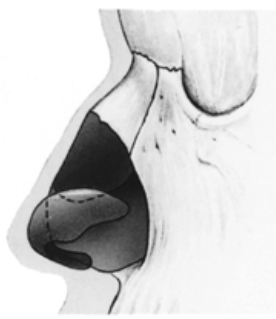


Type of grafts

☐ autog. septal
☐ autog. ear
☐ autog. rib
☐ composite ear
☐ allogeneic
☐ xenograft
☐ alloplast
☐ skin

Graft site

☐ spreader
☐ columella strut
☐ shield
☐ tip onlay
☐ dorsal onlay
☐ dorsal lat.
☐ alar batton
☐ maxillary
☐ naso-front.
☐ naso-lab.



Technique

Septoplasty

Cart. septal work
☐ basal strip
☐ post. chondrotomy
☐ scoring
☐ splinting
☐ resection
Bony septal work
☐ ant. spine red.
☐ ant. spine realignm.
☐ perpend. plate
☐ vomer
☐ grafting

Turbinate reduct.
☐ inf. ☐ L ☐ R
☐ med. ☐ L ☐ R

Tip surgery

☐ cephalic resection
☐ complete strip
☐ incomplete strip
☐ suturing
☐ interdomal
☐ transdomal
☐ lat. crural steal

Bony cart. vault surg.
☐ hump resection
☐ upper lateral
☐ augmentation

Osteotomies
☐ medial-oblique
☐ intermediate
☐ lateral (intranasal)
☐ lateral (percutaneous)
☐ infraction
☐ outfraction
☐ realignment

Alar base surgery

☐ V-shape wedge
☐ invert. V-shape wedge
☐ rectang. shape wedge

Direct postoperative care

☐ packing removal . . . days p.o. ☐ daycare
☐ dressing removal . . . days p.o. ☐ hospitalization
☐ sutures removal . . . days p.o. ☐ antibiotics
post op. consultation date . . . . . ☐ other med.

Figure 36–5 **(B)** Septorhinoplasty operation form.

TABLE 36–1 Approaches to Nasal Tip Surgery

Approaches	Incisions	Indications	Techniques
Nondelivery	transcartilaginous or intercartilaginous	Slight bulbosity Minimal tip rotation	Cephalic resection of lateral crus (complete strip)
Delivery	intercartilaginous and marginal	Moderate bulbosity Extra tip rotation Bifidity Asymmetry	Cartilage resection Scoring and morselization Alar (domal) suturing (complete or interrupted strip)
External	broken columellar and marginal	Congenital deformities Extensive revisions Severe nasal trauma Elaborate reduction and augmentation Shield graft Columella strut	Cartilage resections lateral/medial crura Alar cartilage modifications and reorientation (complete strip/interrupted strip)

APPROACHES AND INCISIONS IN INTRANASAL TIP SURGERY

There are two basic surgical approaches in intranasal tip surgery:

Indication for each of these approaches depends on the specific anatomy of the nose and the proposed changes (Table 36–1):

- Volume reduction
- Reconstruction
- Rotation
- Change of projection

The Nondelivery Approach

The nondelivery approach is very appropriate for:

- Small-volume reduction of the lateral crus
- Slight cephalic rotation of the tip

Volume reduction can be easily accomplished with a *transcartilaginous incision*, in which only slight surgical trauma occurs. The operative procedure of the cartilage-splitting nondelivery approach is as follows: after drawing the skeletal landmarks and boundaries on the skin of the nose, the most cephalic part of the lateral crus to be resected is outlined with a marking pen on the external skin (Fig. 36–6). It is helpful to indicate on the vestibular skin where the transcartilaginous incision should be made. This can be done either by a through-and-through needle from the outside or more elegantly by using the imprint of a surgical instrument on the vestibular skin. Care should be taken to preserve at least 5 mm of uninterrupted cartilage (in a vertical dimension) of the lateral crus. Although some surgeons make their incisions through the vestibular skin and cartilage concurrently, it facilitates the dissection of the vestibular skin to do this in two stages.

Hydraulic dissection with small depots of local anesthesia at the site of the vestibular incision facilitates dissection in the subperichondrial plane. A vestibular skin incision with a no. 15 blade (Fig. 36–7) is followed by dissecting the vestibular skin free from the proposed resection of the cephalic part of the lower lateral cartilage with a pair of sharp pointed curved scissors, leaving the integrity of the lower lateral intact to ensure the best chance for an uncomplicated healing process (Fig. 36–8). Nowadays the retrograde-eversion approach is performed less often. Instead of a transcartilaginous incision, an intercartilaginous incision is made, followed by retrograde dissection over the lateral crus at the nonvestibular side, eversion of the lateral crus, and resection of the planned cephalic portion of the cartilage.

Approaches	Incisions
Nondelivery	
Cartilaginous splitting	Transcartilaginous
Retrograde inversion	Intercartilaginous
Delivery	
Bipedicle chondrocutaneous flap delivery	Marginal and intercartilaginous
Lateral crus delivery	Marginal

Figure 36–6 Marking of the skeletal boundaries and the cephalic parts of the lateral crura to be resected.

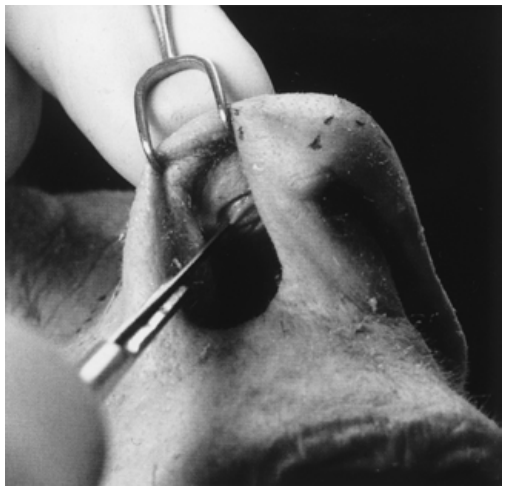


Figure 36–7 Vestibular skin incision.

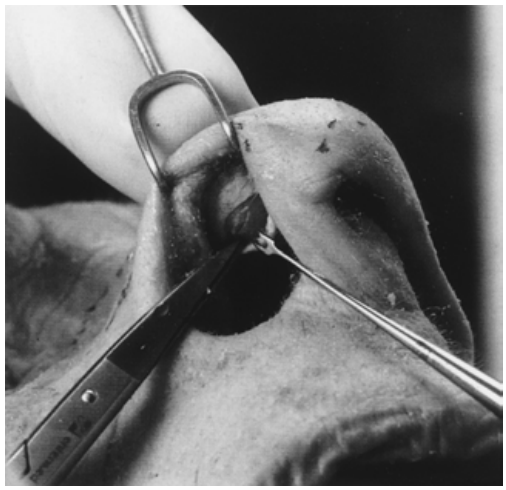


Figure 36–8 Dissection of vestibular skin and perichondrium (subperichondrially).

The Delivery Approach (Bipedicle Chondrocutaneous Flap)

The delivery approach, though more traumatic, is indicated when the planned changes to the nasal tip constitute more than a small-volume reduction. The indications for this approach are:

- Asymmetry
- Bifidity
- Extracephalic tip rotation
- Alteration of the tip projection

With this approach, it is possible to modify the alar cartilage under direct vision up to the dome and interdomal area. Different operative techniques can be applied:

- Precise excision of cartilage to achieve good symmetry
- Remodeling of the alar cartilage by scoring and morselization
- Interdomal suturing to correct bifidity
- Interruption of the continuity of the alar cartilage to reduce an extremely overprojected tip ("Pinocchio" nose) or to enhance cephalic tip rotation
- Lateral crural steal to enhance tip projection

To ensure a dry operation field depots of local anesthesia are used along the caudal margin of the alar cartilages extending at the nonvestibular side. The infiltration procedure should be performed approximately 15 to 20 minutes before the dissection has started.

The surgical procedure to deliver the alar cartilages starts with an *intercartilaginous incision* with a no. 15 blade. It is important to make this incision caudally to the valve area to prevent unnecessary scarring in the valve area. This intercartilaginous incision should be carried well around the anterior septal angle (Fig. 36–9). If not, delivery could be

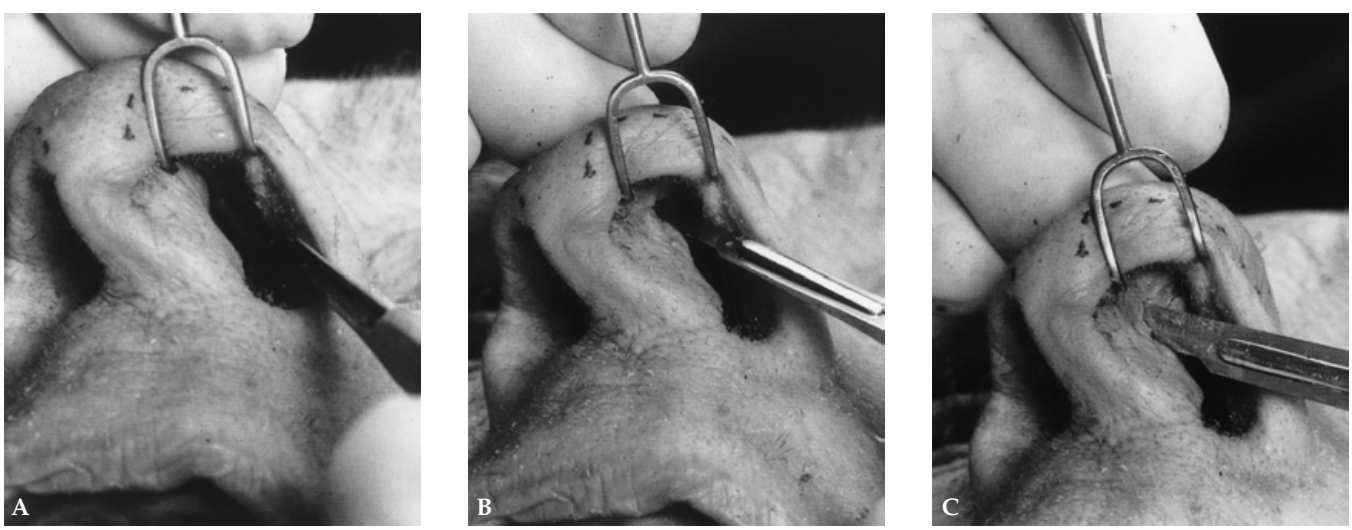


Figure 36–9 Intercartilaginous incision starting **(A)** (1 to 2 mm) laterally to the internal valve, then **(B)** medially and **(C)** caudally well around the anterior septal angle.

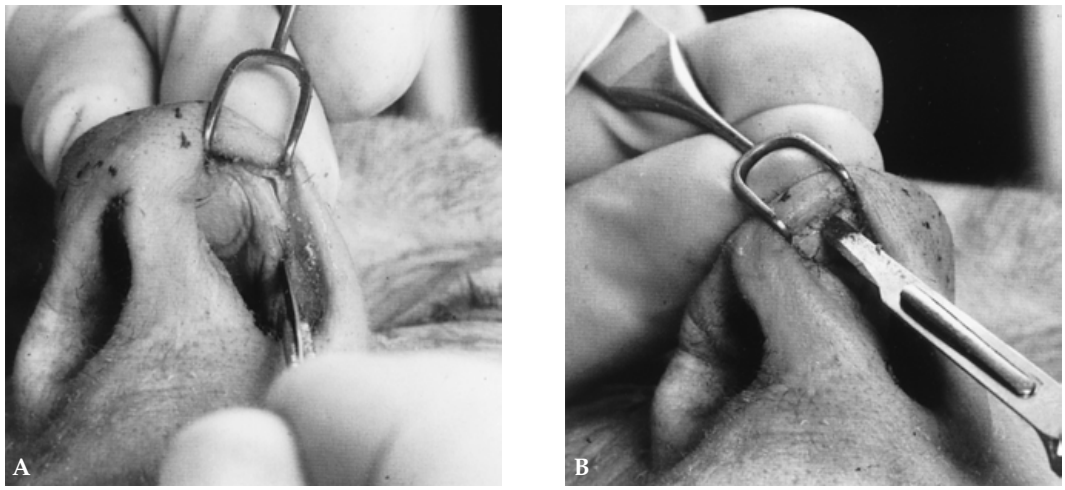


Figure 36–10 Marginal incision in a lateral to medial direction along the caudal rim of the lower lateral crus.

stagnated. The next step is to make a *marginal incision* (no. 15 blade), hugging the caudal edge of the lower lateral to prevent surgical damage to "the soft triangle."

To determine the caudal margin of the lower lateral, it is helpful to know that the skin overlying the cartilage does not consist of hair follicles. Palpation with a no. 15 blade helps to locate the caudal margin of the lateral crus.

The incision starts at the upper part of the caudal margin of the medial crus, goes around the dome, and follows the caudal margin of the lateral crus as far as necessary (Fig. 36–10). After these two incisions, the nonvestibular side of the lateral crus is freed from the soft tissue by dissection with a pair of sharp curved scissors. To deliver the bipedicle chondrocutaneous flaps, a small hemostat or a Joseph periost elevator is very handy (Fig. 36–11).

The Delivery Approach (Lateral Crus Delivery)

Local anesthesia depots, extending to both sides of the lateral crus, are used to ensure a dry operation field and to facilitate especially the subperichondrial dissection at the vestibular side of the lateral crus. A standard marginal incision (no. 15 blade) is made along the caudal border of the lower lateral crus, including the domal area (Fig. 36–12). With a pair of sharp curved scissors, the vestibular skin, including the underlying perichondrium, is freed from the lateral crus (Fig. 36–13). When starting the dissection, it is easier to begin just lateral of the dome; rather than far lateral where the right surgical plane is more difficult to find. After freeing the vestibular side of the lateral crus around the dome up to the medial crus, the nonvestibular side is dissected free from the overlying soft tissue in a supraperichondrial plane (Fig. 36–14). The lateral crus can easily be delivered now (Fig. 36–15).

Figure 36–11 The bipedicle chondrocutaneous flap is delivered.

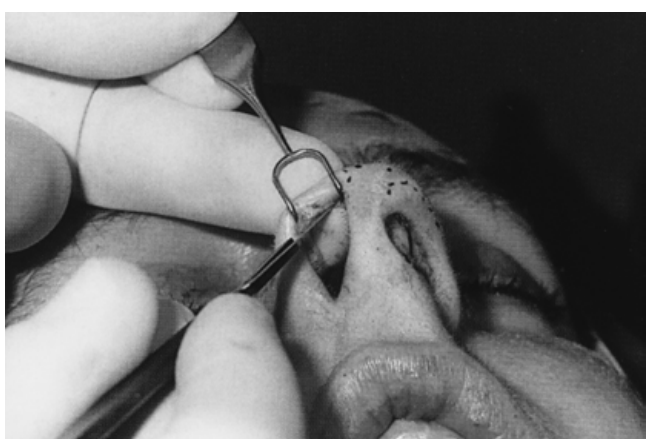


Figure 36–12 Marginal incision along the caudal border of the lower lateral crus.

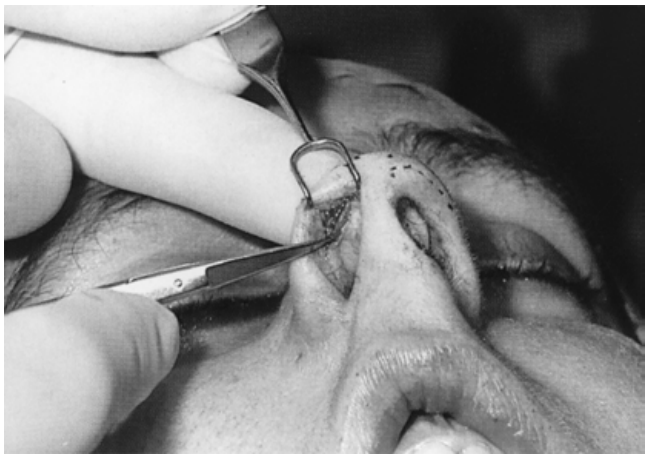


Figure 36–13 Subperichondrial dissection at the vestibular side of the lateral crus with a pair of sharp curved scissors.

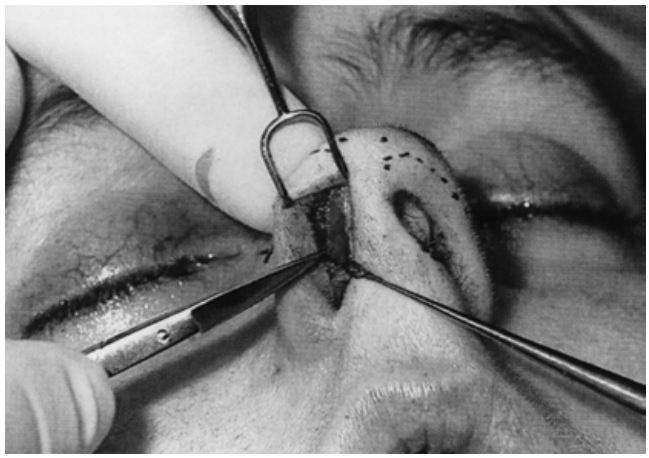


Figure 36–14 Supraperichondrial dissection of the lateral crus at the nonvestibular side.

The external approach, which is out of the scope of this chapter, although even more traumatic and time consuming, gives the best exposure of the three approaches. This approach enables the surgeon to perform bimanual surgery, and it makes judgment of the specific deformities much easier. Therefore, it is especially indicated in the case of:

- Congenital deformities such as the cleft-lip nose
- Extensive revision surgery
- Severe nasal trauma
- Elaborate reduction and augmentation procedures
- Large septal perforations

Nevertheless, there is a tendency to use the external approach routinely, especially by less experienced nasal surgeons. This is justified as long as the surgeon weighs the surgical trauma of the chosen approach against the possibilities of a satisfying postoperative result in each case.

Figure 36–15 Delivery of the lateral crus.

TECHNIQUES IN INTRANASAL TIP SURGERY (TABLE 36–1)

With the *nondelivery approach*, the vestibular skin is freed from the proposed resection area of the cephalic part of the lateral crus. After splitting of the cartilage (no. 15 blade), the nonvestibular side of the cephalic part to be resected is dissected free from the overlying soft tissue and removed (Fig. 36–16). Pressure of the middle finger of the surgeon's hand (holding the double-hooked ala retractor) on the lateral crus will give excellent exposure and control during surgery. After sufficient and symmetrical volume reduction, the vestibular skin should be sutured carefully with 5-0 atraumatic absorbable suture material. This simple tip refinement procedure gives minimal surgical trauma, leaving the integrity of the lower lateral crus intact and ensuring the best chance for an uncomplicated healing process.

The larger the portion of cartilage resection of the cephalic part of the lateral crus, the more upward rotation will be induced. A supplementary procedure to enhance tip rotation is resection of a caudal strip of the septal cartilage.

With the *delivery approach*, the alar cartilages are now delivered as bipedicle chondrocutaneous flaps. Precise excision of cartilage is now possible under direct vision (Fig. 36–17). In the case of bulging of the lateral crus, the weakening procedure (scoring or morselization) is performed, if indicated in combination with resection of a cephalic portion of the lateral crus (Fig. 36–18).

The *delivery approach* is also appropriate in the case of bifidity of the nasal tip, in which the horizontal-mattress suture technique can be performed to advance the domes with a nonabsorbable (Gore-Tex) or a slow absorbable (PDS) atraumatic suture (Fig. 36–19). Another tip suturing technique is the lateral crural steal in which the lateral crus is freed from the vestibular skin, after which the dissected area

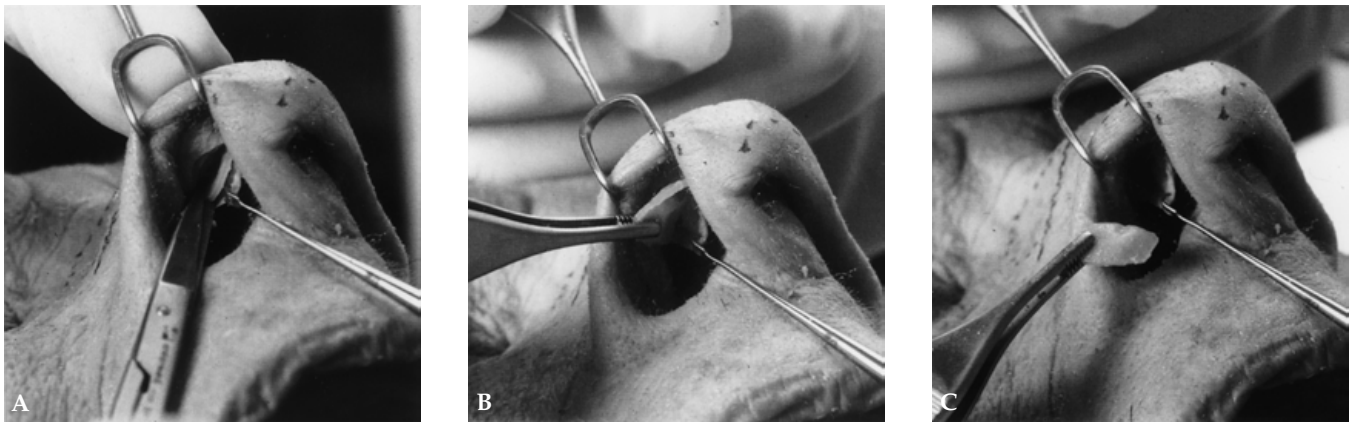


Figure 36–16 Resection of the chosen cephalic part of the lateral crus.

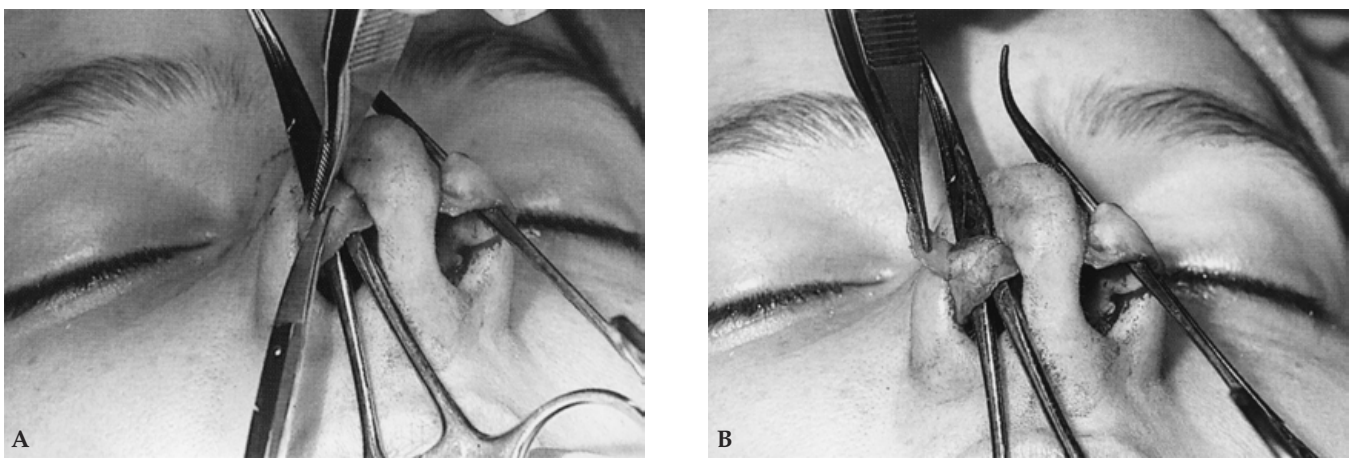


Figure 36–17 Precise dissection and excision of a cephalic protion of the lateral crus.

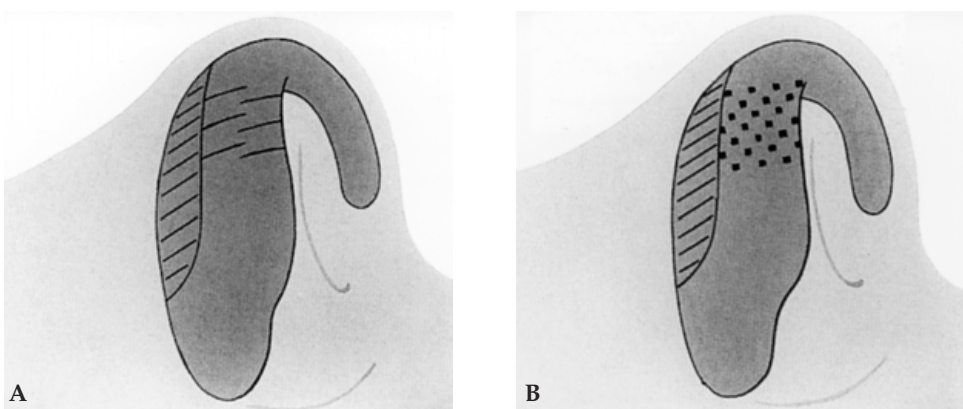


Figure 36–18 Weakening procedure of the lateral crus: **(A)** scoring; **(B)** morselization.

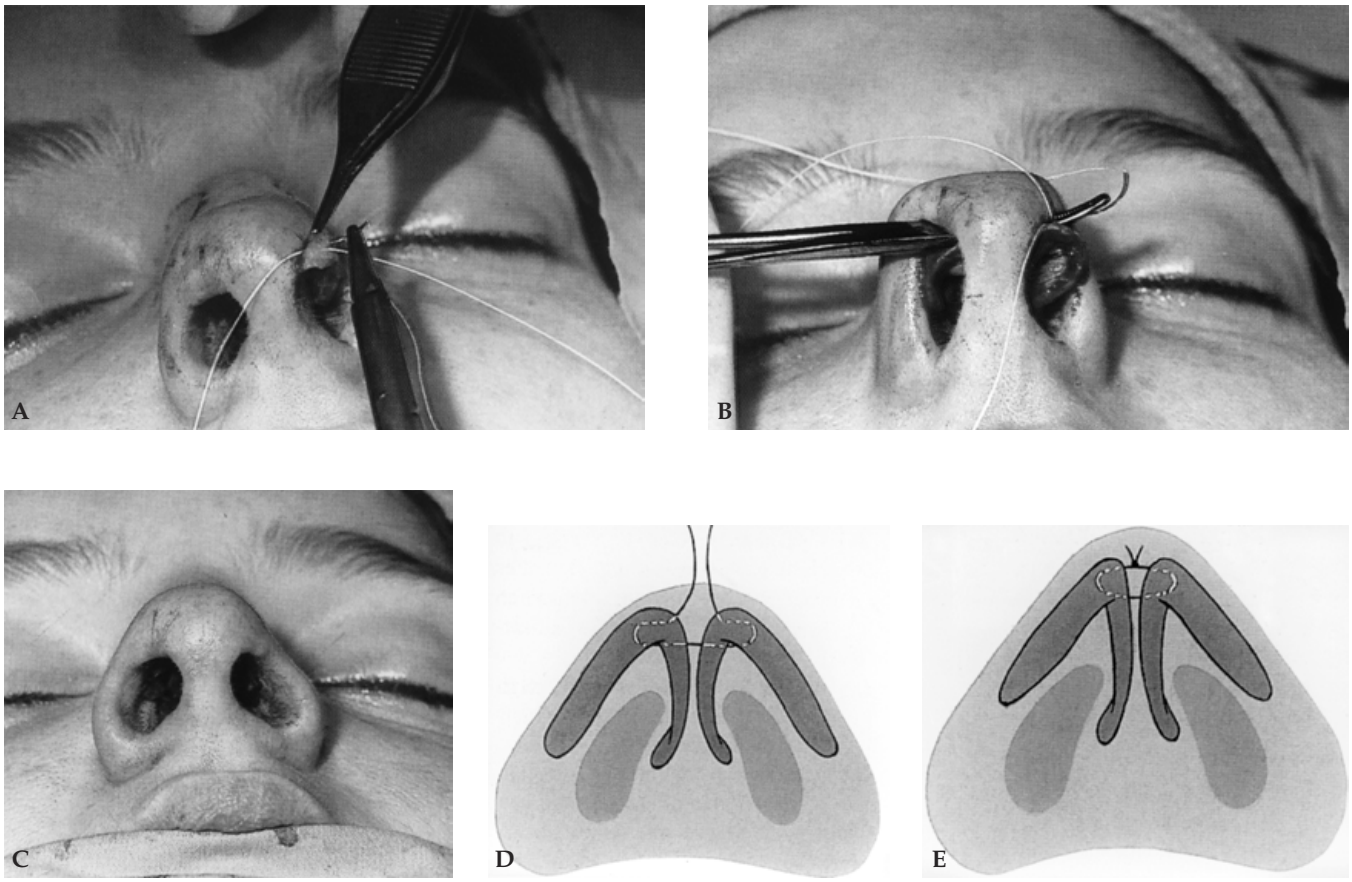


Figure 36–19 **(A, D, E)** Horizontal-mattress suture technique to correct bifidity of the tip. **(B)** Mattress suture with 6-0 Gore-Tex of left lower lateral crus followed by transportation of the needle with a mosquito clamp to the right side for the same procedure. **(C)** Direct postoperative result after advancing the domes with horizontal mattress suture technique.

is advanced medially and fixed in the new position with a mattress suture (Fig. 36–20).

Interrupting the continuity of the alar cartilage (incomplete strip technique) can give some unpredictable scarring, especially visible in thin-skinned noses. In the case of dome amputation to reduce a "Pinocchio" nose, an onlay tip graft will hide possible irregularities in the healing process (Fig. 36–21).

To reduce tip projection and to obtain sufficient cephalic tip rotation, as is indicated in correction of a tension nose, the continuity of the alar cartilage is interrupted by transection of the lateral crus at the junction of its middle and lateral third, followed by resection of the cartilage segment of the lateral third and cephalic part (Fig. 36–22).

With the *modified delivery approach*, whereby the lateral crus is freed from soft tissue at both sides, it is possible to deproject the tip as described by Peck or to correct alar insufficiency by rotating the lateral crus in a cephalic position (Fig. 36–23) as described by Rettinger and Masing. Upward rotation results in a slight bulbosity due to the new position of the lateral crus, which should be corrected by resection of a cephalic part of the lateral crus (Fig. 36–24).

The surgeon should be aware that with the delivery approach the healing process is less predictable than with the nondelivery approach, with a higher likelihood of postoperative asymmetries.

PITFALLS

Basic knowledge of surgical anatomy, tip-supporting mechanisms, tip dynamics, tripod theory, and the basic approaches and techniques in rhinoplasty is a prerequisite to prevent serious sequelae in rhinoplasty. The impact of a disastrous surgical result on a patient's emotional and social life puts a heavy responsibility on the surgeon. Before starting surgical procedures on a patient, an intensive learning process, both theoretical and practical (with cadaver

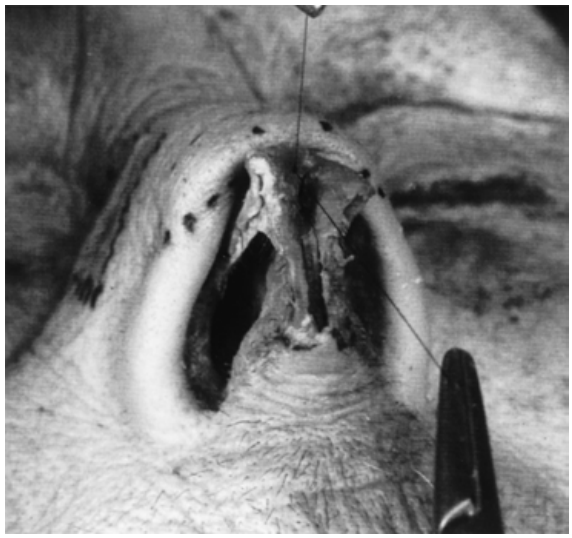


Figure 36–20 Transdomal suture with lateral crural steal to enhance tip projection.

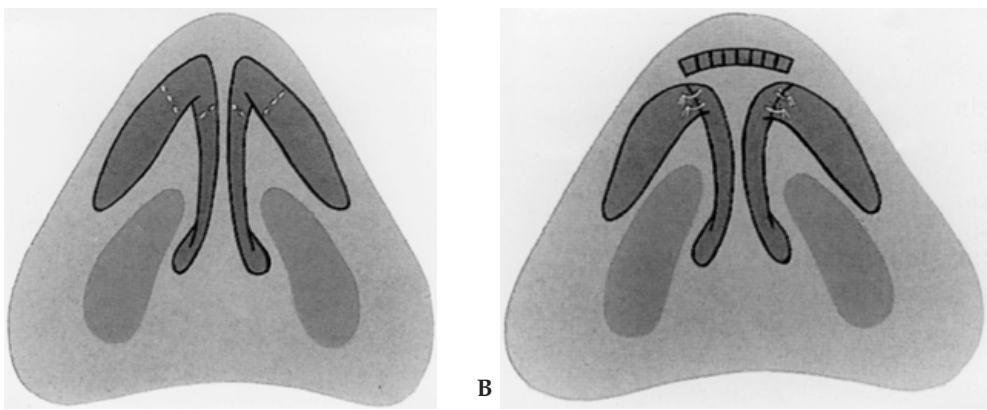


Figure 36–21 **(A)** Dome amputation. **(B)** Sutured lower laterals with an onlay tip graft to hide possible postoperative irregularities.

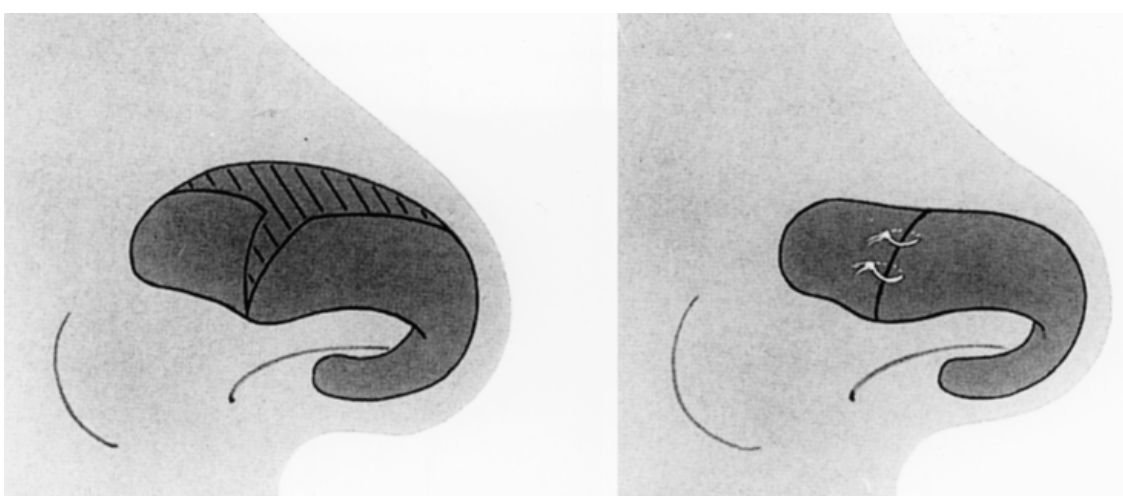


Figure 36–22 Interrupted strip technique to obtain adequate cephalic tip rotation in case of a tension nose.

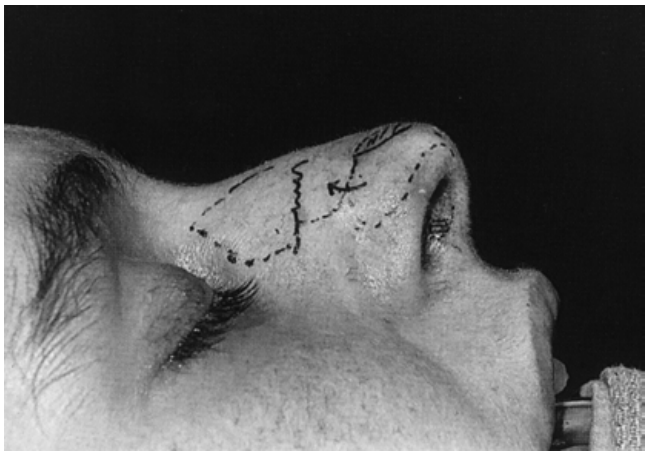


Figure 36–23 Landmarks outlined on the nasal skin with marking of the new position of the lateral crus (*arrow*) and partial resection of the cephalic part of the lateral crus (*striped area*).

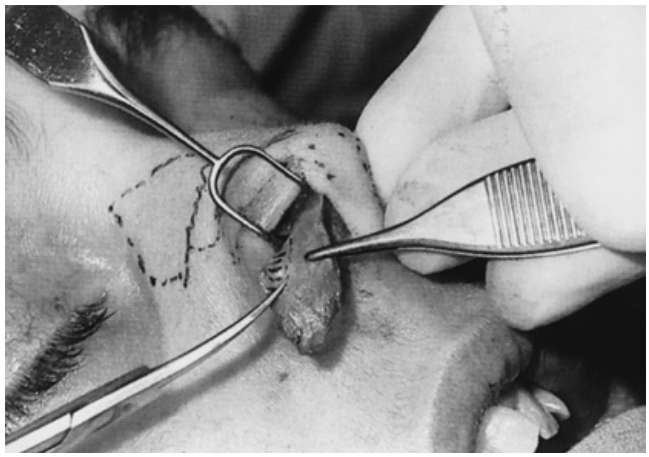


Figure 36–24 Resection of the marked cephalic part of the lateral crus.

dissection), including watching and assisting in live surgery, is obligatory.

Common pitfalls of the *nondelivery approach* and tips for their prevention are as follows:

- *Asymmetric resection* resulting in tip asymmetry. (To prevent asymmetry, the resected cephalic cartilage parts should be compared.)
- *Overresection* resulting in alar insufficiency (external valve collapse). (A caudal strip of 4 to 8 mm, depending on the strength of the alar cartilage, should be preserved.)
- A *wrong cartilage incision line* resulting in an incomplete strip can lead to weakening, asymmetry in shape, extra upward rotation, and bossa formation. (Knowledge of the pathway of the caudal margin of the alar cartilage can prevent such a sequela.)

Common pitfalls of the *delivery approach* (bipedicale chondrocutaneous flap) and tips for their prevention are as follows:

- *Incomplete delivery* due to insufficient extension, medially and laterally, of the intercartilaginous and marginal incisions. This can make the planned technical procedures difficult or even impossible.
- *Asymmetric delivery* due to a different extension of the incision lines at one side. (Helpful in preventing this is to determine the tip defining point corresponding with the domal area by placing a one-prong at either side after which the flap should be delivered and the exact tip-defining point can be marked.)
- *Asymmetric resection* resulting in tip asymmetry. (Marking of the cephalic part with Bonney's blue or a marking pen will help to prevent this.)
- *Asymmetric inter- and transdomal suturing*. (This can be prevented by checking for smooth level of the domes in the horizontal plane and of the medial crura in the vertical plane.)
- *Overscoring and overmorselization*, which can result in asymmetry of the tip with typical bossa formation.
- *Compromising the tip support* by performing a complete transfixion (disturbing a major tip support mechanism, i.e., the medial crural footplate attachment to the septum) without the intention to diminish tip projection.

Common pitfalls of the *delivery approach* (lateral crus delivery) and tips for their prevention are as follows:

- Careless preparation resulting in *tearing the lateral crus* in the domal area. (Suturing and placing a small cartilage splint can restore the continuity.)
- *Wrong indication* for the rotation technique to treat alar insufficiency when there is no malposition of the lateral crus and protrusion in the vestibulum.
- *Overrotation* resulting in weakening of the alar support or supratip fullness.

Keep in mind that the goal in modern rhinoplasty is to minimize surgical trauma to achieve a more predictable long-term outcome. The low-trauma approaches described in this chapter should be part of the armament of all rhinoplastic surgeons (Figs. 36–25 to 36–27).

Figure 36–25 Pre- and postoperative views of a patient who underwent a rhinoplasty: first a septoplasty, followed by a cephalic resection of the lower laterals by a nondelivery approach and removal of a bony cartilaginous hump, microosteotomies, and infracture of the nasal bones.

Figure 36–26 Pre- and postoperative views of a rhinoplasty by the delivery approach to narrow the broad trapezoid tip with transdomal and interdomal suturing, followed by a bilateral cephalic resection of the lower laterals and a small resection of the cartilaginous dorsum. The asymmetry of the nostrils due to a caudal septal deviation to the left was corrected by a septoplasty through a hemitransfixion incision. *(continues on next page)*

Figure 36–26 *continued*

Figure 36–27 Pre- and postoperative views of a patient with alar collapse due to a malposition of the lateral crura. Furthermore, there is a bony cartilaginous hump with a slight deviation of the dorsum to the left and slight asymmetry of the nasal tip. Through marginal incisions the lateral crura were delivered (up to the dome), bilateral cephalic resection and at the left side a scoring procedure in the dome area to correct tip asymmetry were performed. Through the marginal incision the overlying soft tissue was dissected from the osseocartilaginous vault, followed by hump resection, medial oblique microosteotomies, and repositioning of the lateral crura with a guiding suture into a prepared pocket in a more cephalic position. Finally, lateral microosteotomies were performed, followed by realignment of an infraction of the dorsum.

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Chapter 37

Surgery of the Nasal Tip: Vertical Dome Division

Robert L. Simons and John S. Rhee

In recent years, three major trends have influenced the changes in nasal tip surgery. First, techniques have incorporated methods of greater medial stabilization and support of the nasal base. Second, more surgeons are relying on cartilage incisional and suture techniques of the alar cartilages rather than excisional ones to achieve desired changes. Finally, the use of the external approach for visualization of the alar cartilages has become commonplace, with the endonasal approach becoming an increasingly lost art form.

PHILOSOPHICAL TENETS OF VERTICAL DOME DIVISION

Ironically, the first two trends were longstanding philosophical tenets of Irving Goldman back in 1957.[1] Since his first published report on the importance of the medial crura and through subsequent articles on vertical dome division (VDD),[2–5] the message has been consistent: preserve and conserve rather than resect and regret. Yet the concept of incising the alar cartilage at the domal region has been labeled by many as dangerous, destructive, and radical rather than conservative and reasonable. It is vitally important not to combine excisional techniques and philosophy with an incisional procedure such as VDD. The complications of postoperative alar notching, collapse, unnatural tent-pole appearance, pinching, and bossae formation are caused more often by too much excision of the lateral crura than by dome division.[6,7]

In almost all primary cases and in most revision cases, our approach to tip surgery is an endonasal one, using the marginal incision delivery technique. Sufficient delivery of this bipedal flap requires vestibular incisions at the caudal border of the alar cartilages and medial extension along 50% of the anterior columellar border. Attention to these details will allow a wide and adequate exposure to irregularities and asymmetries in the lobular tissues. More importantly, it will allow symmetrical incisions and suturing of tissue without the need for a transcolumellar incision. Insertion of additional filler or onlay cartilage in the lobular or columellar area can be easily accomplished via the marginal incisions.

PREOPERATIVE ANALYSIS

As with all rhinoplasty, preoperative analysis of the nasal tip is critical in choosing the correct tip procedure. Decisions about where and when to incise cartilage and how much to remove are made during the preoperative assessment. With adequate tip projection, two factors are generally seen. First, the lateral view evidences a 1:1 relationship between the length of the base of the nose and the upper lip (Fig. 37–1). Second, the base view shows a triangular strength with an equilateral appearance, suggesting sufficient lateral battens of cartilage and strong medial support. The length and strength of the medial crura are evidenced in the ideal 2:1 relationship of the columella to the lobule (Fig. 37–2). The desired double break occurs naturally from the retrousse curve of the medial crus at the columellar–lobular junction (Fig. 37–3).

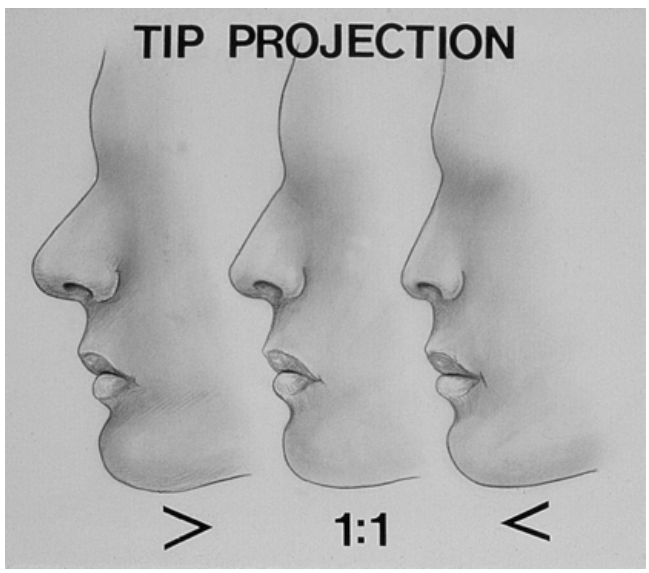


Figure 37–1 Desired 1:1 ratio of length of nasal base to upper lip. Note that the change in lobular length directly affects tip projection.

The cephalic movement of the nasal tip along the same radial arc from the facial plane defines tip rotation (Fig. 37–4). Rotation is accomplished through the interrelated steps in rhinoplasty involving lowering of the nasal dorsum, shortening of the caudal septum, plumping of an acute nasolabial angle, and resection of the cephalic portion of the lower lateral cartilage. A conservative cephalic resection of alar cartilage alone does little to effect tip rotation. Also, overzealous resection leads to postoperative sequelae of alar collapse and nasal bossae.

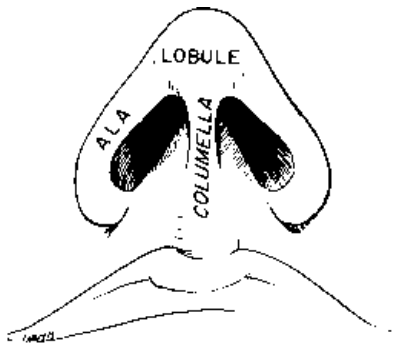


Figure 37–2 Strong base view with desired 2:1 ratio of columella length to lobule.

VDD

Over the past 30 years, we have used various forms of vertical dome division in more than 1000 patients. The rationale behind VDD is the ability to change projection directly as well as to narrow and rotate the lobule with minimal cartilage excision. These desired effects can be accomplished without the use of additional struts or tip grafts because of the medial stabilization and strength provided by VDD techniques. Inherent in the philosophy is the preservation of surrounding tissues, such as the septal angle or caudal septum, further decreasing the risk of the postoperative appearance of an overrotated or "overoperated" nose.

There are three distinct VDD techniques that are effective in addressing the nasal tip: the classic Goldman prototype, the Simons modification, and the hockey-stick modification. The indications and surgical technique for each of these procedures will be discussed.

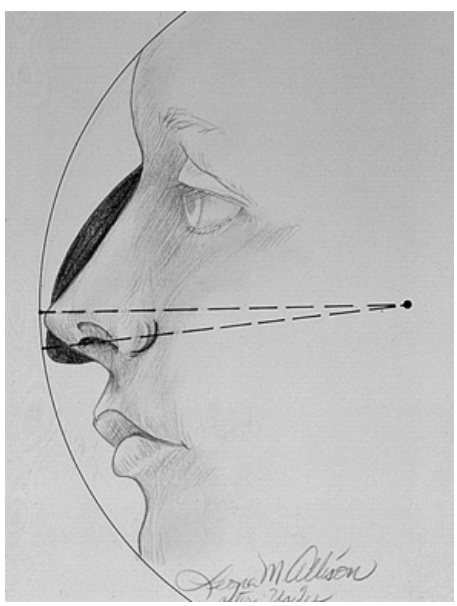


Figure 37–4 Rotation of tip maintains same radial distance from facial plane.

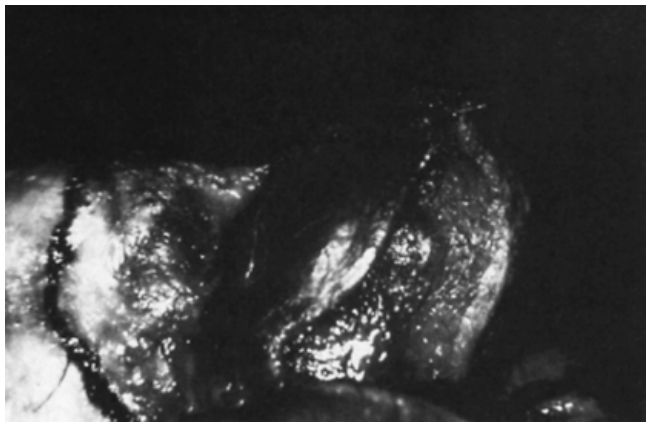


Figure 37–3 Anatomical evidence of double break created by curvature of strong medial crura.

Goldman Technique

The prototype of VDD procedures is the classic Goldman technique, which calls for the creation of a chondrocutaneous strut by division of the alar cartilage along with the underlying vestibular skin. When employing the Goldman technique, the septal and dorsal alignment generally precede the tip surgery. It is both crucial and advantageous that the initial lowering of the dorsum be minimal and that dorsal strength be maintained before the projection of the tip is changed.

The alar cartilages are delivered through marginal incisions. The high point of the lobular apex is marked on delivery by a right-angled hook. It is important to remember not to borrow more than 2 or 3 mm from the lateral crus (Fig. 37–5). The 3-mm borrowing boundary is measured along the caudal margin of the alar crus. The obliquity of the vertical cut at the dome allows more than 3 mm to be mobilized superiorly, thereby necessitating trimming of the posterior excess once the medial crura are brought together. The chondrocutaneous strut is sutured together with anterior, posterior, and superior horizontal mattress sutures of 4-0 chromic catgut (Fig. 37–6).

It is critical to preserve at least 8 to 10 mm of width of the lateral crura when trimming the cephalic border. It is worth reemphasizing that one should not borrow more than 2 or 3 mm from the lateral crus when dividing the dome vertically. Remembering these admonitions will help one to avoid the outcome of an unnatural tent-pole appearance (Fig. 37–7).

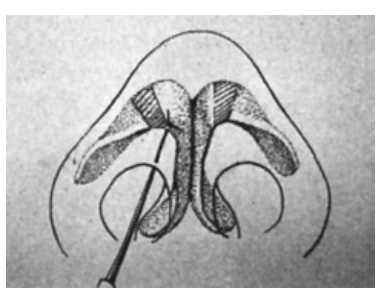


Figure 37–5 Borrowing boundaries relate to distance from lobular apex (marked with right-angled hook) to cut at caudal margin.

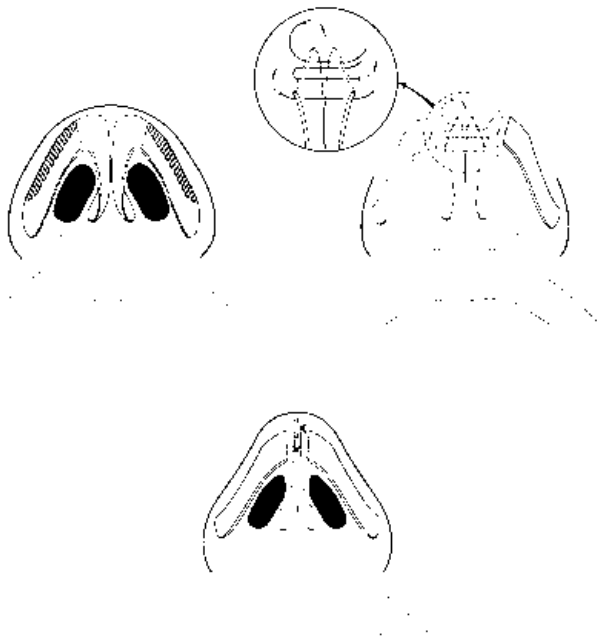


Figure 37–6 Schematic representation of the Goldman technique.

Sharp edges of cartilage are trimmed and the sutured crura are repositioned in the lobule. A final high, securing suture closes the space between the caudal septum and membranous septum. No effort is made to suture medial crura directly to septum. The marginal incisions are closed and no attempt is made to suture the medial to the lateral crura (Fig. 37–8).

The Goldman technique is preferred for the ptotic or aging situation whereby the vertically displaced alar complex requires direct redirection (Figs. 37–9 and 37–10). If the nasolabial angle is particularly acute and the strength of the cartilage is suspect in regard to its ability to support the thick overlying skin, we often use a cartilaginous strut between the medial crura. Septal cartilage is generally used for the strut, which extends from the feet of the medial crura to the superior cut edges. This "sandwich" of chondrocutaneous leaves and cartilage is sutured together in the same manner as in the classic Goldman technique.

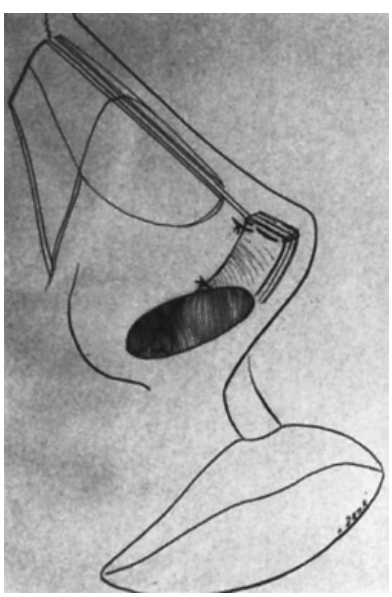


Figure 37–8 Limited distance between cut medial strut and septal angle critical in classic Goldman technique.

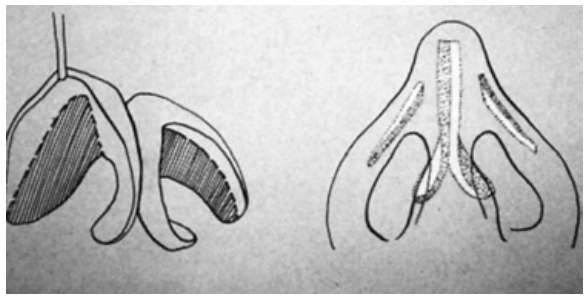


Figure 37–7 Unnatural tent-pole appearance created by combining large excision of lateral crura with vertical dome division.

By rotating the medial crura together, the convex columella–lobular angle or so-called double break is at times created or accentuated. With a weaker, straight, or retracted columella, a cartilaginous batten or plumping grafts may further augment the tip procedure. Plumping grafts are small pieces of cartilage placed beneath the feet of the medial crura through a separate stab incision at the base of the columella. The cartilaginous batten is placed anterior to the medial crus via the medial aspect of the marginal incision (see section "Adjunctive Techniques").

Simons Modification

More common than the underprojected or ptotic tip is the lobule needing more subtle changes of increased medial strength and medial movement of the lobular domes. A widened or divergent lobule is defined as one in which the domal highlights are more than 4 mm apart. In these more frequent situations, we use our own modification of the VDD technique[3–5] (Fig. 37–11).

As outlined previously, the anatomic apex of the lobular dome is marked by a right-angled hook as the bipedal flap is delivered through marginal incision. The high point or anatomic apex of the dome is not synonymous with the junction of the medial crura and lateral crura or the cartilaginous isthmus between the inferior and superior genus. Rather, it represents the most anterior cartilaginous point of the nasal base, most easily punctured and identified by the right-angled hook.

Following delivery of both domes, soft tissue overlying the alar cartilage is removed. It is important to clear out the fatty fibrous tissue between the two domes, especially when there is intralobular weakness or frank bifidity. Even if intradomal sutures are not used, the postoperative scarification will aid intradomal stabilization.

The alar cartilages are vertically incised but, unlike the Goldman tip, the underlying vestibular skin is kept intact. Vertically cutting the dome allows direct inward and upward movement of the medial lobular portion. As with the classic Goldman maneuver, limiting the lateral distance of the cut

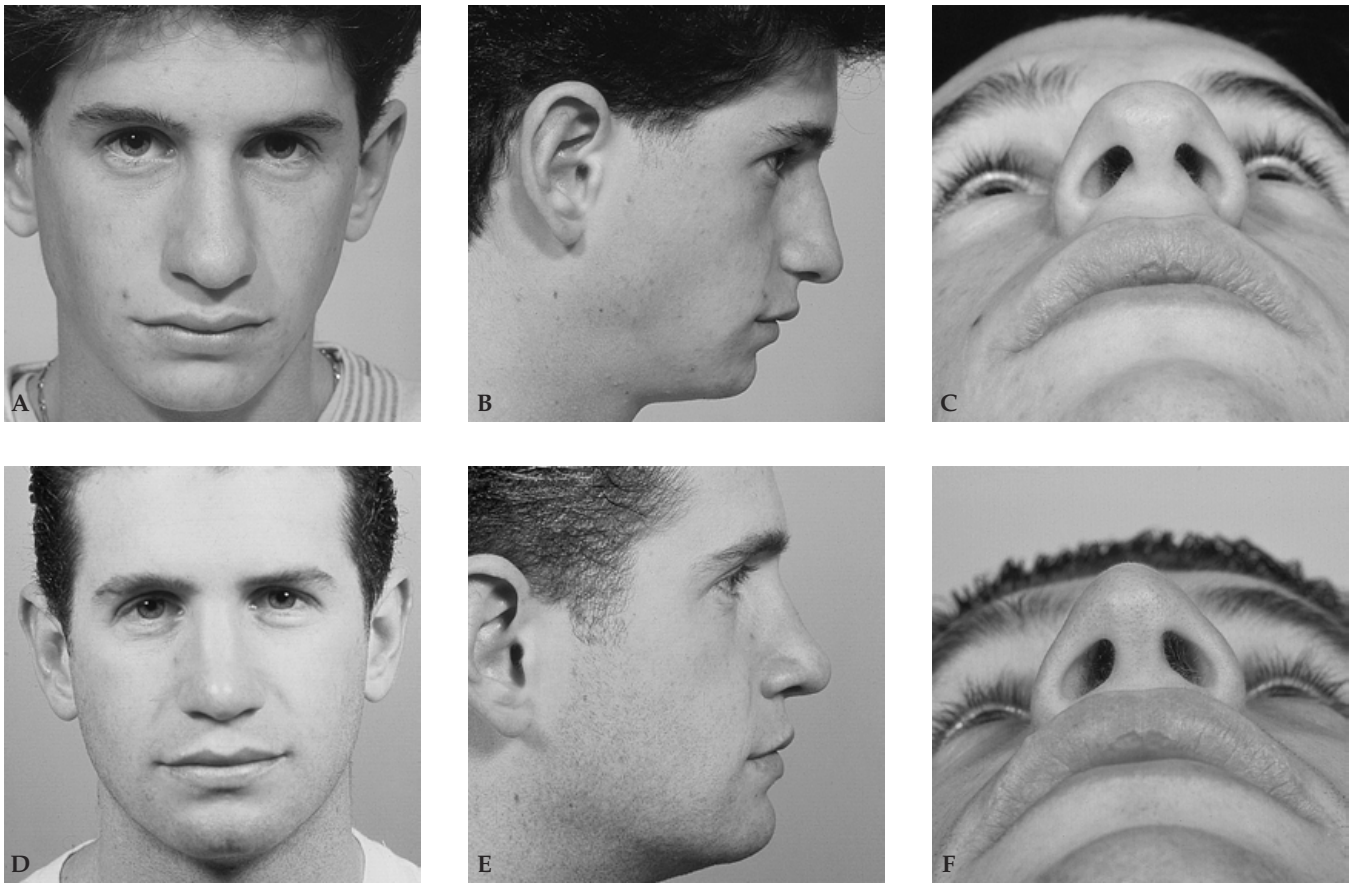


Figure 37–9 **(A–C)** Preoperative views of patient with heavy ptotic tip. **(D–F)** Six-year postoperative views following Goldman technique.

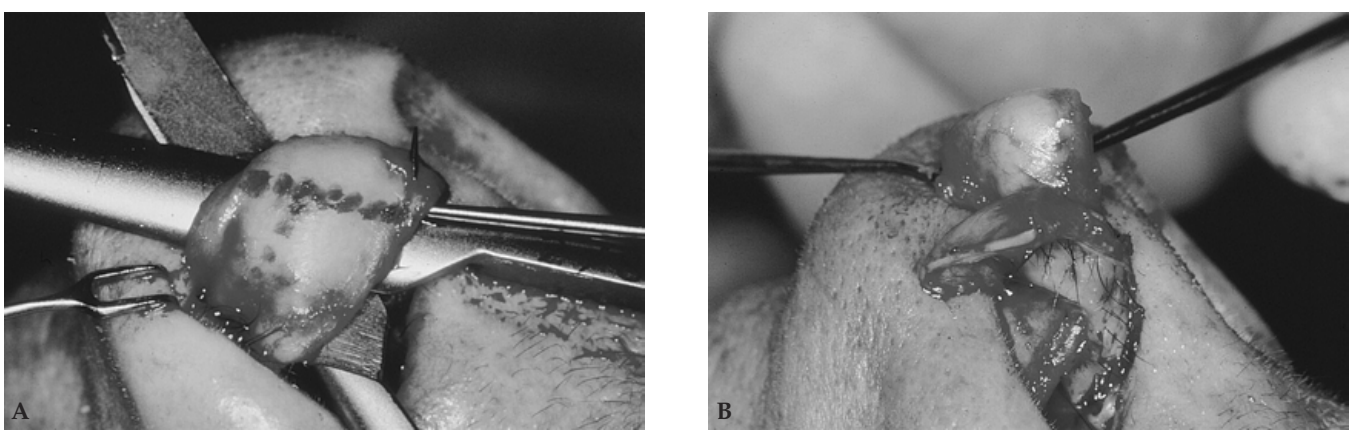
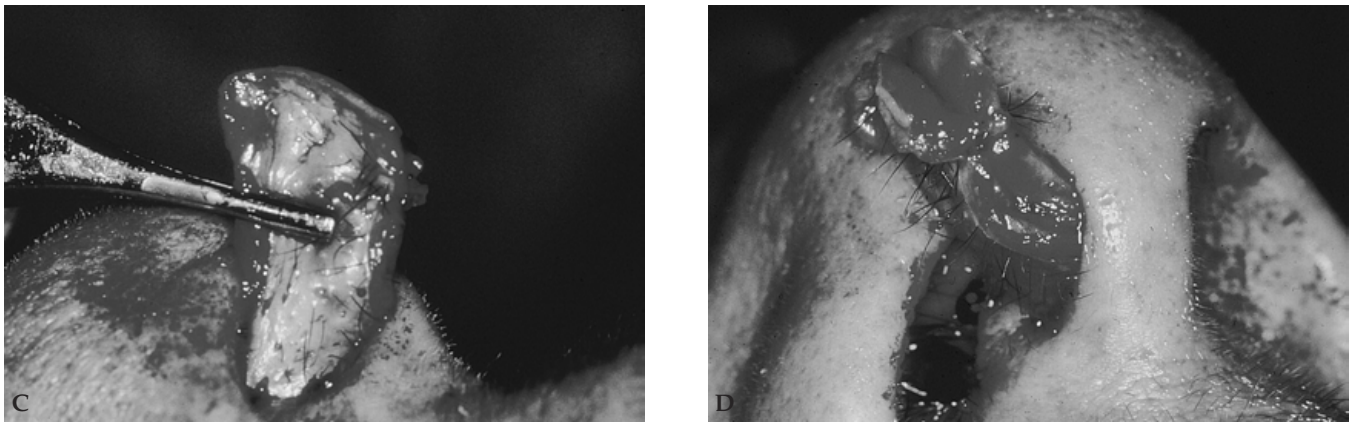


Figure 37–10 **(A–D)** Intraoperative demonstration of Goldman technique. *(continues on next page)*



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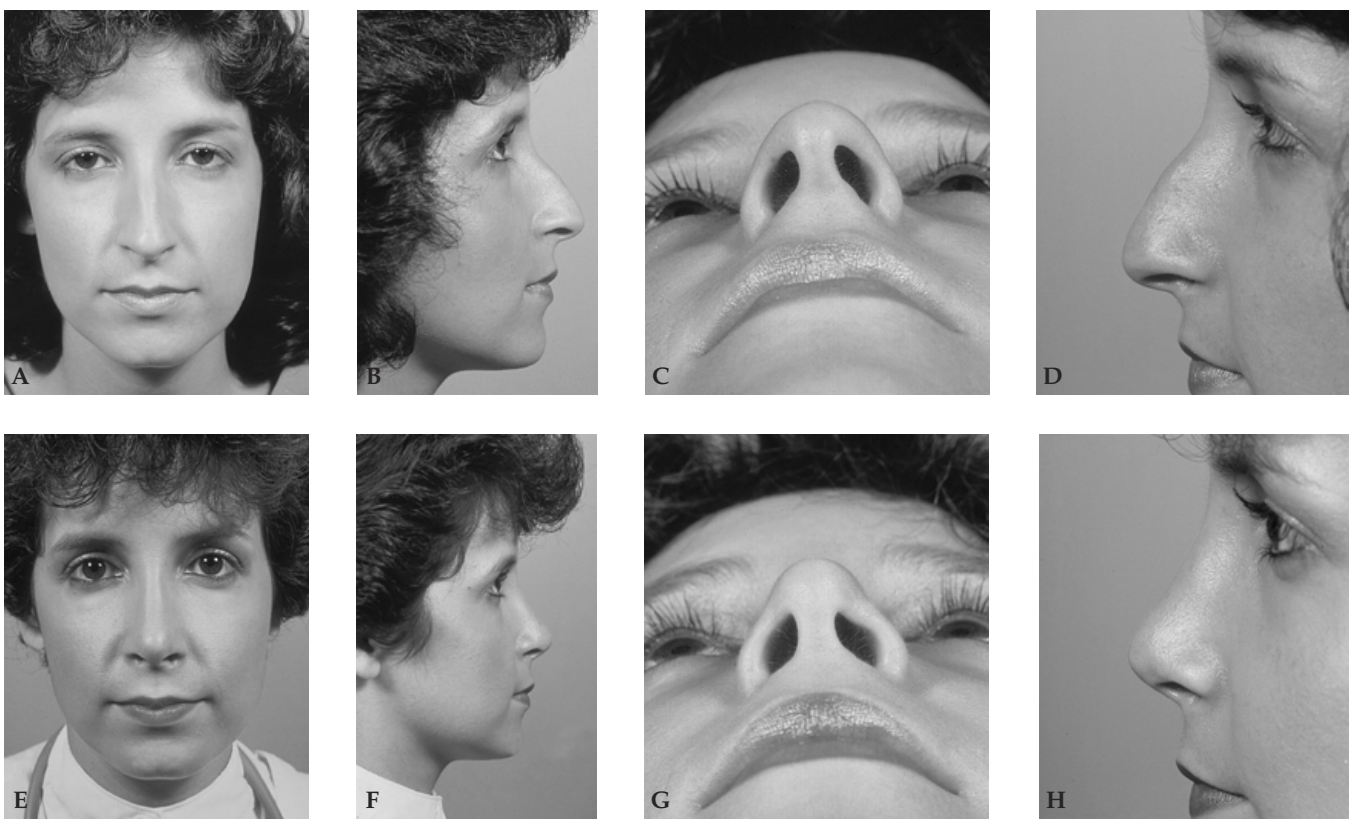


Figure 37–11 **(A–D)** Preoperative views of patient with divergent and dependent lobule. **(E–H)** Two-year postoperative views after Simons modification of vertical dome division.

to 3 mm from the lobular apex at the caudal margin prevents notching. Preserving at least 6 to 8 mm of the lateral crus after horizontal cephalic excision prevents alar collapse and helps to stabilize the pyramidal base.

Maintenance of symmetry and further medial stabilization depends on proper placement of the intradomal suture. On presentation of both domes into the right nostril, a 5-0 clear nylon suture is used in a horizontal mattress fashion to bind the medial edges of the vertically divided alar cartilages. The first pass of the needle is closer to the left superior edge than the more medial inferior exit, with no attempt made to go beyond the interior perichondrium. A mirror image of that needle passage is carried out on the right side with the knot buried between the medial crura superiorly (Figs. 37–12 and 37–13).

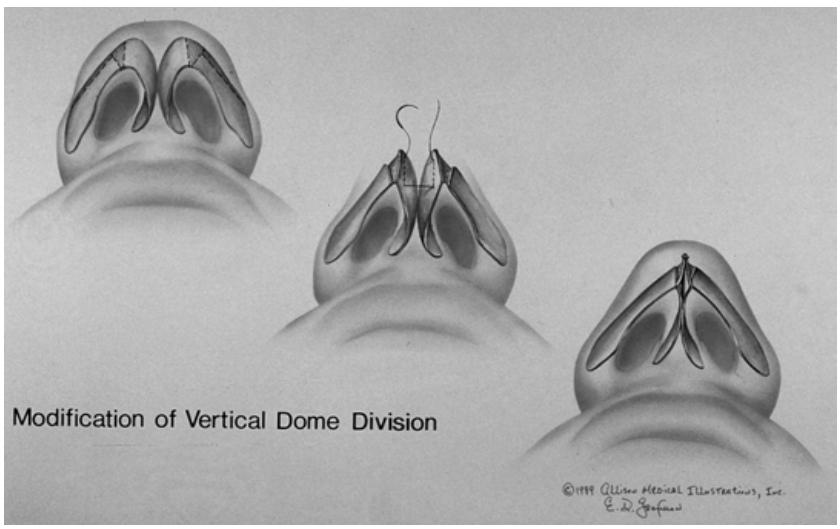


Figure 37–12 Schematic representation of Simons modification of vertical dome division. Note the oblique placement of the intradomal horizontal mattress suture. Superior tie of intradomal suture helps to ensure the desired narrowing and symmetry of the newly defined tip.

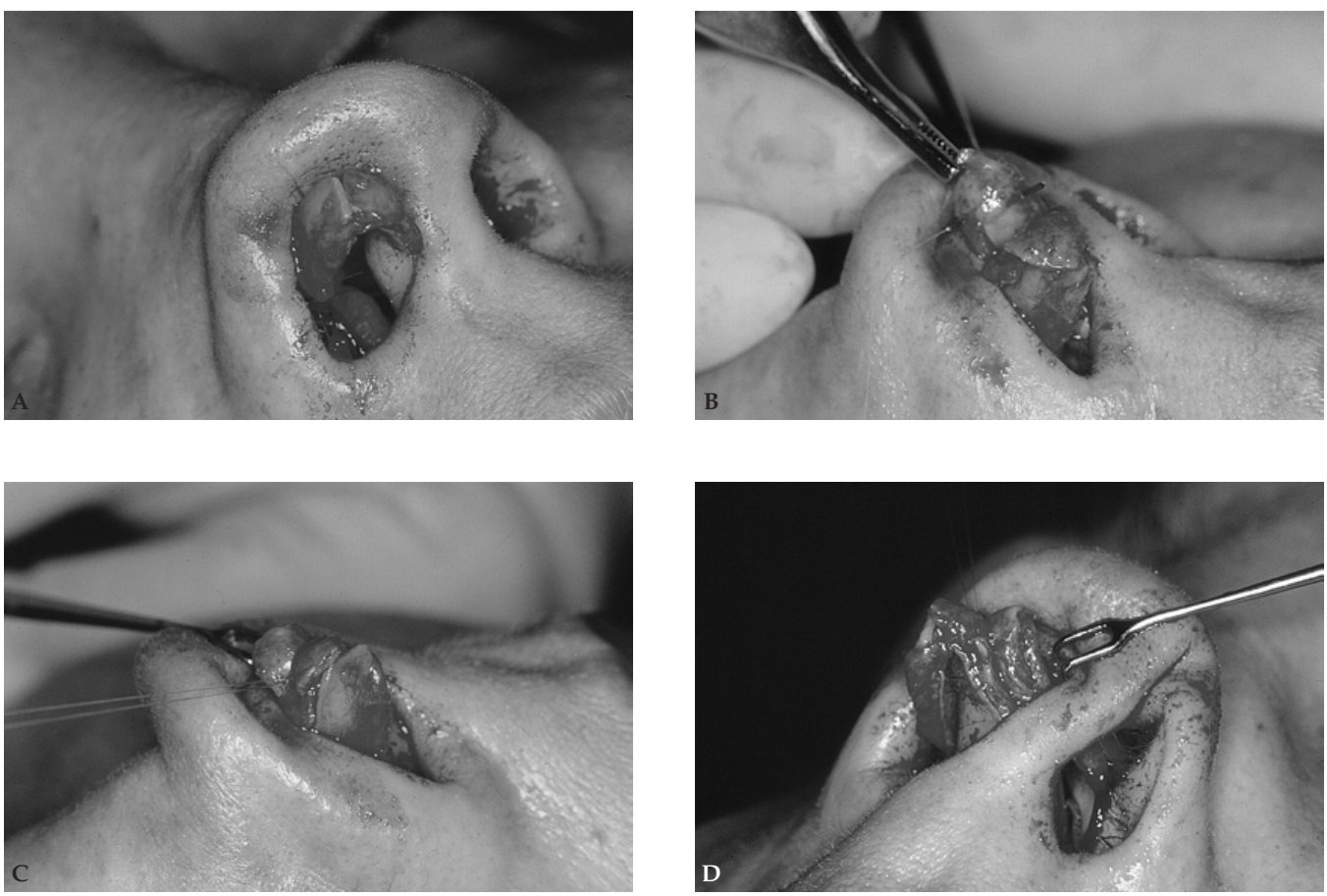


Figure 37–13 **(A–D)** Intraoperative views of the Simons modification of vertical dome division.

Figure 37–14 **(A–D)** Preoperative views of patient with boxy tip. **(E–H)** Two-year postoperative views after hockey-stick modification of vertical dome division.

When the cut medial edge gently leads the lateral, nature does a wonderful job of reconstituting the dome. Our use of sutures in the tip is limited to stabilizing medial components. Attempting to reconstruct the dome by suturing the medial crus to the lateral crus is unnecessary and may lead to asymmetries. Moreover, suturing medial to lateral or lateral to lateral crural components defeats the purpose of VDD and may again result in an unnatural narrowing of the lobular apices.

"Breaking the spring" or "relaxing the incision" is the conceptual precept of the VDD technique. In our experience, depending on sutures alone to produce medial strength has proven less effective than the combination of vertical domal incision and suture medial stabilization.

Hockey-Stick Modification

The boxy tip and overprojected tip present not infrequently with excessive cartilage both laterally and anteromedially (Fig. 37–14). Too much projection and excess width is an undesirable combination that is encountered frequently. This is the one situation in which a combination of incisional and excisional techniques is employed.

Reduction of volume is carried out by the "hockey stick" excision of cartilage.[3–5] As opposed to the previously described Goldman and Simons modification procedures, whereby the domal incision is made at or lateral to the lobular apex, the initial cuts in this case are made medial to the domal apex. Segmental sections of the dome (no more than 2 mm to either side of the apex) and a cephalic portion of the lower lateral cartilage are removed (Fig. 37–15).

The intact underlying vestibular skin acts as a scaffold for reconstitution of the less projected dome. Again, the only suture advised is between the medial crura to narrow and obliterate intralobular width or bifidity. A 5-0 clear nylon suture is placed

Figure 37–15 Schematic representation of the hockey-stick modification, combining incisional and excisional techniques.

in a horizontal mattress fashion in the same manner as in the Simons modification procedure. The lateral crural batten if not overly resected or undermined from the underlying tissues will heal medially, achieving a more pyramidal appearance.

As with any tip procedure, the hockey-stick procedure is not the only technique to be considered in reducing the overly projected tip. In thinner skinned individuals with long, angular lobular configurations, resections of cartilage lateral and inferior to the domal area will retrodisplace the tip by shortening the lateral and medial components of the tripod base.

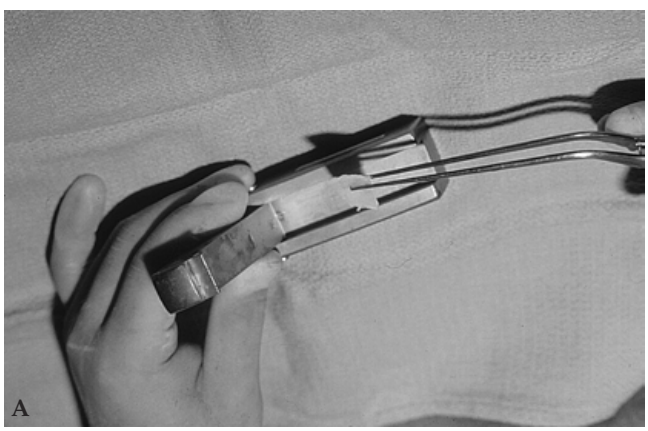
If the quadrangular septal cartilage is excessive, creating a tension-like overprojection of the tip, resection of the dorsal and caudal elements of the septum are in order. Seldom in our experience has a full transfixion incision alone allowed an overly projected tip to retrodisplace. At times, excision of the feet of the elongated medial crura or reduction of a prominent anterior nasal spine helps to settle or reduce tip projection.

ADJUNCTIVE TECHNIQUES

We have increasingly employed the use of a soft onlay of crushed septal cartilage in the lobule. Using a Cottle crusher, septal cartilage can be crushed into a thin, lacy, malleable graft or lightly bruised to form a thicker, firmer, filler graft. This cartilage is placed into the infratip area through the medial aspect of the right marginal incision (Fig. 37–16). Depending on the needs of the tip, this onlay of crushed cartilage may serve as a delicate cover, camouflaging sharply incised alar cartilages, or as an augmentation lobular graft if a larger amount of bruised cartilage is introduced into the lobule.

When the columella is somewhat retracted or inadequate, a batten contoured from septal cartilage may be positioned anterior to the medial crura through the marginal incision (Fig. 37–17). The batten is differentiated from a strut, which extends from below the feet of the medial crura to the intradomal space and is placed between the medial crura before they are sutured together. In certain situations, the use of the batten may create or accentuate the desired double break of the lobule (Fig. 37–18). In addition, the batten can be used in conjunction with lobular crushed cartilage to lengthen the short nose.

Marginal incisions should be closed by placing two or three interrupted sutures of 4-0 chromic catgut in an oblique fashion. This maneuver encourages medial movement of the bipedal chondrocutaneous flap during the healing process. It is important not to create notching by placing the more medial exit of the suture too close to the alar rim. A lobular "cinch dressing" of clear tape is kept in place for 3 to 4 days with Telfa pads used as internal splints. The tape and plaster cast external dressing is removed from the nose approximately 5 to 6 days postoperatively.



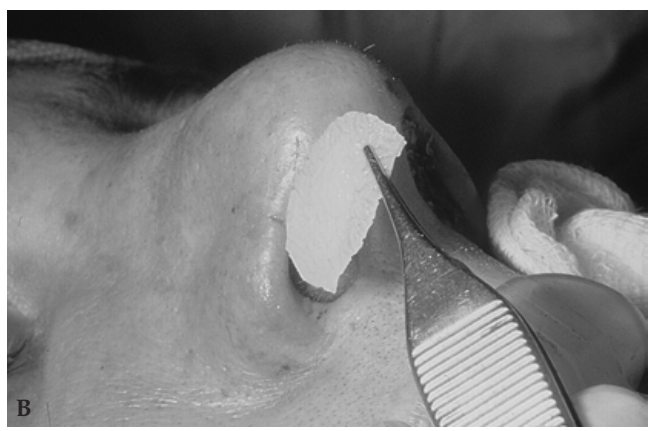


Figure 37–16 **(A)** Crushed cartilage on Cottle crusher. **(B, C)** Operative demonstration of crushed cartilage placed in infralobular area through right marginal incision.

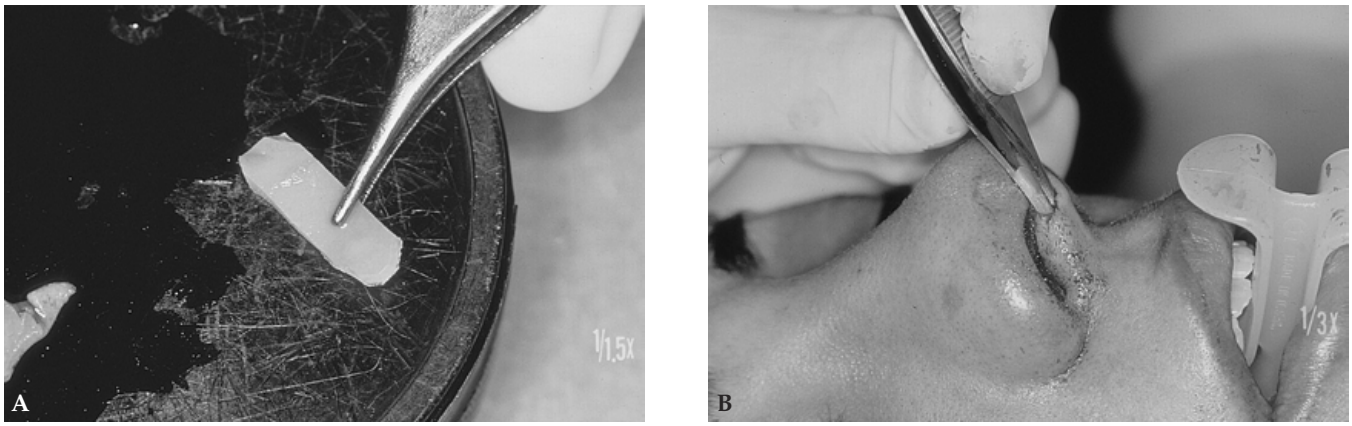


Figure 37–17 (A, B) Batten contoured from septal cartilage being placed anterior to the medial crura via right marginal incision.

Figure 37–18 (A–C) Preoperative views of patient with dependent tip and poor lobule definition. **(D–F)** Two-year postoperative views after Simons modification of vertical dome division, columellar batten, and infralobular crushed cartilage.

SUMMARY

In summary, VDD is an excellent method for achieving long-lasting domal highlights, narrowing, and appropriate projection of the nasal tip. It creates medialization and stabilization of the alar cartilages, providing an alternative to tip grafts in primary and some revision cases.

The use of extended marginal incisions to deliver the medial and lateral crura allows for accurate placement of incisions and excisions of cartilage and symmetrical suturing of the medial elements. When defining tip cartilages in primary cases, there is little need for the external approach.

The classic Goldman technique is used on patients requiring a substantial increase in tip projection, support, or a change in lobular direction. The Simons modification allows for more frequently needed adjustments in tip position and narrowing when simple cephalic resection of the lateral crura is inadequate or when the divergence of the medial crura demands better medial stabilization. The hockey-stick procedure employs a combination of incisional and excisional techniques and is a reliable way to address the overprojected or boxy tip.

Whatever the choice of tip procedures, the admonition to preserve and conserve rather than resect and regret rings true. Incisional techniques allow for strong, natural-looking, long-lasting results, often without the need of additional struts or grafts. A better understanding of the nuances of VDD procedures will only strengthen a surgeon's armamentarium of answers for the rhinoplasty patient.

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Chapter 38

Secondary Rhinoplasty

M. Eugene Tardy, Jr., Deborah Watson, and Maria Chand

Revision rhinoplasty presents reconstructive challenges to the nasal surgeon different from those encountered in primary surgery. The patient requesting secondary rhinoplasty presents complex psychological as well as anatomical problems to the nasal surgeon. Having experienced one or more failed procedures, patient disenchantment with the surgical process (and even the primary surgeon) represents a common preoperative condition. Often issues of anger, guilt, and fear compound preoperative counseling. Permanent alteration of the nasal tissues (scar formation, obliteration of surgical tissue planes, alteration of skin thickness and elasticity) dictates significant limitations in the process of reconstruction. Therefore, it is essential that patients understand and accept the potential limitations inherent in revision surgery before embarking on further surgery.

Secondary rhinoplasty procedures range from very simplistic *minor* revisions (resection of the small bossa or rasping of a tiny bony dorsum irregularity) to profoundly *major* corrections (tip grafts, spreader grafts, dorsal onlay grafts, and so forth) (Table 38–1). Selected corrections may be best

TABLE 38–1 Challenges in Revision Rhinoplasty

Tip
- Bossa
- Bulbosity
- Asymmetry
- Overprojection
- Underprojection
- Pinched
- Wide (boxy), bifid
- Deviated
- Ptotic
- Dependent
- Overrotated
- Twisted
- Crucified
- "Shrink-wrapped"

Bony Pyramid
- Irregularity
- Overreduction
- Underreduction
- Asymmetry
- Overwide
- Overnarrow
- Deviated
- Open roof
- Shallow nasofrontal angle
- Deep nasofrontal angle
- Saddling

Cartilaginous Pyramid
- Overreduction (various forms of saddling)
- Underreduction (pollybeak)
- Irregularities
- Prominent anterior septal angle
- Deviation
- Twisted
- "Inverted-V" deformity
- Midvault collapse (unilateral, bilateral)
- Asymmetries
- Overnarrow
- Overwide
- "Shrink-wrapped"
- Foreign bodies
- Soft tissue excess

Columella
- Overwide
- Overnarrow
- Twisted
- Deviated
- Depression
- Short
- Elongated
- Collapsed
- Visible strut
- Overlong strut
- Foreign body
- Overwide pedestal
- Asymmetry
- Scarred
- Dependent
- Retracted (hidden)
- Webbed
- Overconvex
- Poor contour (angulation)
- Obtuse nasolabial angle
- Acute nasolabial angle

Alar Lobule
- Retracted alar margin
- Dependent a far margin (hooding)
- Asymmetrical lobules
- Alar-columellar disproportion

Alar Base
- Overwide alar base
- Overnarrow alar base
- Asymmetrical alar base (nostrils)
- Poor alar base scars

Epithelial Canopy
- Irregularities
- Scarring
- Thickening
- Thinning
- Pigment changes
- Telangiectasias

accomplished by small incisions that limit tissue dissection and create little new scarring. More profound revisions demand greater exposure provided by the delivery or open approach, which generally commits the surgeon to a complete and total reconstruction, creating the hazard of additional scarring and upredictable outcome.

If both nasal function and appearance are involved in revision surgery, *functional* improvement should always take precedence. Fortunately, except for the more severely damaged noses, both form and function usually can be improved.

GENERAL PRINCIPLES

Secondary rhinoplasty embodies certain surgical principles different from those involved in primary rhinoplasty. Because the nasal soft tissues and skeletal support foundations have been disturbed, removed, or reoriented, new approaches and procedures must be invoked after thorough *palpation* and *inspection* of the anatomical conditions encountered has been done. The inevitable presence and magnitude of scar tissue influences planning for the type and extent of surgical intervention, and may limit the possibilities for improvement. Internal scar contracture, lining loss, and synechiae commonly exist. In particular, any damage to or thinning of the overlying skin–subcutaneous tissue complex plays a vital role in what can and cannot be accomplished. Decisions must be made about whether it is more appropriate and safe to engage in a major dissection or exploration of the nasal anatomy via the external approach, or whether more *limited incisions and dissection* created through endonasal approaches place the damaged tissues (and therefore the patient) at less risk due to improved control of healing. Each successive revisional rhinoplasty procedure may render the anticipated outcome less predictable due to the vagaries of scar tissue healing and diminished blood supply. Therefore, *accurate preoperative diagnosis* is vital to correction of the problem in a final restorative procedure.

The vast majority of revision rhinoplasties may be categorized as operations in which less was accomplished (underoperation) than was required, more was carried out (overoperation) than was necessary, or a combination of the two. Common among secondary cases are noses in which an incomplete primary operation has occurred (Fig. 38–1). The surgeon must accurately diagnose the deficiencies and create an orderly game plan to complete the procedure to produce a more finished project. Equally common are those noses in which overaggressive surgery has produced deformities, requiring at the very least restoration of supportive structure by grafting and augmenting with appropriate materials to restore balance, function, and harmony (Fig. 38–2). In addition, asymmetrical noses often displease patients and require reoperation. Rhinoplasty is, after all, the consequence of two operations carried out on opposing sides of the nose in an attempt to produce a single symmetrical midline organ of refinement and elegance. Camouflaging grafts can create asymmetry where none existed preoperatively. Finally, copious combinations of the above surgical shortcomings are encountered, in which attention must be devoted to adding to, subtracting from, reorienting, and harmonizing the previously operated nose to achieve an acceptable outcome.

GUIDELINES IN SECONDARY RHINOPLASTY

Three decades of experience in rhinoplasty has illuminated significant principles and guidelines deemed useful in secondary rhinoplasty. We may significantly shorten this arduous learning curve by religiously studying the evolving dynamics of the nasal healing process through graphic records coupled with longitudinal standard and uniform

Figure 38–1 **(A)** Classic example of rhinoplasty complication in which an *incomplete* and *unfinished* operation has occurred, requiring further *reduction* rhinoplasty to effect improvement. **(B)** Following revisional correction.

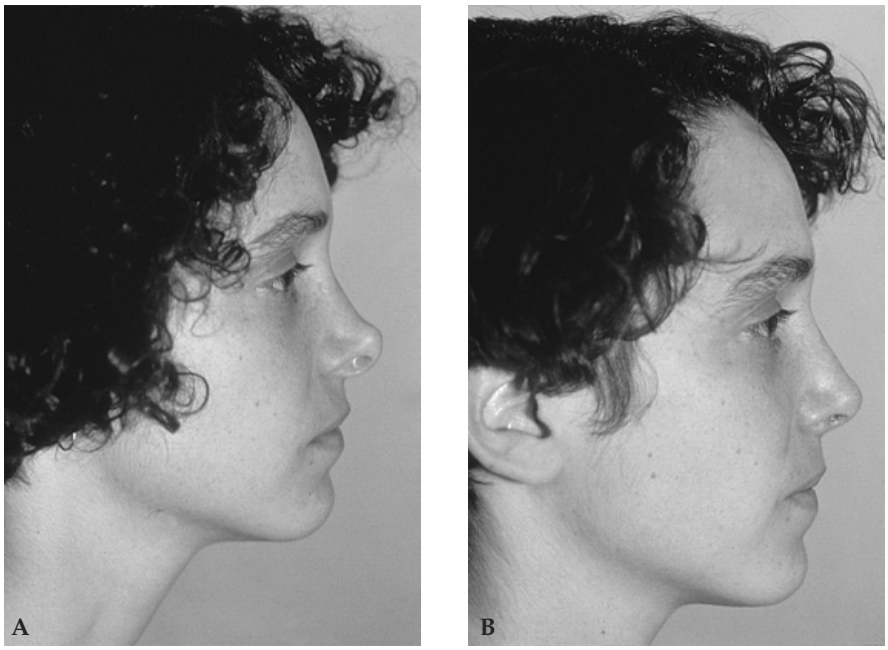


Figure 38–2 **(A)** In this patient an overaggressive reduction of the dorsum has led to serious visible disharmony of proportion. **(B)** Correction of overreduced profile with cartilage onlay grafts.

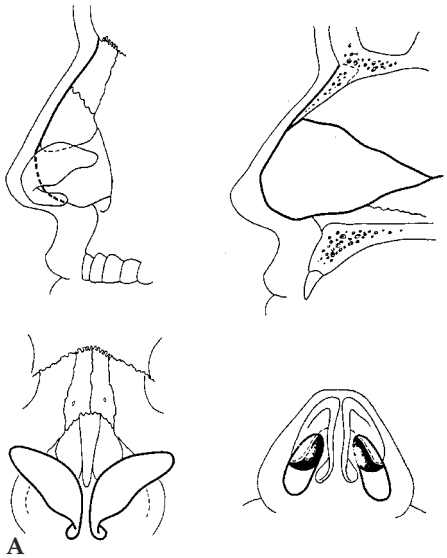
photographs (Fig. 38–3). "Ten Commandments in Secondary Rhinoplasty" are offered as a helpful guideline to surgeons involved and interested in the nuances of revisional rhinoplasty (Table 38–2). Clearly additional principles will apply in individual cases.

1. *Ensure that improvement is possible*. It is tempting to try to revise every nasal deformity, no matter how difficult or problematic. Not all rhinoplasty deformities can be satisfactorily corrected, and they may even be made worse by surgical intervention. The wise surgeon distinguishes, by psychological evaluation and painstakingly precise diagnosis, between those problems that can be reasonably helped and those that cannot ("in the first place, do no harm"). Noses still twisted after multiple operations represent very difficult challenges to straightening, which may only be realized by camouflage cartilage grafting to provide the *illusion* of straightening.
2. *Make an accurate diagnosis*. This principle is essential for assuring principle 1. Palpation of the suppleness, mobility, thickness, and scarring of the skin–subcutaneous tissue complex is equally important to visual inspection of the topography, skeletal support, and internal airway of the nose. Determining which anatomical components of the nose require repair (reduction, augmentation, or reorientation) and, just as importantly, which do not is vital. Determinations must be made about which regions of the nose require additional reduction and which need supplemental augmentation. In deviated noses, the exact anatomic component(s) creating the deviation must be clearly identified before effective repair is possible. The presence or absence of residual septal cartilage, confirmed by palpation or transillumination, provides information about the need for cartilage grafts from the auricle or rib if septal cartilage is absent. Fortunately, almost all patients seeking revision surgery possess some residual septal cartilage available for harvest and grafting.

   Of even greater importance in the diagnostic process is the psychological determination of whether or not the patient's expectations can be realized, a task that is often more difficult than physical diagnosis. We routinely query patients about their most important concerns; the problems are rank-ordered by preference in case it is not possible to correct every abnormality.
3. *Instill realistic patient expectations.* The overarching goal in every rhinoplasty, primary or secondary, is to make the patient happy. Unless there is a clear comprehension of the patient's concerns and expectations, it is unlikely that any outcome, no matter how well achieved in the surgeon's mind, will be successful. Because of differences in experience as well as aesthetic preferences, surgeon and patient may harbor entirely different expectations about revisional surgery. It is mandatory to place the patient in front of a three-way mirror and require a detailed description of what is disliked and what is expected. Because it is not always possible to correct every complication of rhinoplasty, it is useful to gently demand of the patient, in order of preference, a ranking of what problems are most disturbing. Nowhere in aesthetic facial surgery is

TABLE 38–2 Ten Commandments in Secondary Rhinoplasty

1.	Ensure that improvement is possible
2.	Make an accurate diagnosis
3.	Instill realistic patient expectations
4.	Consider surgical timing carefully
5.	Diagnose and correct functional problems
6.	Plan reconstruction options and alternatives
7.	Limit surgical dissection
8.	Implant autogenous tissue only
9.	Maximize concepts of "illusion" in revisions
10.	Avoid irreparable deformities



A

NAME_____ AGE_____ DATE_____

TYPE
[ ] Primary
[ ] Revision (mine)
[ ] Secondary
[ ] Partial
[ ] Deviated
[ ] Cleft lip-nose
[ ] Non-caucasion
[ ] Over-projecting
[ ] Under-projecting

APPROACH
[ ] Cartilage splitting
[ ] Cartilage Delivery
[ ] External (open)
[ ] Other_____

TIP-LATERAL CRURA
[ ] Complete strip
[ ] Alar batten
[ ] Attenuated
[ ] Transdomal suture
[ ] Interrupted strip
[] medial
[] lateral
[ ] Other_____

TIP REFINEMENTS
[ ] Columellar [] strut
[] contour
[] plump
[ ] Tip graft
[ ] Alar spreader graft
[ ] Unusual suturing
[ ] Resected caudal septum
[ ] Alar base resection
[ ] Other_____

TIP-EFFECT
[ ] Increased tip projection
[ ] Decreased tip projection
[ ] Increased tip rotation
[ ] Lengthened nose
[ ] Altered col-alar relationship
[ ] Altered col-labial angle
[ ] Other_____

DORSUM
[ ] Reduction
[ ] Augmentation
[ ] Altered N-F Angle
[] augmented
[] deepened
[ ] Widened
[ ] Spreader grafts [ ] Grafts
[ ] Other _____

TIP-MEDIAL CRURA
[ ] Transdomal Suture
[ ] Sutured to strut
[ ] Resected
[] caudal margin
[] vertical segment
[] footplates
[] Other_____

GRAFTS-AUTOGENOUS
[ ] Septal [ ] Auricular
[ ] Rib [ ] Fascia
[ ] Dermis [ ] Scar

IMPLANTS
[ ] Homologous cartilage
[ ] Other_____

MISCELLANEOUS
[ ] NSR
[ ] Turbinate resection
[ ] Mentoplasty
[] Augmentation
[] Reduction
[ ] Frenuloplasty
[ ] Malar augmentation
[ ] Closure of septal perforation
[ ] Banked cartilage
[ ] Blepharoplasty
[ ] Facelift
[ ] Other_____

UNIQUE FINDINGS:
_____
_____
_____

BONY PYRAMID
[ ] Medial-oblique osteotomies
[ ] Lateral osteotomies
[]complete [] greenstick
[] multiple [] unilateral
[] percutaneous

NOTES:_____
_____
_____

B

Figure 38–3 Graphic record (after Gunter) of rhinoplasty procedure completed immediately after surgery and used as an important adjunct to standardized photographs to analyze long-term postoperative outcomes.

true informed consent more important. Limitations of reparative surgery must be stressed, with realistic acceptance by the patient being the passport to undertaking the surgeon's revision.

A small but critical group of patients seeking revision surgery can never be satisfied with any outcome, no matter how much improvement is realized. If uncertainty exists about a patient's psychological preparedness for possible imperfect surgery, secondary surgery is best not undertaken.

4. *Consider surgical timing carefully.* Surgical textbooks commonly recommend that an individual wait at least one year before undertaking revision rhinoplasty. It is true that at least this amount of time must elapse before scar tissue is sufficiently mature to withstand additional repair without a worsening of the complication. Depending on the amount and degree of trauma created by the first operation, a delay of more than a year may be necessary to ensure safety and predictable healing. Exceptions to this temporal principle exist that when properly diagnosed and understood allow revision much sooner than a year and promote earlier patient satisfaction without undue risk.

For example, an incomplete, inadequate, or lateralized green-stick osteotomy may be safely and effectively infractured early (several weeks) after detection (Fig. 38–4). Delaying corrective osteotomies arbitrarily for 1 year serves no useful purpose and adds to patient anxiety and discontent. Alar base reduction, deferred at the primary operation, does not require months of healing to carry out for ultimate improved refinement of nasal proportion. Likewise, alar retraction in the early postoperative period

Figure 38–4 Unilateral osteotomy correction of widened bony pyramid due to incomplete osteotomy.

may be safely corrected with internal auricular composite grafts (Fig. 38–5). Rasping of an asymmetry or minimal elevation of the nasal bony profile is generally safe and effective within several months after primary rhinoplasty. Other modest corrective procedures, if they involve minimal and limited tissue dissection, may be safely performed.

All major surgical revisions, particularly those requiring structural grafting, should always be delayed until the tissues are pliable, scar tissue is supple and mature, and few further healing changes are anticipated. In general, patients possessing thin skin may be safely reoperated earlier than those with thick, sebaceous skin quality because earlier "shrink-wrapping" of the skin–subcutaneous complex renders minor deformities more evident.

5. *Diagnose and correct functional problems*. A common indication for revision surgery is failure to correct nasal obstruction that is the result of septal deviation or deformity. Thorough rhinoscopy following shrinkage of the nasal mucosa should reveal the majority of obstructive problems. Also necessary may be correction of nasal valve collapse, turbinate hypertrophy, alar collapse after overreduction of alar cartilages (Fig. 38–6), and overnarrowing of the nasal bony pyramid.
6. *Plan reconstruction options and alternatives*. Unlike primary rhinoplasty, where studious inspection and palpation reveal for the experienced surgeon a clear understanding of the surgical needs to be employed, revision rhinoplasty not uncommonly leads to surprises on entering the nose. Subcutaneous scar tissue often imparts unpredictable contours to the external cutaneous topography, which may change significantly when undermining of the soft tissue sleeve is undertaken. Dense scar likewise hinders accurate palpation of the skeletal support of the nasal tip. Commonly, twisted and overreduced alar cartilage remnants demand suture straightening, supportive grafting, and contouring. During revision rhinoplasty, the surgeon must remain flexible as the dynamics of the operation unfold differently from what might be expected. In particular, plans for grafting with

Figure 38–5 Correction of severe alar retraction utilizing composite graft from auricle. **(A)** Preoperative. **(B)** Postoperative.

Figure 38–6 **(A)** Inspiratory alar collapse after overreduction of supportive lower lateral cartilages, a commonly encountered postoperative complication. **(B)** After insertion of convex alar batten graft from auricle.

cartilaginous or soft tissue autografts are essential in the majority of secondary procedures. Surgical improvisation, based on experience and good surgical judgment, requires that the successful revision rhinoplasty surgeon possess mastery of a wide variety of reconstruction techniques to manage the myriad complications that are possible after rhinoplasty.

7. *Limit surgical dissection*. The blood supply of the scarred nose is tenuous and unpredictable; extensive dissection and undermining involve increasing risk of poor healing. In the majority of reconstructive revision rhinoplasties, it is judicious to *limit dissection of nasal tissues to the minimum possible to gain exposure*. Less additional scar is produced, unpredictable healing is minimized, and the visual results of tissue grafting are readily and more quickly apparent. If dissection in several regions of the nose is required, we prefer, when possible, to create several different precise tissue pockets, through limited incisions, to gain access to the nose for either reduction or augmentation surgery.

   The exposure provided by the external rhinoplasty approach is unparalleled and provides the surgeon with the twin benefits of binocular vision and bimanual surgery. We reserve this approach, requiring extensive tissue dissection, for those revision patients requiring exploration for unexplained deformities, severe distortion of the nasal tip, and large grafts requiring suture-fixation for long-term stabilization.
8. *Implant autogenous tissue only*. The previously operated nose, especially if blood supply is compromised and the skin–subcutaneous complex is damaged, scarred, or attenuated, supports all forms of alloplastic implants poorly. Respected surgeons worldwide are nearly unanimous in their preference for autogenous tissue implant reconstruction in secondary rhinoplasty. We prefer autogenous cartilage (septal, auricular, rib), bone, fascia (temporalis or facial superficial muscular aponeurotic system), dermis and occasionally mature scar (if available) for nasal reconstruction. In particular, the young patient undergoing revision rhinoplasty, with a life expectation of 60 to 70 years, deserves the demonstrated long-term safety of autogenous materials. In the near future, biogenetic engineering will undoubtedly be able to provide unlimited quantities of cloned nonimmunogenic cartilage for effective and safe reconstruction of damaged noses. Grafts of manufactured acellular dermis (AlloDerm, LifeCell Corporation) appear promising for providing additional soft tissue cover to the nasal skeleton; however, long-term outcomes do not yet exist.
9. *Maximize concepts of "illusion" in revisions*. In many secondary rhinoplasties, chosen with care, elegant refinement can be accomplished by creating visual illusions by changing nasal proportions or by grafting. Deviated noses may be "straightened" by carefully designed cartilage grafts on or along the nasal dorsum. Overrotated noses may be visually "lengthened" by dorsal onlay grafts combined with cartilage grafts to the infratip lobule (Fig. 38–7). Recessing the dependent "hanging" columella may render an apparently overlong nose proportionate. Wise surgeons recognize that not every revision patient requires a "complete" secondary rhinoplasty; improvement is often best achieved with more conservative but equally effective surgery.
10. *Avoid revision surgery in irreparable deformities*. Every rhinoplasty surgeon encounters patients with deformities of such a serious nature that no amount of surgical skill or ingenuity can provide satisfactory correction. Although often difficult, it is always judicious to gently refuse to operate on such patients because the outcome will undoubtedly be unsatisfactory to patient and surgeon alike.

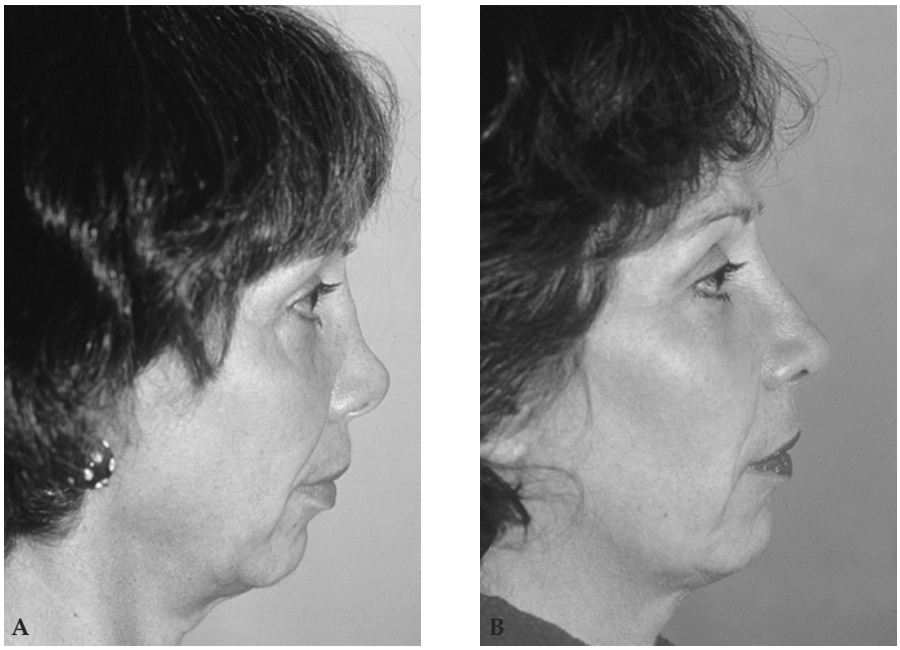


Figure 38–7 Favorable lengthening of nose with cartilage grafts placed in infratip lobule. **(A)** Preoperative. **(B)** Postoperative.

PREOPERATIVE ANALYSIS AND PLANNING

Patients seeking revision rhinoplasty uniformly require more evaluation time than patients undergoing primary rhinoplasty. After one or more unsatisfactory procedures, often the preoperative consultation is initiated by the patient's expressing anger, guilt, disenchantment, and disillusionment regarding nasal surgery in general while at the same time seeking reassurance that improvement can be achieved.

It is wise to begin the evaluation process by accurately documenting the previous nasal procedures both major and minor. Of some importance are the procedure dates and time intervals between each—if more than one procedure has been accomplished.

The identity of the surgeon(s) involved in the previous procedures may or may not be relevant. If the surgeon is known to us—and considered to be highly capable—our initial recommendation is for the patient to return to the primary surgeon for further care and treatment. If the patient finds this avenue of approach unacceptable, then we begin an examination to determine what functional and appearance problems exist and are troubling the patient.

A common problem arises when patients, who are angry and disenchanted solicits the secondary surgeon's opinion about the outcome achieved by or the credentials of the primary surgeon. We have a steadfast rule *never* to comment about the surgical result or the primary surgeon (particularly when the outcome is obviously excellent and the patient's concerns are unrealistic). It serves no useful purpose to criticize the work of other surgeons and may even trigger a spurious, unjustified liability action. These patients are gently but firmly advised that further evaluation and possible surgical improvement must be predicated on the findings as they exist now (the surgically altered nose) and not on the anatomy or appearance that existed prior to primary surgery.

Photographs accompanying the patient may be highly useful to (1) gain insight into each patient's aesthetic sense and self-image, (2) identify serious and even uncorrectable deformities, and (3) demonstrate what can or cannot be reliably corrected. Compared and contrasted with standard and uniform photos we record, defects and aesthetic shortfalls unrecognized by the patient may be documented and a useful educational process carried out.

Previous operative notes, possessed by the patient, provide information of variable reliability. Certain information regarding technique, findings, and implants is valuable, but it is a truism that previous operative notes are often highly unreliable. On the other hand, graphic surgical records routinely contain information of value.

Patients are asked to rank-order, from most to least severe, which symptoms or features problems trouble them most profoundly. Early in the discussion it is made clear—and documented—that (1) it may not be possible to satisfactorily correct each and every problem; (2) in certain difficult cases more than one procedure may be required to reach a mutually satisfactory outcome; and (3) every surgical effort will be made to resolve the problem that exists but that outcomes are less predictable in secondary surgery and *no guarantees can be made*.

In every active rhinoplasty practice, patients will be encountered who present imagined defects or unrealistic outcome expectations. It is best to agreeably disengage from such individuals; we generally do so by simply suggesting that we do not possess the skills needed to meet their requests and cannot honestly proceed with further surgical procedures. If a request is made, the names of other highly reliable and qualified surgeons are provided (although this may not represent a professional favor to another surgeon!). It is wise, in revisional surgery, to operate only when the opportunities for significant improvement are reasonably assured.

Perhaps the most difficult decision regarding revision surgery relates to the timing of additional surgery. Traditionally, a period of delay of 1 year is advised, but this axiom clearly is simplistic, failing to take into account the individual deformity and the nasal anatomical component involved.

For example, unequal or asymmetrical osteotomies, rendering the bony pyramid deviated, overwide, or poorly positioned, may be quite safely and accurately corrected with proper osteotomies in a matter of just a few weeks after rhinoplasty. The same principle exists for alar base narrowing reduction overlooked or deferred at the previous surgery. No valid justification exists for delaying these corrections and refinements for a year or more.

In contrast, correction of scars, irregularities, and thickening of the skin–subcutaneous tissue complex anatomical unit should be deferred until complete softening and maturation has taken place, which may require up to 18 months or more. Prematuration attempts may magnify the problem, creating additional scarring and irregularity. Most nasal tip revisions require 12 to 18 months of healing and shrinkage before correction can be safely undertaken; exceptions may exist in certain tips in which overprojection or underprojection persists after initial surgery.

Patients and surgeons who seek instant gratification by ignoring the surgical canons related to surgical timing invite disappointment.

ILLUSTRATIVE CLINICAL EXAMPLES

To demonstrate the usefulness of many of the previous principles and guidelines, three clinical examples will be examined that incorporate the thought processes and techniques expressed.

Clinical Case 1 (Fig. 38–8)

This 25-year-old schoolteacher underwent primary rhinoplasty elsewhere 11 years ago. The immediate and long-term outcome has led to increasing dissatisfaction and negative comments by friends and colleagues. Immediately following the initial surgery she voiced concerns to her surgeon about overreduction of the nasal dorsum and low nasal bridge. As healing progressed over the years, tip asymmetry and bossa became more evident. Nasal breathing is difficult due to a significantly deviated septum to the right.

Analysis

A marked disproportion between the upper nose and the tip is immediately apparent. The dorsum appears wide and "washed out." Prominent asymmetrical bossae exist, with tip bifidity apparent as a consequence of diverging intermediate crura. Exquisitely thin skin accentuates the tip abnormality. Clefting exists between the crura. A significant alar–columellar

Figure 38–8 Two-year outcome of secondary rhinoplasty by technique described in text.

disproportion exposes an excess of vestibular skin and membranous columella, with the appearance of a hanging columella.

Overall, the nose is significantly unbalanced and reveals the classic stigmata of an operated appearance.

Rhinoscopy reveals an intact deviated septum to the right, obstructing 80% of the nasal airway. The nasal mucosa and turbinates are normal.

The exquisitely thin skin with sparse underlying subcutaneous tissue makes coverage of cartilage grafts, essential for reconstruction, difficult.

Frontal View

- Thin skin–subcutaneous tissue complex
- Wide, flat dorsum
- Hanging infratip lobule
- Asymmetrical tip
- Prominent bossae
- Tip bifidity

Base View

- Prominent bossae
- Wide, bifid tip
- Intercrural clefting
- Prominent medial crural footplate
- Elongated medial crura
- Asymmetrical tip-defining point

Lateral View

- Shallow, overreduced dorsum and radix
- Indistinct profile "starting point"
- Slightly overprojected tip
- Overly convex columella
- Alar–columella disproportion
- Excess membranous columellar exposure

Oblique View

- Confirms other views

Psychosocial Evaluation

This pleasant young schoolteacher is acutely aware that her nasal appearance is abnormal and invites negative comments from her pupils and associates. Confidence in her original surgeon was lost early on; she has requested revisional surgery shortly after becoming aware of the surgical appearance shortfalls. Inadequate finances had prevented her from seeking corrective surgery heretofore.

Psychological evaluation revealed a stable, pleasant, realistic young woman who easily understood the risks inherent in secondary surgery and was eager to breathe better as well as to improve her appearance.

Surgical Technique and Strategy (Fig. 38–9)

The principles involved in the reconstruction of this problem primarily involve an augmentation of the shallow dorsum, reduction-refinement of the nasal tip bossae, and repair of the deviated septum. Augmentation of the dorsum will help restore proportion to the upper and lower nasal structures, as well as to provide the illusion of narrowing. The scarred contracted bossae must be reduced by removal and reconstitution, creating indicated retroprojection. Tip narrowing by transdomal suturing is mandatory. Finally, the alar–columellar disproportion must be regularized. Crushed cartilage autografts of septal cartilage provide a softening buffer between the scarred strong alar cartilages and the thin tip skin.

Operative Technique and Sequence

1. Harvest of right auricular cartilage grafts.
2. Left Killian septal incision.
3. Elevation of light septal mucoperichondrial–periosteal flaps. Septal reconstruction by:
   a) Disarticulation of ethmoid from quadrangular cartilage (followed by transeptal quilting mattress suturing of septal flaps)
   b) Excision obstructing ethmoid plate and tail of septal cartilage
   c) Excision 3 mm strip of cartilage along floor of nose
   d) Harvest septal cartilage grafts
   e) Suture caudal septum to periosteum of spine

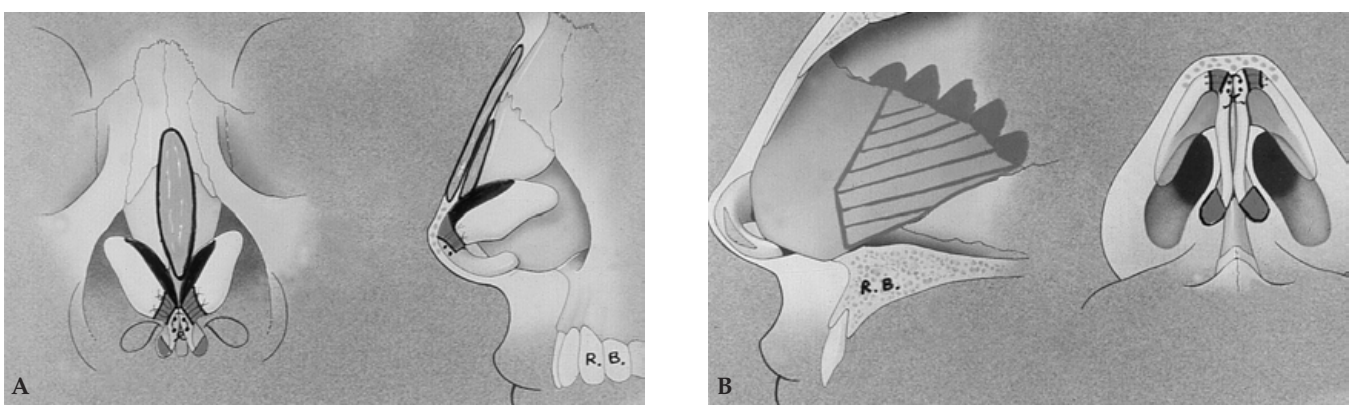


Figure 38–9 Graphic representation of surgical techniques employed in Case 1.

4. Delivery of alar cartilage through intercartilaginous and marginal incisions; complete transfixion incision to retroproject tip.
5. Amputation of scarred domes (bossae) and suture-repair of cut cartilage margins to reconstitute complete strip.
6. Narrowing of bifid tip with transdomal sutures.
7. Resection of portion of flared medial crural footplates.
8. Resection of crescent of excess membranous columella and caudal septum.
9. Elevation of narrow pocket over dorsum for graft insertion.
10. Onlay grafting of shallow dorsum with dual-layer cartilage grafts.
11. Insertion of multiple crushed cartilage, and septal cartilage grafts to tip and infratip lobule.
12. Bilateral curved low lateral osteotomies for bony pyramid narrowing with 3-mm microosteotome.
13. Suture-repair of all incisions with 5-0 chromic catgut suture.
14. Application of Denver splint.

Retrospective Analysis and Critique

At 1 year, balance and proportion have been restored to the nose and face, providing an improved relationship between the nasal dorsum and tip by profile augmentation and tip retroprojection. The bifidity, apparently unappreciated at the patient's initial surgery, is now corrected with improved triangularity and symmetry on base view (the diagnostic triad of thin skin, strong cartilages, and tip bifidity or divergence of the domes must always be recognized in primary rhinoplasty and the domes brought closer together). The bossae have been excised and the alar cartilage dome integrity restored with fine suture repair. The nose, which appeared overshort and excessively rotated, now demonstrates proper length.

The visually distracting alar-columellar disproportion is corrected. The most important long-term consideration is whether the thin skin–subcutaneous tissue layer will allow the onlay grafts to become visible with continued epithelial thinning. Marginal shave-excision and edge beveling of grafts aid in the prevention of visible graft edges.

Clinical Case 2 (Fig. 38–10)

This 37-year-old homemaker underwent rhinoplasty twice (with two different surgeons). During the intervening years the normal appearance has progressively worsened, with increasing bilateral airway obstruction. She requests repair of her external deformities (primarily the profile and tip abnormalities) and wishes to breathe more comfortably.

Figure 38–10 Two-year outcome of secondary rhinoplasty techniques described in text.

Analysis

The surgical outcome of two procedures in this patient represents multiple problems of overreduction of the bony dorsum, undercorrection of the cartilaginous dorsum, loss of tip support with bilateral alar collapse, and bilateral bossae formation with tip bifidity clearly apparent. The bony dorsum is low and discontinuous from the cartilaginous dorsum, which demonstrates both a cartilaginous and a soft tissue pollybeak. Internally and externally, the alar sidewalls are flailed and collapsed inward, contributing to nasal obstruction. The asymmetrical tip bossae have developed as a consequence of failure to initially diagnose and subsequently properly treat the triad of thin skin, strong cartilage, and crural bifidity. The overall nose is unbalanced in proportion and appears distinctly surgical.

Frontal View

- Indistinct, washed-out bony dorsum
- Inverted "V" deformity; upper lateral cartilage collapse
- Discontinuous aesthetic lines from brow to tip
- Collapsed supratip regions bilaterally
- Prominent tip bossae
- Intermediate crural bifidity and divergence
- Thin skin

Base View

- Thin skin revealing strong cartilage
- Significant bifidity and crural divergence
- Bilateral tip bossae
- Pollybeak visible in supratip midline
- External alar sidewall collapse
- Internal alar sidewall collapse accentuated with inspiration

Lateral View

- Overreduced bony dorsum—nose appears short
- Underreduced cartilaginous dorsum, with tip–supratip disproportion
- Tip ptosis with loss of support
- Supraalar depression
- Bossa evident
- Unbalanced, disproportionate nose

Oblique View

- Confirms other views

Psychosocial Evaluation

This attractive mother of two children suffers from loss of self-esteem as a consequence of the surgical-appearing nose, revealing several complications. She confided that she felt "stared at" in public and that her children had commented negatively about her nose. As the alar collapse had progressively worsened, breathing through the nose worsened, leading to constant mouth breathing.

She realistically accepted the limitations and risks inherent in an additional procedure and was eager for airway and appearance improvement.

Operative Technique and Strategy (Fig. 38–11)

This patient's nose represents overaggressive surgical reduction in some areas of the nose, with undercorrection in other regions. Balance of the upper and lower nose must be restored by onlay grafting of the upper nose combined with reduction of the cartilaginous–soft tissue pollybeak deformity. The bifid nasal tip requires refinement and narrowing by shave-excision of the scarred bossae and suturing the divergent crura and domes closer together. Use of bilateral curved cartilage battens from the auricle is necessary to resupport the alar sidewalls and prevent inspiratory collapse, thus favorably improving the nasal airway.

Operative Technique and Sequence

1. Harvest of auricular cartilage from cavum and cymba conchae.
2. Delivery of alar cartilage remnants through intercartilaginous and marginal incisions.
3. Removal of soft tissue interdomal area.
4. Shave-excision of sharp edges of bossae.
5. Transdomal suture narrowing of bifid domes with 4-0 PDS suture.
6. Elevation (wide) of skin–subcutaneous tissue complex of cartilaginous dorsum.
7. Knife excision of cartilaginous–soft tissue pollybeak with excision excess supratip scar.
8. Creation of limited (narrow) pocket in midline over bony dorsum.

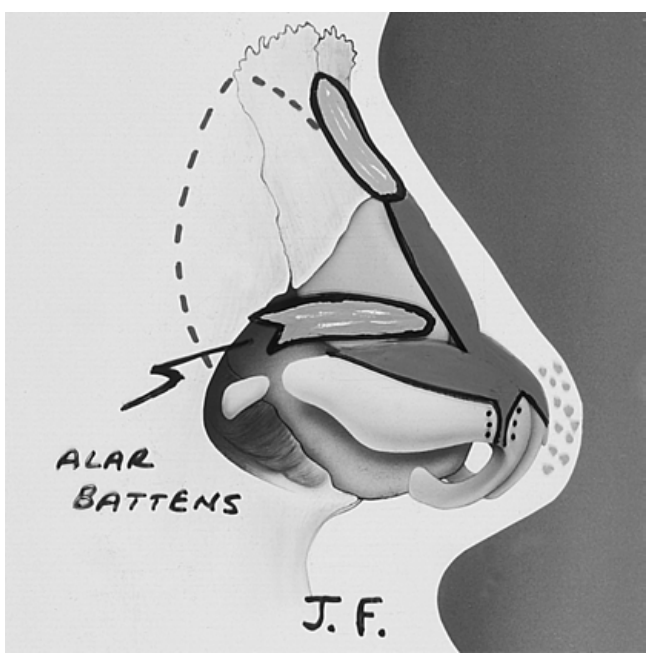


Figure 38–11 Graphic representation of surgical techniques employed in Case 2.

9. Onlay grafting of bony dorsum with two-layer sandwich graft of auricular cartilage.
10. Creation of precise subcutaneous pockets in supraalar regions bilaterally in exact areas of alar collapse.
11. Insertion of bilateral convex auricular cartilage battens into supraalar pockets.
12. Suture-repair all incisions with 5-0 chromic catgut suture.
13. Insertion of layer of crushed cartilage into tip lobule subcutaneously.
14. Bilateral curved low lateral osteotomies with 3-mm microosteotome.

Retrospective Analysis and Critique

A combination of augmentation as well as reduction revision surgery characterizes this procedure, which has produced a more balanced, proportionate, and natural nose. Attention is thus drawn to attractive eyes and away from the nose. Aesthetic lines are improved on all views, and the alar collapse is corrected with airway improvement. Reorienting and grafting of scarred tip structures has restored appropriate triangularity to the tip. The nose now appears longer and balanced to the face.

Clinical Case 3 (Fig. 38–12)

Now in midlife, this patient underwent primary rhinoplasty many years ago. She immediately noted overrotation of the nose with slow but progressive collapse of the supratip region, resulting in a saddle nose. Recent comments by acquaintances about the nose being too short and excessive nostril show have prompted her to seek secondary surgery.

Analysis

The overdeep dorsum is apparent on frontal view, with asymmetry of the opposing lateral sidewalls. It is apparent that the nose is clearly overrotated, allowing the observer to look directly into the exposed nostrils. The alar base is overwide, making the nose "bottom-heavy." Laterally, a distinct supratip saddling exists. Combined with overrotation of the tip, with an excessively extreme columellar "double-break," the nose appears snubbed and too short. The skin is thick, demonstrates high sebaceous gland activity, and reveals rhytidosis near the nasal root.

Palpation and translumination of the nasal septum reveals almost totally absent cartilage.

Frontal View

- Thick sebaceous skin with rhytidosis
- Asymmetrical lateral sidewall lines
- Supratip depression
- Overshort nose
- Excessive nostril exposure
- Wide alar base

Base View

- Wide alar base
- Lateral alar sidewall indentation

Lateral View

- Significant supratip saddling
- Bony pyramid profile irregularity
- Severe nasal overrotation
- Abnormal columellar "double break"
- Obtuse columellar-labial angle

Oblique View

- Confirms other views

Psychosocial Evaluation

The patient demonstrates excellent motivation for secondary rhinoplasty. Her life is stable, fulfilled, and happy except for the increasing concern about the "snubbed" appearance to the nose, worsened by the progressive saddling. Comments from friends and family have prompted her to seek reconstruction. She particularly dislikes the extent of visible nostril from frontal and oblique views. Her understanding of the limitations and risks associated with augmenting and lengthening the nose is realistic and appropriate.

Figure 38–12 Three-year outcome of secondary augmentation rhinoplasty carried out employing techniques described in text.

Operative Technique and Strategy (Fig. 38–13)

The surgical goal in this attractive, middle-aged woman is to augment the nose to restore a strong, elegant dorsum while correcting the overshortness. Ear cartilage grafts will be needed if insufficient septal cartilage remains for harvest. The central segment nasal length will require true elongation via addition of cartilage grafts to the infratip lobule, which will produce the added benefit of restoring a normal columellar inclination. The lateral sidewalls, because of heavy alar lobules, are of adequate length. Finally, the bottom-heavy alar base will benefit by bilateral alar base reduction procedures, narrowing the excessive horizontal width of the nasal base.

Operative Technique and Sequence

1. Harvest of auricular cartilage from cavum and cymba concha.
2. Exploration of nasal septum through left Killian incision—thick cartilage harvested from junction at maxillary crest (majority of septal cartilage absent).
3. Elevation of limited midline skin–subcutaneous pocket over entire nasal dorsum.
4. Rasp of bony dorsum prominence.
5. Insertion double-layer auricular cartilage grafts, stabilized in place by cephalic and caudal transcutaneous pull-out sutures of 5-0 mild chromic catgut.
6. Creation of precise pocket below infratip lobule with small bilateral infradomal marginal incisions.
7. Insertion of two-layer triangular auricular cartilage grafts to lengthen central segment of nose.
8. Bilateral alar base reduction with wedge excisions.
9. Suture-repair of all incisions with 5-0 chromic catgut.
10. Application of Denver splint for 5 days.

Retrospective Analysis and Critique

Balance and proportion have been restored to the nose of this patient by enlargement and lengthening (well-proportioned large noses are infinitely more attractive than malpositioned small noses). Both actual length and the illusion of lengthening have been achieved. No longer can the observer gaze directly into the nostril. Alar base reduction aids in balancing the upper two thirds and lower third of the nose. The frontal aesthetic lines are improved and more symmetrical, though not perfect. In retrospect, a longer dorsal graft might have provided improved frontal lines. In addition, modest chin augmentation would provide improved facial balance but was not desired.

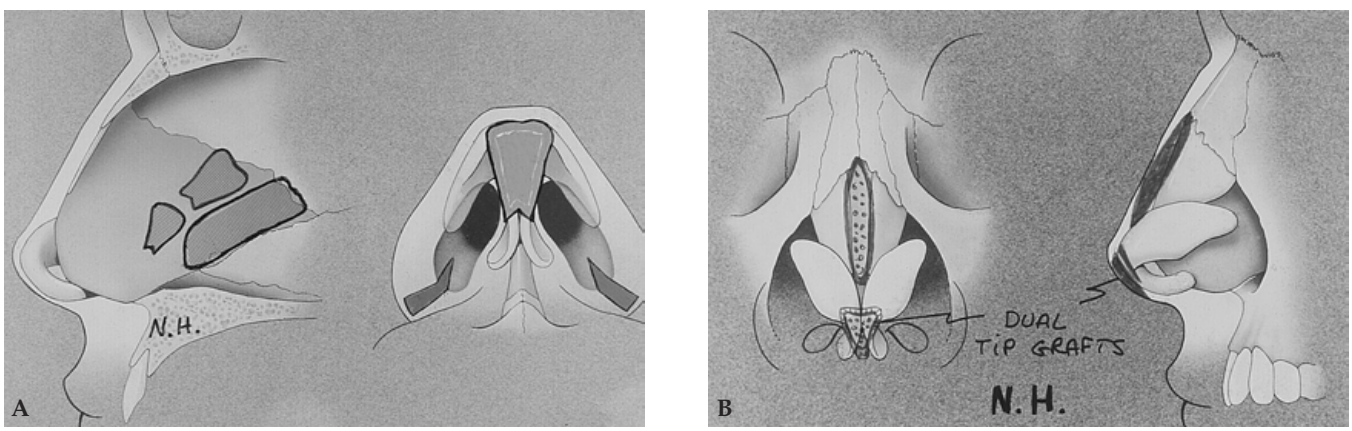


Figure 38–13 Graphic representation of techniques utilized in Case 3. Tip grafts are utilized here to lengthen nose, not to increase tip projection.

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Chapter 39

Complications of Rhinoplasty

Daniel G. Becker

The nose plays a functional role in nasal breathing, as well as an aesthetic role as it represents the most prominent and central facial feature. That the nose has enormous psychological, emotional, social, and symbolic importance is indisputable.[1] Most studies suggest that the great majority of rhinoplasty patients benefit psychologically from the operation.[1] While rhinoplasty can be a satisfying procedure for both patient and surgeon, the literature reports an incidence of postoperative rhinoplasty complications ranging from 8% to 15%.[2–4] The rhinoplasty surgeon must take great care to minimize the incidence of both functional and cosmetic complications.

How is a "complication" defined? In most cases with an unacceptable result, the patient and surgeon recognize an unacceptable result, and a corrective plan is agreed upon. At times, the surgeon may notice a relatively subtle abnormality that is amenable to correction, but the patient is not concerned by it. It should be a rare situation that the surgeon is proud of the outcome while the patient is displeased.[5]

A candid discussion with the patient regarding the goals and expectations of surgery is an essential aspect of preoperative planning. A discussion of the potential complications is critical, so that the patient understands the risks of a complication. *Although most complications are relatively minor and correctable, more serious and debilitating complications do occur. All complications must be addressed with forthright recognition, close attention to the patient, and appropriately timed corrective measures.*

Careful preoperative anatomical diagnosis and a conservative approach guided by an understanding of the postoperative changes that occur during healing are critical in minimizing complications. Failure to recognize the precise anatomical cause of a nasal feature may result in failure to effect the desired change. Problems with technical execution is another potential cause. Despite careful preoperative analysis and meticulous attention to surgical detail, less than ideal aesthetic results may still occur.

Complications in rhinoplasty may be categorized as functional or aesthetic in nature; often, there are elements of both. In considering this subject, it may also be helpful to organize aesthetic complications by the specific nasal subunit affected.

Problems after rhinoplasty commonly relate to issues of *underresection*, *overresection*, and/or *asymmetry*. In general, it is easier to address a problem relating to underresection because the surgeon needs only to "take a little more." Problems relating to overresection can be difficult, and are often complicated by scarring, need for graft material, and other issues.[2]

Anatomical diagnosis is helpful in the prevention of complications and is also critical in the proper evaluation and treatment of complications when they occur. In this chapter we will address many of the more commonly described surgical complications with special attention to their cause and treatment. Emphasis is placed on the anatomical basis of each complication, as this approach provides a guide to correction. Although complications have been generally arranged by anatomical location, there are some topics that cross categories.

NASAL TIP

General Considerations

In the nasal tip, overreduction may violate critical tip support mechanisms (Table 39–1),[5,6] which can lead to complications such as *tip ptosis* and *inadequate tip projection* (see below). Alternatively, overresection of the caudal septum can

TABLE 39–1 Tip Support Mechanisms

Major tip support mechanisms
1. Size, shape, and strength of lower lateral cartilages
2. Medial crural footplate attachment to caudal septum
3. Attachment of caudal border of upper lateral cartilages to cephalic border of lower lateral cartilages

[Nasal septum is also considered a major support mechanism of the nose.]

Minor tip support mechanisms
1. Ligamentous sling spanning the domes of the lower lateral cartilages (i.e., interdomal ligament)
2. Cartilaginous dorsal septum
3. Sesamoid complex of lower lateral cartilages
4. Attachment of lower lateral cartilages to overlying skin/soft tissue envelope
5. Nasal spine
6. Membranous septum

result in overrotation of the nasal tip with excessive shortening of the nose. Overresection may also contribute to other complications, such as *bossae*, *alar retraction*, and *alar collapse*[2,7–9] (see below).

Underreduction may simply be due to overcaution but may also be due to a failure to correctly assess preoperatively the anatomical situation. For example, failure to recognize an overprojected nose or to diagnose the steps required based on the patient's anatomy to adequately address this can lead to a persistent overprojected state.[7,10] Failure to adequately resect cartilaginous dorsum may result in a *pollybeak deformity*.[2,7–9,11]

Asymmetry of the nasal tip may be due to unequal reduction of the lower lateral cartilages or to asymmetrical application of dome-binding sutures.[7] It may also be caused by unequal scarring that can occur during the natural healing process and may not be evident for months or even years after surgery. Asymmetry is often present preoperatively and should be recognized and pointed out to the patient prior to surgery.

Specific Complications in the Nasal Tip

Ptotic Tip

A critical principle in avoiding undesired changes of the nasolabial angle is assessment of tip anatomy and tip support, followed by maneuvers that maintain or augment tip support and restore the nose to a more natural appearance. However, as mentioned above, maneuvers that result in loss of tip support may lead to a droopy tip (tip ptosis with an overly acute nasolabial angle). The normal nasolabial angle (angle defined by columellar point–to–subnasale line intercepting with subnasale–to–labrale superius line) is 90 to 120 degrees.[12] Within this range, a more obtuse angle is more favorable in females, a more acute angle in males. Loss of tip support can lead to a ptotic, underprojected, drooping nose.

Management of complications relating to a ptotic nose relies on restoration of tip support and tip projection. When faced with an operative complication such as a droopy, ptotic tip, appropriate diagnosis will guide correction.[7] There are numerous rhinoplasty maneuvers to increase tip support, reproject the nose, and rotate the nose (Table 39–2).[6]

TABLE 39–2 Operative Maneuvers

Increase rotation
Lateral crural steal
Transdomal suture that recruits lateral crura medially
Base-up resection of caudal septum (variable effect)
Cephalic resection (variable effect)
Lateral crural overlay
Columellar strut (variable effect)
Plumping grafts (variable effect)
Illusions of rotation—increased double break, plumping grafts (blunting nasolabial angle)
Decrease rotation (counterrotate)
Full-transfixion incision
Double-layer tip graft
Shorten medial crura
Caudal extension graft
Reconstructed L strut, as in rib graft reconstruction (integrated dorsal graft/columellar strut) of saddle nose
Increase projection
Lateral crural steal (increased projection, increased rotation)
Tip graft
Plumping grafts
Premaxillary graft
Septocolumellar sutures (buried)
Columellar strut (variable effect)
Caudal extension graft
Decrease projection
High partial- or full-transfixion incision
Lateral crural overlay (decreased projection, increased rotation)
Nasal spine reduction
Vertical dome division with excision of excess medial crura, with suture reattachment
Increase length
Caudal extension graft
Radix graft
Double-layer tip graft
Reconstructed L strut
Decrease length
See increased rotation
Also, deepen nasofrontal angle

Overrotated Tip

Conversely, one may face a patient with a nose that has been overrotated, with an overly obtuse angle. Overresection of the caudal septum is a common cause of overrotation of the tip. Overrotation of the nose creates an unsightly, overshortened appearance.

Careful preoperative assessment can identify those patients in whom operative rotation should be avoided. Management of complications relating to a short, overrotated nose relies on maneuvers that lengthen and counterrotate the nose.[7] There are specific rhinoplasty maneuvers to lengthen and counterrotate the nose (Table 39–2).[6]

Bossae

A bossa[2,7,9] is a knuckling of the lower lateral cartilage at the nasal tip due to contractural healing forces acting on weakened cartilages. Patients with thin skin, strong cartilages, and nasal tip bifidity are especially at risk. Excessive resection of lateral crus and failure to eliminate excessive interdomal width may play some role in bossa formation. Bossae are felt to be the result of scar contracture on an overly narrowed complete rim strip, causing a bulge during postoperative healing. Some investigators have described an association between cartilage splitting techniques and bossa formation.[2] However, others maintain that vertical dome division techniques are reliable when performed correctly and do not contribute to these difficulties.[9,13]

As an isolated deformity, bossae are typically treated through a small marginal incision with minimal undermining

over the offending site followed by trimming or excising the offending cartilage. In some cases, the area is covered with a thin wafer of cartilage, fascia, or other material to further smooth and mask the area.

Alar Retraction

Cephalic resection of the lateral crus of the lower lateral cartilage is commonly undertaken to effect refinement of the nasal tip. If inadequate cartilage is left, then the contractile forces of healing over time will cause the ala to retract (Fig. 39–1).[2,7–9,14] This is a commonly seen sequela of overresection of the lateral crus. The surgical rule of thumb is to preserve at least 6 to 9 mm of complete strip. Nevertheless, an anatomical study of the alar base recognized that in a normal patient population 20% of patients have a thin alar rim. This anatomical variation must be recognized, as these patients may require even more conservative approaches to avoid the risk of alar retraction and/or external nasal valve collapse.[15] Also, vestibular mucosa should be preserved, as excision of vestibular mucosa contributes to scar contracture with alar retraction.

Alar retraction may be treated by cartilage grafts in more minor cases (1–2 mm).[2] The area of retraction is marked prior to injection, and a small marginal incision allows dissection of a precise pocket. A contoured cartilage graft (commonly of auricular or septal cartilage) may be inserted into the precise pocket; it should extend inferiorly to the sesamoids and be wide enough to simulate the normal shape of the lateral crus at the dome.

Auricular composite grafts are commonly used in more severe cases. The cymba concha of the opposite ear (e.g., left ala, right ear) provides the best contour. An incision several millimeters from the nostril rim is followed by careful dissection with freeing of adhesions, creating a defect and displacing the alar rim inferiorly. The fashioned composite graft is carefully sutured into place.[2,16]

Alar–Columellar Disproportions

Alar–columellar disproportions can be areas of significant patient concern.[17,18] The range of normal columellar show is generally considered to be 2 to 4 mm. The complexities of the alar–columellar relationship have been categorized by Gunter and colleagues,[18] who describes the position of the ala and the columella in relationship to a line drawn through the long axis of the nostril.[18] All patients have a hanging, normal, or retracted ala and a hanging, normal, or retracted columella. Thus, there are nine possible anatomical combinations making up the alar–columellar relationship (Fig. 39–2).

Alar–columellar disproportion may exist in the unoperated nose; also, it may be caused by surgical misadventure (Fig. 39–1). A protruding or hanging columella may be due to a persisting uncorrected deformity, such as an overly wide medial crura or an overly long caudal septum.[7] The deformity may be increased columellar show secondary to retraction of the alar margins rather than an actual protrusion of columella. A deficient or retracted columella may be due to a preexisting uncorrected deformity, or it may be due to excessive resection of soft tissue, cartilage, or nasal spine. The surgeon should avoid excessive resection of the caudal septum, and should avoid resection of the nasal spine.[2,7,17]

Management of a protruding or hanging columella may include resecting full-thickness tissue from the membranous columella, including skin, soft tissue, and perhaps a portion of the caudal end of the septum itself. If the medial crura is excessively wide, management may include a conservative excision of the caudal margin of the medial crura.[7,17]

Retracted columella may be improved with plumping grafts inserted at the base of the columella to address an acute nasolabial angle; columellar struts may also be helpful for minor deformities. A cartilage graft may be used to lengthen the overshortened nose. The use of composite grafts has also been described.[2,7]

Figure 39–1 Patient many years after rhinoplasty, with alar–columellar disproportion due to alar retraction.

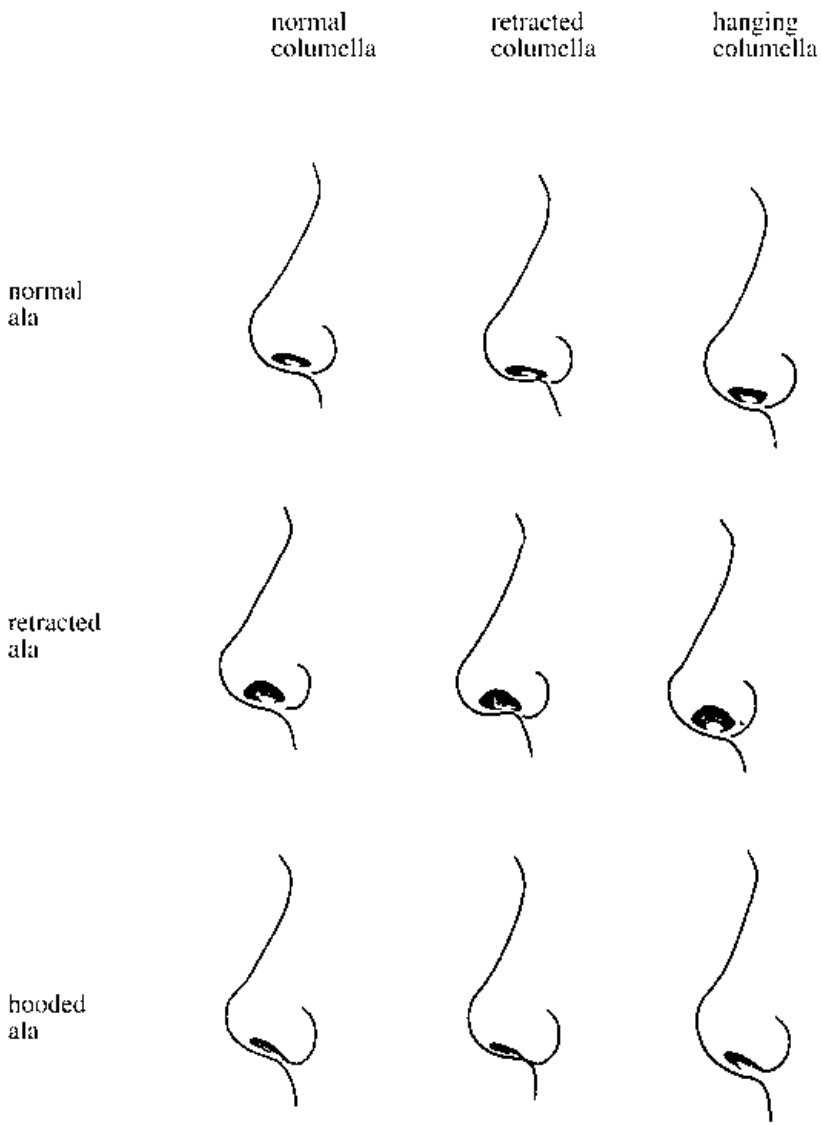

Figure 39–2 The alar–columellar relationship can be described with nine possible anatomical combinations. (From Toriumi DM, Becker DG. *Rhinoplasty Dissection Manual*. Philadelphia: Lippincott Williams & Wilkins; 1999. With permission.)

Pollybeak

A pollybeak[2,7,9,11] refers to postoperative fullness of the supratip region, with an abnormal tip–supratip relationship (Fig. 39–3). This may have several causes, including failure to maintain adequate tip support (postoperative loss of tip projection), inadequate cartilaginous hump (anterior septal angle) removal, and/or supratip dead space/scar formation.

Management of the pollybeak deformity depends on the anatomical cause. If the cartilaginous hump was underresected, then the surgeon should resect additional dorsal septum. Adequate tip support must be ensured; maneuvers such as placement of a columellar strut may be of benefit. If the bony hump was overresected, a graft to augment the bony dorsum may be beneficial. If pollybeak is the result of excessive scar formation, Kenalog injection or skin taping in the early postoperative period should be undertaken prior to any consideration of surgical revision.

Columellar Incision

The external rhinoplasty approach includes a columellar incision.[19] Great care must be taken when making this incision not to bevel it but rather to ensure that the incision is perpendicular to the skin, thereby avoiding the complication of a trapdoor deformity. Great care must be taken in closing the incision to avoid notching at the margins or other deformity (Fig. 39–4).

A single subcutaneous 6-0 polydioxanone (PDS) suture can be positioned in the dermal tissues to enhance skin edge eversion and take tension off of the closure. This suture should provide skin edge alignment and slight eversion. Excessive eversion will create a deformity that may require many months to resolve. The level of the skin edges must be precisely aligned with this suture; otherwise an unsightly scar may result. If there is no tension on the closure, a subcutaneous suture may not be needed.

To close the skin, five 7-0 nylon vertical mattress sutures are used. The first suture lines up the apex of the inverted V. The next two sutures are angled from medial on the lower flap to lateral on the upper flap to properly align the closure. A 6-0 chromic suture is used to line up the vestibular skin at the corner of the columellar flap. This corner suture is important because aberrant healing of this corner can result in a visible notch defect.

Figure 39–3 Patient with overresected bony dorsum and underresected cartilaginous dorsum. Her pollybeak deformity was due to persistent cartilaginous dorsum and was therefore corrected by additional excision of cartilaginous dorsum. Her overresected upper nasal third was augmented to create a more balanced profile. **(A)** Preoperative lateral view. **(B)** Postoperative lateral view.

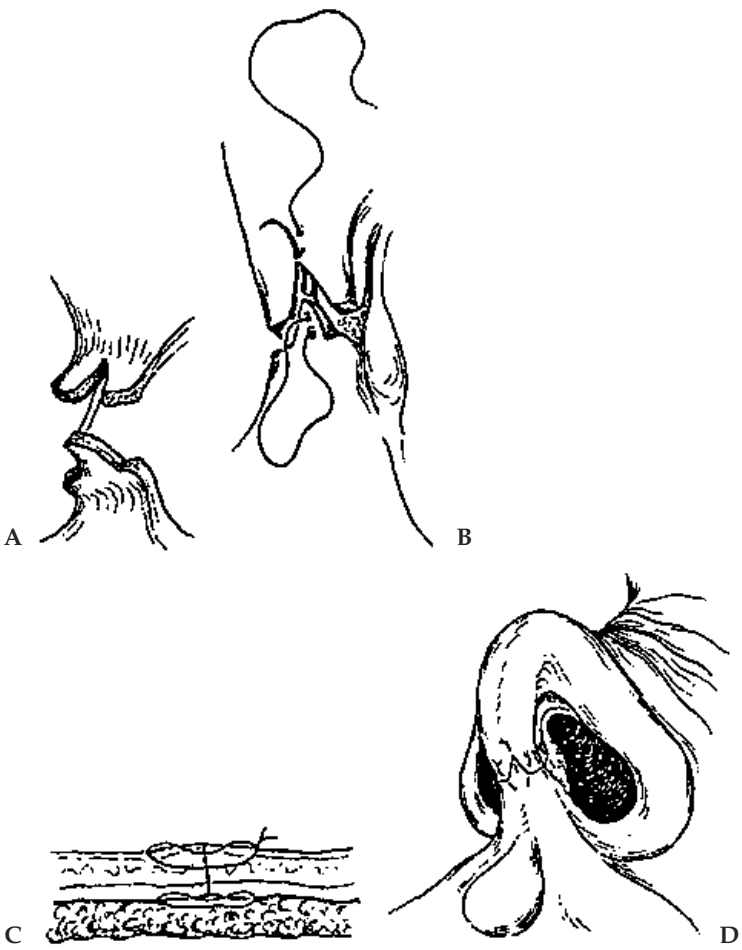

Figure 39–4 Special attention should be given to the columellar incision, and to its closure, when undertaking external rhinoplasty. Great care should be taken to perform these maneuvers properly (see text) to avoid a visible deformity. (From Toriumi DM, Becker DG. *Rhinoplasty Dissection Manual*. Philadelphia: Lippincott Williams & Wilkins; 1999. With permission.)

THE NASAL VAULT (MIDDLE AND UPPER NASAL THIRDS)

General Considerations

The aesthetic importance of the nasal profile and the tip–supratip relationship makes profile reduction a critical step in rhinoplasty. Overreduction of the bony component may lead to a flattened appearance that simulates pseudohypertelorism. Overreduction of the bony and cartilaginous nasal vault results in an overly concave, operated appearance. Overreduction may lead to iatrogenic *saddle-nose deformity*. While undertaking profile reduction, great care must be taken to preserve support of the middle nasal vault; failure to do so can lead to complications such as *nasal valve collapse* and *inverted-V deformity*.[2,7,9]

Prevention of over- or underresection requires knowledge of skin thickness and the anatomical contributions of bone and cartilage to the nasal dorsum. The bony contribution of the nasal dorsum is less than that of the cartilaginous structures; great care must be taken in the resection of each component. The skin/soft tissue envelope is thicker over the nasofrontal angle and the supratip region and thinnest over the rhinion. Less hump is taken at the rhinion to accommodate this.

Underreduction leads to a persistent deformity. Underreduction may not only leave a persistent dorsal hump but may also create a supratip prominence or pollybeak, or, alternatively, an unsightly prominence at the upper nasal third. Nevertheless, this deformity is preferable to overreduction because it is easier to correct the underreduction secondarily when indicated.

Asymmetrical resection may lead to an unsightly appearance. Correction of this deformity is challenging. This may be accomplished with onlay grafts, either through a precise pocket placement or via an external rhinoplasty approach.

Specific Complications of the Nasal Vault

Saddle Nose

Saddle nose refers to the appearance of the nose after loss of support of the nasal vault with subsequent collapse (Fig. 39–5). This deformity has been described after overresection of the septum, with failure to preserve an adequate L strut. A minimum of 15 mm of cartilage is recommended as a rule of thumb; if a dorsal hump resection is also planned, this must be accounted for in planning adequate L strut for nasal support. Other causes of saddle-nose deformity include septal hematoma, septal abscess, and severe nasal trauma. Excessive dorsal hump resection also leads to saddle-nose deformity.

Onlay grafting can effectively camouflage and correct mild and moderate saddle deformities. Septal or auricular cartilage in single or multiple layers is commonly used effectively.[20,21] Severe saddle-nose deformity may require major reconstruction with cantilevered cartilage or bone grafts.[22–24]

Inverted-V Deformity

In inverted-V deformity, the caudal edges of the nasal bones are visible in broad relief (Fig. 39–5). Inadequate support of the upper lateral cartilages after dorsal hump removal can lead to inferomedial collapse of the upper lateral cartilages and an inverted-V deformity.[25] Inadequate infracture of the nasal bones is another significant cause of inverted-V deformity.

When executing hump excision, it is helpful to preserve the underlying nasal mucoperichondrium (extramucosal dissection), which provides support to the upper lateral cartilages and helps decrease the risk of inferomedial collapse of the upper lateral cartilages after hump excision. When

Figure 39–5 Patient with large septal perforation, loss of cartilaginous nasal support, and subsequent severe saddle-nose deformity. On frontal view the caudal aspect of the patient's nasal bones is visible in broad relief, demonstrating the inverted-V deformity.

undertaking osteotomies after hump excision, appropriate infracture and narrowing of the bony vault must be achieved.

Nasal Valve Collapse

The internal nasal valve is bounded by the caudal margin of the upper lateral cartilage and the septum. The external nasal valve refers to the area delineated by the cutaneous and skeletal support of the mobile alar wall, anterior to the internal nasal valve.[30] Excessive narrowness or flaccidity in either of these locations may cause nasal obstruction. Weakness at either of these locations may result in collapse with the negative pressure of inspiration, resulting in nasal airway obstruction. Nasal valve collapse is seen most often as a sequela of overresection of lateral crura or middle vault collapse. Overaggressive resection of the lateral crura and the subsequent postoperative soft tissue contraction frequently leads to nasal valve compromise. Failure to maintain proper middle vault support may lead to inferomedial collapse of the upper lateral cartilages, with internal nasal valve compromise.

Treatment of internal nasal valve collapse may include the use of spreader grafts. Spreader grafts act as a spacer between the upper lateral cartilage and septum, correcting an overly narrow middle vault and internal nasal valve, or preventing excessive narrowing when undertaking a rhinoplasty in the high-risk patient.[25–30]

Careful preoperative analysis should determine the need for other supportive and reconstructive maneuvers, such as conchal cartilage grafts to restore support to a collapsed lateral nasal wall. Alar batten grafts, typically of curved septal or auricular cartilage, placed to support the alar rim can correct internal or external nasal valve collapse (Fig. 39–6).[25–30]

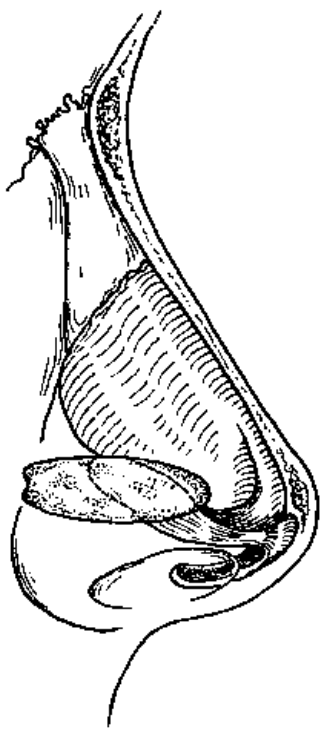

Figure 39–6 Alar batten grafts may be used to treat nasal valve collapse. (From Toriumi DM, Becker DG. *Rhinoplasty Dissection Manual*. Philadelphia: Lippincott Williams & Wilkins; 1999. With permission.)

Deviated Nose

Persisting deviation after rhinoplasty may occur at the upper third, middle third, or tip of the nose, or may occur postoperatively in a previously straight nose. Preoperative anatomical diagnosis is a critical component of successful treatment. Persisting deviation of the nasal bones may occur due to greenstick fractures or other problems with osteotomies.[31,32] Inherent deviations in the cartilage of the middle nasal vault may prove especially challenging.[33] Also, hump removal may uncover asymmetries that result in postoperative deviation where none existed previously. Tip asymmetry may be overlooked preoperatively, or it may be due to asymmetrical excision of lateral crura, asymmetrical placement of a columellar strut, or placement of an overlong columellar strut, as well as other causes. A number of surgical maneuvers are available to address the deviated nose.[25,31–33]

UPPER THIRD OF THE NOSE

Specific Complications

Rocker Deformity

If osteotomies are taken too high (into the thick frontal bone) the superior aspect of the osteotomized nasal bone may project or "rock" laterally when the bone is infractured. This is a "rocker" deformity. A 2-mm osteotome may be employed percutaneously to create a more appropriate superior fracture line and thus correct the rocker deformity.[31]

Dorsal Irregularities

After creation of an "open roof" by hump removal, the bony margins should be smoothed with a rasp. Any bony fragments should be removed, with care taken to ensure that all obvious particles are removed from under the skin/soft tissue envelope. Failure to remove all fragments may lead to a visible and/or palpable dorsal irregularity.

Bony dorsal irregularities are a well-recognized complication of rhinoplasty. In the search for an approach that could reliably assure a smoother contour without sharp edges, irregularities, or asymmetries, surgeons have reported on the use of various onlay grafts, including homograft sclera,[34] gelatin film,[35] temporoparietal fascia,[36] and superficial musculo-aponeurotic system (SMAS).[37] Becker et al[38] have described the use of a powered drill or rasp, which they thought might decrease the incidence of dorsal irregularities. The multiple proposals in the literature on this subject may suggest the lack of a completely satisfactory solution.

"Open-Roof" Deformity

After hump removal, the free edges of the nasal bones are palpable beneath the skin/soft tissue envelope. Failure to perform lateral osteotomy, or inadequate osteotomy, results in an open-roof deformity. Lateral osteotomies are typically undertaken to "close" the open roof.

Greenstick Fracture

Incomplete fracture of the nasal bones after osteotomy, also known as greenstick fracture, may lead to the recurrence of a deformity (such as nasal deviation) due to "memory" and "spring" in the nasal bone. While this may be acceptable in certain patients, such as an elderly rhinoplasty patient with thin, brittle bones, greenstick fractures commonly lead to recurrence of a preoperative nasal bony deformity.

SKIN/SOFT TISSUE ENVELOPE

The skin/soft tissue envelope has well-defined tissue planes in which avascular dissection may be undertaken. Operating in more superficial planes not only leads to a bloody surgical field but also risks damage to the vascular supply with potential damage to the skin. Once the skin/soft tissue envelope is damaged, it can never be fully restored. The damaged skin creates an aesthetically displeasing appearance.[39]

Vascular supply and lymphatics are found superficial to the nasal musculature.[40] The soft-tissue layers in the nose are epidermis, dermis, subcutaneous [this plane contains blood vessels and lymphatics, and also a (typically) thin layer of fat], muscle and fascia (musculoaponeurotic) plane, areolar tissue plane, and perichondrium/periosteum. Dissection during rhinoplasty in the proper tissue planes (areolar tissue plane, i.e., submusculoaponeurotic) preserves nasal blood supply and minimizes postoperative edema.

Use of alloplastic implants risks skin complications. The nose fulfills few of the requirements for use of alloplastic materials. If the alloplast extrudes through the skin, the skin–soft tissue envelope is permanently and irreparably damaged.

Infection of the skin/soft tissue envelope is a rare complication of septorhinoplasty. Nevertheless, cellulitis characterized by erythema, edema, and pain is a potential risk that must be identified and treated promptly. If oral antibiotics are not quickly effective, intravenous antibiotics must be used to quickly control this rare but potentially serious complication. Nasal culture may guide therapy in difficult cases.[39]

FUNCTIONAL COMPLICATIONS OF SURGERY

The list of possible functional complications can be exhaustive. Note must be made of possibly serious complications.[41,42] Intracranial complications may occur in association with septal surgery, as the perpendicular plate of the ethmoid has an attachment superiorly in the floor of the cranial cavity. Great care must be taken, particularly in the elderly, to avoid avulsing ethmoid bone and creating a fracture with cerebrospinal fluid leak. Other functional complications of septoplasty and septorhinoplasty include septal perforation, toxic shock syndrome, septal hematoma, and abscess.

Airway complications merit a chapter in themselves. In brief, the surgeon must take a careful history to recognize medical causes of obstruction, such as allergy, sinusitis, or medication misuse (rhinitis medicamentosa).

It is critical that rhinoplasty maintain or improve the nasal airway. Failure to preserve nasal airway function can be crippling. The causes of nasal airway obstruction must be identified and addressed. Conservatism must be emphasized; for example, overresection of turbinates can lead to atrophic rhinitis, which can be crippling. Overnarrowing of the bony pyramid, with failure to preserve the airway at the nasal valve, can also lead to nasal obstruction.[43] Overresection of the lateral crus can lead to aesthetic complications that are often accompanied by nasal valve collapse and breathing problems.

CONCLUSION

An overview of rhinoplasty complications addresses the prevention, diagnosis, and management of common complications of rhinoplasty. Careful preoperative diagnosis and a conservative approach guided by an understanding of the postoperative changes that occur during healing are critical in minimizing complications. These principles are also essential in the treatment of complications when they occur.

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Chapter 40

Reconstructive Surgery of the Nasal Septum

Jan L. Kasperbauer, George W. Facer, and Eugene B. Kern

The deviated nasal septum has been addressed in multiple fashions in the past and currently. Prominent nineteenth-century rhinologists, including Bosworth, Roe, Watson, Gleason, Asch, and Douglas, utilized a variety of techniques to address nasal septal deformities.[1] The most common approach was that of Bosworth,[2] which employed a saw to remove the deformity and preserved one side of the septal mucosa. Septal perforation was a common complication. Watson[3] described an early septoplasty technique with preservation of mucosa, and Asch[4] introduced cartilage modification techniques. The twentieth century in rhinology opened with the development of the submucous resection technique. Freer[5] and Killian[6] introduced the concept of submucous resection, which allowed relief from a septal obstruction without sacrifice of mucosa. Briefly, an incision is made in the respiratory mucosa 1.5 to 2 cm behind the columella. The incision is carried through the cartilage, and subsequent elevation of mucoperichondrium in a posterior direction on each side of the septum allows removal of obstructive septal structures (Fig. 40–1). Closure is accomplished by mattress stitch approximating mucoperichondrium. Precepts associated with the submucous resection dictate preservation of a dorsal caudal strut of approximately 1 cm of cartilaginous septum. Although the submucous resection was a significant advancement, several shortcomings were noted (Table 40–1), with a significant problem involving the inability to address caudal end deformities. Metzenbaum[7] and others[8–12] proposed alternative methods for addressing management of caudal end deformities.

Modern reconstruction surgery of the nasal septum is based on principles forwarded by Maurice Cottle[13] and provides a method to address the nasal septum in a comprehensive fashion. When compared to the submucous resection, the incision is placed through skin (i.e., stratified squamous epithelium rather than respiratory mucosa) and is located at the distal end of the quadrangular cartilage. This subsequently allows access to all borders of the bony and cartilaginous septum (Fig. 40–2). Cottle termed this the *maxilla–premaxilla approach*.[14] Basic principles formulated with this approach include preservation of mucosa, repair of mucosal tears experienced during the dissection, avoidance of circumferential incisions, and replacement of bony and cartilaginous fragments to reconstruct the septum. This is the approach favored by the authors and described in some detail subsequently. The major advantages are significant and

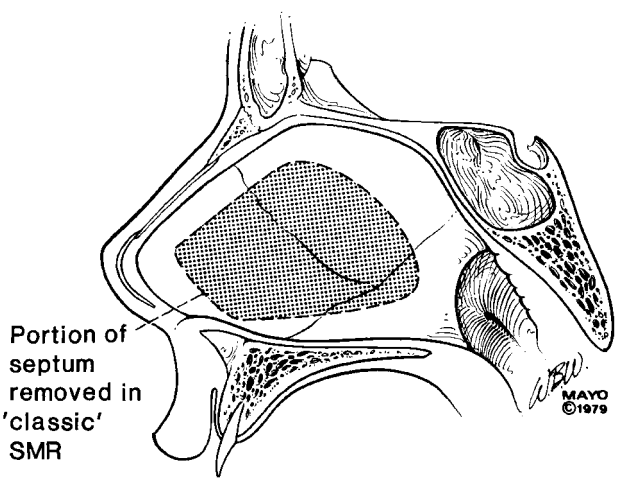

Figure 40–1 Shaded area represents the portions of the nasal septum that can be approached by submucous resection.

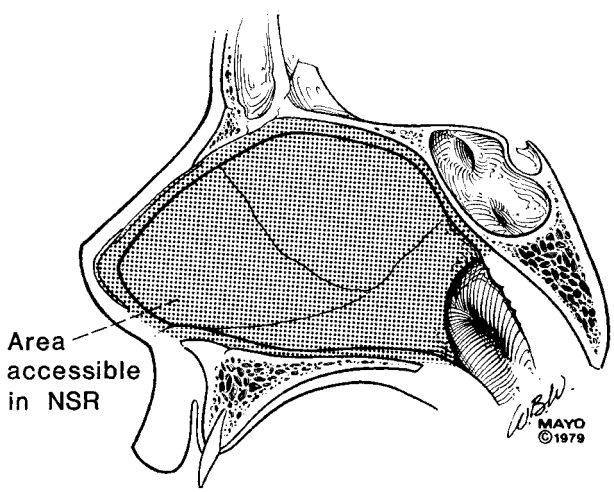

Figure 40–2 Structures of the nasal septum and upper lateral cartilage that can be approached by the nasal septal reconstruction concept using the maxillar–premaxilla approach. The shaded area represents the portions of the entire septum that can be exposed by this method.

TABLE 40–1 Limitations of the Submucous Resection

- Caudal end deformities are not addressed.
- Access to the premaxilla and nasal spine is limited.
- Convexities of the nasal valve area are not addressed.
- Submucous resection is not applicable to children.
- Revision surgery is more difficult due to lack of cartilage or bone.

include mobilization of the entire septum when necessary and preservation or replacement of the caudal septum. Realistically, practicing rhinologists use their knowledge of both procedures when operating on nasal septal deformities. Rhinologic innovation in the late twentieth century included endoscopic approaches to paranasal sinus disease and, subsequently, endoscopic septoplasty.[15] In this situation, endoscopic equipment in use for paranasal sinus surgery is utilized to complete a submucous resection of limited septal deformities. This technique promotes teaching when video monitors are used, avoids the use of a headlight, and minimizes mucoperichondrial flap dissection.

Obviously, nasal septal surgery has evolved as knowledge of the anatomy, physiology, and pathophysiology of the nose has developed. Rhinomanometry has significantly advanced the understanding of nasal physiology and pathophysiology while providing objective pre- and posttherapy data.[16] This information has led to a confirmation of the importance of the anterior septum, nasal valve area, and mucosa (turbinates) in nasal respiration,[17,18] regulating air flow and mass transfer.[19] The structures in the nasal valve area (valve angle, septum, anterior inferior turbinate, and anterior floor of nose) require careful investigation. This dynamic area requires a straight, stable septum and an appropriately flexible upper lateral cartilage that provides variable resistance, such as a Starling resistor.[20] Thus, combined with the maxilla–premaxilla approach, rhinomanometry and an understanding of nasal physiology allow the rhinologic surgeon to selectively address septal, mucosal (turbinates), and nasal valve pathologies, thereby improving patient care.

The most common application of the maxilla–premaxilla approach is in addressing septal deformities, which result in airway obstruction. The true flexibility and potential wide exposure of this approach enable incorporation with open and closed rhinoplasties and utilization as a method of midline exposure of the sphenoid sinus (e.g., transseptal transsphenoidal pituitary surgery). In addition, this approach allows mobilization of the septum to allow adequate exposure of the lateral wall of the nose when septal deviations limit exposure to the ethmoids. The least common application of the maxilla–premaxilla approach is to reduce septal deformities associated with face pain.

PREOPERATIVE ASSESSMENT

Patients with disturbed nasal physiology require a complete history, a careful clinical examination, laboratory tests, and a frank discussion prior to surgical intervention. The nose plays a key role in active breathing and ultimately in oxygen and carbon dioxide exchange at the alveoli (respiration). Disturbances of respiration can have far-reaching somatic and psychological effects. A major diagnostic goal is to determine whether the patient's disturbed physiology is related primarily to a mucosal disturbance, a structural abnormality, or both. If the history suggests a mucosal component to the patient's complaints, then appropriate medical therapy should be initiated and improvement evaluated following an adequate therapeutic trial prior to addressing structural abnormalities. The key elements sought in the history are the symptoms of allergic and nonallergic rhinitis, chronic and acute sinusitis, topical nasal decongestant abuse, use of hypertensive medications, and a history of hypothyroidism or pregnancy. These are but a few of the causes of mucosal abnormalities that can produce disturbed nasal physiology and nasal symptoms.

In addressing structural abnormalities that may be associated with disturbed air flow or abnormalities of mass transfer, it is important to assess the location of the septum and its upper lateral cartilaginous extensions well as the structure and position of the lower lateral cartilage, the nasal valve area, and the lateral nasal wall (especially the head of the inferior turbinate) (Fig. 40–3). Historical points that may be significant include a history of congenital abnormalities predisposing to structural defects, such as a cleft lip or cleft palate deformity, Binder's syndrome, or septal trauma with dislocation. Inflammatory diseases, which may produce structural abnormalities, include Wegener's granulomatosis, sarcoidosis, and syphilis. A history of trauma is common but important to note, as is a prior history of rhinologic surgery. Certainly, the history suggestive of any neoplastic process is important to note preoperatively, as is a history of sleep apnea. Keep in mind that patients with atrophic rhinitis may present with a complaint of nasal obstruction, and patients with overzealous turbinate surgery seem to present with complaints related to abnormalities in mass transfer (dry, crusted, congested nose; bleeding and pain may be part of the clinical picture).

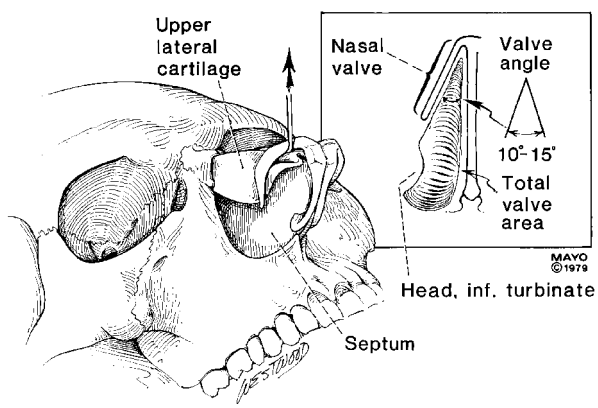

Figure 40–3 The nasal valve area is bounded by nasal septum, caudal end of upper lateral cartilage, soft fibrofatty tissue overlying pyriform aperture and floor of nose, and posteriorly by the head of the inferior turbinate. This area is shaped like an inverted cone or teardrop, the slitlike apex of which is the nasal valve angle and normally subtends an angle of 10 to 15 degrees.

Examination of the patient's nose should then be correlated with the historical facts. The rhinologic exam should include notation of any external deformities. The caudal end, including the valve area, must be carefully evaluated, as this is the most common site of symptomatic septal deformities. This may require trimming of the vibrissae and utilization of either a pediatric nasal speculum or a four-pronged retractor to allow visualization of the vestibule and nasal valve area with minimal distortion. The position of the septum should be evaluated in relationship to the lower lateral cartilage, the nasal spine, the premaxilla, and the remainder of the nasal valve area. As depicted in Fig. 40–3, the normal valve angle is 10 to 15 degrees. This examination should be done prior to and following decongestion. After a thorough visualization of the nasal cavity, it is often beneficial to use a rigid or a flexible endoscope to further assess the mid- and posterior portions of the nasal cavity. This can be easily done following topical application of 1% phenylephrine hydrochloride (Neo-Synephrine). Midseptal deformities can frequently be noted and generally are asymptomatic from an obstructive standpoint; however, they may present with a history of facial pain or a predisposition to recurrent sinusitis.

Sensitive, specific, cost-effective, and reliable tests of nasal function would ideally quantify abnormal nasal physiology and confirm response to treatments. Today the documentation of many nasal functions remains elusive or impractical for most facial plastic or rhinologic surgeons. Pertinent to nasal septal surgery, measures of respiratory and olfactory function are available but problematical. The tools readily available for the measurement of olfaction include the University of Pennsylvania Smell Identification Test (UPSIT) and commercially available odorants used in an individualized fashion. Threshold detection testing is complex, time consuming, not readily available, and not considered further in this review. The UPSIT is an easily administered forced-choice test based on microfragrance samples from the 3M Company (St. Paul, Minnesota). The test consists of scratch-and-sniff methods of odorant presentation and interpretation based on data from a large number of individuals with "normal" olfactory function. Results from the UPSIT are scored from 0 to 40, with higher scores representing greater olfactory function. Tables are provided that allow scoring of an individual's result as a percentile of the normal population. Scores can also be categorized into normosmia, microsmia (decreased but not anosmic), total anosmia, and probable malingering. It is difficult to interpret results at age extremes in part due to the sample size and score variability in the normal population studied. Currently this kit is available from Sensonics, Inc. (Haddonfield, NJ).

The utility of olfactory testing is easily recognized when a patient who has had nasal surgery presents with the complaint of decreased olfactory function. Mechanisms responsible for olfactory injury from nasal surgery include direct trauma to the olfactory epithelium, traction on the olfactory nerve due to cribriform plate motion, vascular compromise of the olfactory neuroepithelium during surgery, drug effects, atrophic rhinitis due to excessive removal of intranasal tissue, mucosal edema due to or exacerbated by surgical trauma preventing odorant access to the neuroepithelium and idiopathic development of anosmia in the postoperative period. Kimmelman[21] utilized the UPSIT to study 93 patients before and after nasal surgery to identify the risk to olfaction. Thirty-four percent of patients scored lower on the UPSIT postoperatively, with a mean decline of 2.25 correct responses resulting in a decline in percentile rank of 25 percentile points. In the group of patients studied, 1.1% developed total anosmia postoperatively and 66% either improved or were unchanged.

Olfactory testing is not routinely performed for patients undergoing nasal and paranasal sinus surgery because it adds time and cost. However, the utility of routine olfactory testing becomes clear when the surgeon is faced with a disturbed patient who reports altered olfaction following nasal surgery.

Rhinomanometry provides objective information regarding the respiratory function of the nasal airway. Rhinomanometry quantifies nasal air flow and pressure, allowing calculation of airway resistance. Three methods exist to measure air flow based on the location of the pressure catheter. Anterior rhinomanometry relies on a catheter placed in a sealed nasal vestibule to measure pressure changes in the opposite side of the nose. Posterior rhinomanometry involves peroral placement of a catheter in the oropharynx, which allows both sides of the nose to be measured simultaneously. Pernasal rhinomanometry requires passing a pressure catheter transnasally to the nasopharynx. This is similar to posterior rhinomanometry, which provides simultaneous measurement of flow and pressure from both sides of the nose. In each method, the patient either wears a mask or is in a chamber that allows measurement of pressure and air flow changes related to breathing. Posterior rhinomanometry requires the greatest degree of patient education and has the highest rate of test failure. Pernasal rhinomanometry causes some irritation with the catheter placement but provides the most consistent results.[22] Anterior mask rhinomanometry is the most common method because it requires the least patient cooperation and has the least complicated equipment.

Data gained from rhinomanometry include the simultaneous pressure and flow of nasal respiration, which are nonlinear during the respiratory cycle. Although a variety of results can be computed, nasal resistance (pressure/flow) is most commonly reported. However, resistance varies at different points on the pressure–flow curve due to the nonlinear relationship. A consistent point on the pressure–flow curve must be selected to allow comparison between tests in the same patient as well as among patients. It is important to report the nasal resistance at a given pressure (150 Pa)[23] and at a given radius.[24] Additional parameters that can be reported include maximal nasal resistance[25] and mean resistance.[26] Both maximal and mean resistance can be calculated for all patients, which is advantageous over measuring resistance at set points along the pressure–flow curve because some patients require a voluntary increase in ventilation to reach these points. The challenge for any data gathered from rhinomanometry is variability as well as correlation with clinical symptoms. Some variability is due to nasal sources and includes variable mucosal congestion from exercise, postural changes, pressure applied to certain body areas, nasal secretions, and the nasal cycle. Medications, height, anthropologic type, and age may also induce variability. Methodologic sources of variability include mask leakage, equipment repositioning, and inadequate equipment warm-up. Factors that minimize variability include symmetrical patient sitting position, avoiding exercise 30 minutes prior to testing, consistent temperature and humidity, avoidance of medications prior to testing, and alleviation of patient anxiety by appropriate explanation of the testing procedure.[27]

Acoustic rhinomanometry is a method of measuring the cross-sectional area of the nasal cavity as a function of distance from the nostril. This technique requires a sound generator, wave tube, microphone, nosepiece, and computer. The sound generator produces an acoustic signal (pulsed or continuous) that travels down the wave tube into the measured object. The sound waves are partially reflected by narrowings in the measured object, thereby representing a change in the cross-sectional area. A microphone measures the transmitted and reflected sound, which is digitized with reconstruction of the impedance and area profile plotted as a function of area versus distance. These calculations are based on several assumptions. First, the measured object is a series of cylinders of the same length. Second, there is an infinite signal–to–noise ratio. And third, significant wall inertia exists. All of the above assumptions can contribute to inaccuracies in the measurement of cross-sectional areas. Despite these limitations, accurate measurements can be obtained and have been confirmed by a variety of models.[28] A critical portion of the apparatus to measure acoustic rhinomanometry is the nosepiece. The nosepiece must form an acoustic seal with the wave tube and nose yet not distort the nasal tip/valve region. Nosepieces of different shapes and materials yield different data values when the same object is measured. It is best to use nosepieces of the same material and that are anatomically conformed to obtain accurate measurements.

The results from acoustic rhinomanometry represent the cross-sectional area (cm^2) of the nasal cavity as a function of distance (cm) from the end of the nosepiece. The data from acoustic rhinomanometry in normal individuals can vary with race, craniofacial development, mucosal variations, environmental conditions, and skeletal variations. Data from acoustic rhinomanometry reveals an initial decrease in cross-sectional area related to the narrowing in the region of the nasal valve followed by a subsequent narrowing due to the anterior head of the inferior turbinate. These constrictions are typically noted at approximately 1.3 and 3.6 cm from the nosepiece. The cross-sectional area distal to the head of the inferior turbinate gradually increases to the region of the nasopharynx. Acoustic rhinomanometry should be performed with the patient in a comfortable, symmetrical sitting position before and after decongestion. Several studies have reported the results on normal individuals and patients with allergic rhinitis, vasomotor rhinitis, and patients before and after septal surgery.[29–31]

Although acoustic rhinomanometry provides data on the cross-sectional area of the nasal cavity, it does not detail the shape of the airway. Therefore, acoustic rhinomanometry cannot provide information on nasal airway resistance. Rhinomanometry determines overall nasal patency but cannot provide information about the geometry of the airway. One can conclude that these are complementary methods of investigating key elements of the nasal airway. The utility of rhinomanometry and acoustic rhinomanometry is limited by the potential need for both studies, equipment-related expense, lack of reimbursement, and test variability. Routine use cannot be mandated, but the benefits are realized in the context of complex procedures or potentially litigious patients.

The final aspect of the preoperative assessment consists of discussing the findings of the history, physical examination, and laboratory studies, including the etiology of the disturbed nasal physiology and the planned therapeutic approach. This includes a frank discussion regarding alternative therapies, potential complications, an estimate of the likelihood of success, and, if surgery is required, postoperative recovery time and possible reoperation.

SURGICAL TECHNIQUE

The outlined approach to reconstructive surgery of the nasal septum is based on the following precepts and concepts. First, the goal of surgery is to remove pathology and reconstruct the abnormal septal parts into normal position so that normal physiologic airway function can take place. Second, the aim of the incisions and subsequent dissection is to completely expose the pathologic septal structures. Third, the mucosal lining is the valuable organ of the nose where the defense and biochemical reactions occur and incisions should be in the skin to preserve the integrity of the mucosa. Fourth, the goal of surgery is to help relieve the patient of symptoms that distort his or her well-being.

Positioning on the operating table for nasal surgery should provide comfort for both the patient and the surgeon. The patient should be placed on a well-padded table or chair (dental flexible chair) as close to the right side of the table as possible to minimize the distance the surgeon must reach to address the nose. A semi-Fowler's position is frequently used to aid in patient comfort. Two power surgical loops are very helpful in the performance of this delicate surgery.

Nasal septal surgery can be performed under either general anesthesia or local anesthesia with intravenous sedation. Premedication should include analgesics and sedatives. In either situation the nose is infiltrated with a solution containing epinephrine. The concentration of epinephrine varies; in general, a concentration of 1:100,000 is safe. The solution should be injected in the areas to be approached surgically and additionally focused in areas of incisions and vascular areas. Therefore, areas that are generally infiltrated include that of the hemitransfixion incision between the medial crura, the region of the incisive foramen, the heads of the inferior and middle turbinate (to allow decongestion and increased visualization of the nose), and the region between the upper and lateral cartilage and lower lateral cartilage near the intercartilaginous incision. The external cartilaginous and bony pyramid of the nose is also anesthetized at a similar time. Frequently, 5 cm^3 is adequate to accomplish this. It is often advisable, especially under local anesthesia with intravenous sedation, to first spray the nose and vasoconstrict with 1% phenylephrine hydrochloride and then topically anesthetize the nose by spraying two or three puffs of 4% lidocaine. Subsequent application of approximately 100 to 150 mg of cocaine flakes on cotton carriers directly to the region of the anterior ethmoid nerves and sphenopalatine ganglion provides excellent anesthesia. Halothane, enflurane, and isoflurane are commonly used inhalation anesthetics. These agents and cocaine sensitize the myocardium to the actions of the sympathomimetics.[27] Therefore, the combination of these agents with the infiltration of an epinephrine containing solution requires careful cardiac monitoring and minimal dosages of cocaine and epinephrine.[32]

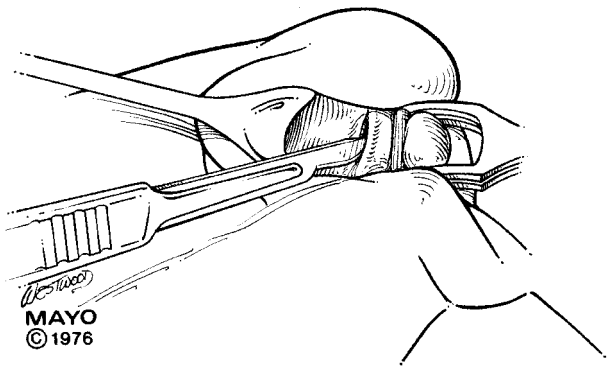

Figure 40–4 A right-handed surgeon holds a Cottle columellar clamp in the left hand and the assistant holds an alar protector. After a columellar clamp has been applied to identify the caudal end of the septum, a right hemitransfixion incision is made about 1 to 2 mm behind the caudal end of the nasal septum with a no. 15 blade.

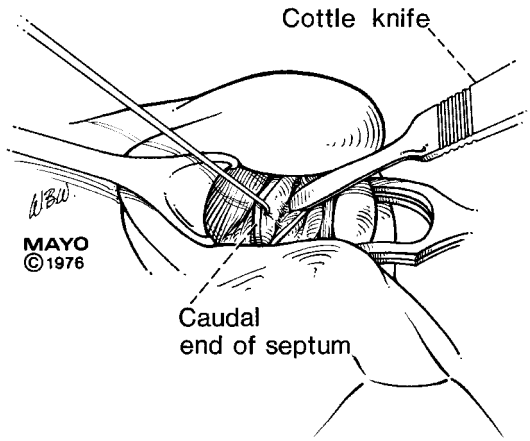

Figure 40–5 Through the right hemitransfixion incision, the quadrangular septal cartilage is retracted to the right with a hook, and the Cottle knife is used to begin the dissection beneath the mucoperichondrium of the septal cartilage.

The opening incision for septal surgery is the right hemitransfixion incision (Fig. 40–4). The hemitransfixion incision extends from the anterior part of the caudal end of the septum to the area just anterior to the nasal spine. This incision parallels the caudal end of the septum in the skin. Instruments used to expose the caudal septum and identify the caudal end of the septum include a Cottle clamp and an alar protector. For a more advanced surgeon, a nasal speculum may be all that is required. After the caudal end of the cartilaginous septum is isolated, the elevation of the mucoperiosteum from the left side of the septum or left anterior tunnel is begun (Fig. 40–5). It is important to obtain a dissection plane between the cartilage and perichondrium to maintain the vascular supply to the perichondrium. Several instruments are helpful in this dissection. Selection varies on the history of previous surgery and the particular deformity encountered. When the plane is clearly identified elevation of the mucoperichondrium proceeds quickly, with an appropriate length nasal speculum providing retraction onto the mucoperichondrium as well as visualization of the area where the mucoperichondrium is still attached to the septum (Fig. 40–6). With adequate vasoconstriction, anesthesia, hypotension, and dissection in the correct plane below the perichondrium, bleeding is usually not a significant problem and blood loss is minimal. A Cottle dissector is an excellent instrument to effect elevation of the perichondrial flap away from the septal skeleton. This technique works for the majority of the anterior septum as well as the posterior septum after the bony cartilaginous junction has been passed. The ligamentous attachments of the inferior septum to the spine and premaxilla are somewhat thick and the mucosa tenuous because it is frequently here that a deviation is present, requiring careful dissection to maintain continuity of the mucoperichondrial flap.

SPECIFIC PROBLEMS

Transverse Anterior Septum

A nose that has had significant trauma may have a deformity of the anterior septum being nearly transverse, with a fracture line in the cartilage extending from the spine superiorly to the "K" area formed by the junction of the upper lateral cartilage and nasal bones. This results in a particularly unstable caudal end of the septum when the subsequent deflections are removed or reduced. In situations where this results in lack

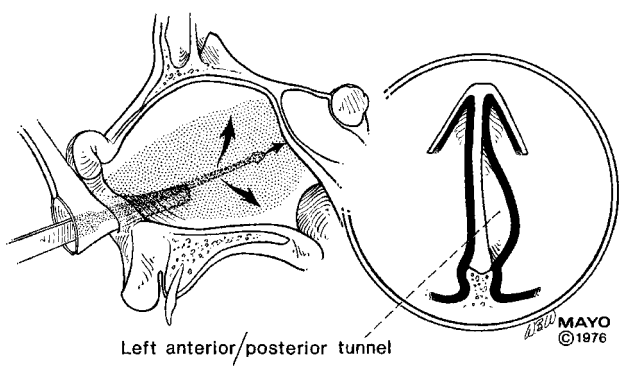

Figure 40–6 As the dissection continues, the left anterior tunnel becomes a left anterior/posterior tunnel, with elevation of the mucoperiosteum of the perpendicular plate of the ethmoid bone and the vomer in the posterior portion of the nose. Following placement of a nasal speculum through the hemitransfixion incision into the left anterior tunnel, a Cottle elevator is used to continue mucoperichondrial and mucoperiosteal elevation back to the face of the sphenoid.

of adequate support for the tip or a concern about maintenance of a correct position for airway patency, the anterior septum may require removal and subsequent reconstruction with an autogenous (cartilage or bone) material. In this situation, it is helpful if the posterior bony septum is intact to allow harvesting of a large piece of septal skeleton that can subsequently be shaped to replace the anterior cartilaginous septum. It is frequently helpful in this situation to use the caudal end as a template to size the height of the graft, which will be placed in the caudal end. The bone is subsequently shaped to resemble the cartilaginous caudal end and a small pocket created anterior to the hemitransfixion incision between the medial crura with the implant subsequently placed using 4-0 chromic guide sutures on a Keith needle (Fig. 40–7).

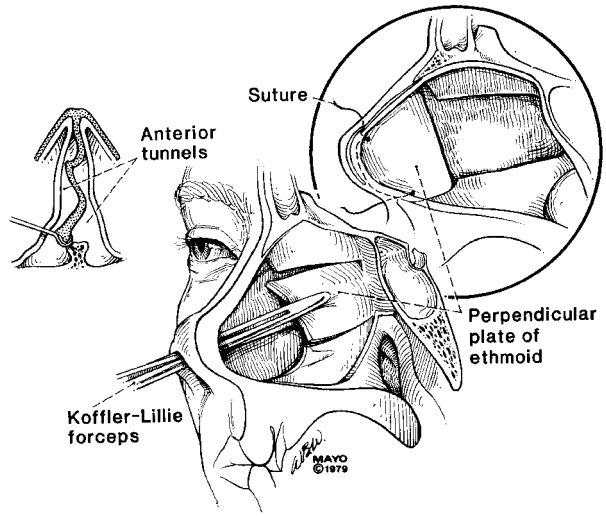

Figure 40–7 Bilateral anterior and posterior tunnels have been created to allow removal and replacement of deformed caudal end of septum with autogenous bone graft from perpendicular plate of ethmoid.

Broad Deviated Premaxillary Crest

A common finding in septal deformities is that the deformity includes a broad and frequently asymmetric premaxillary wing or crest. As in other areas of septal surgery, exposing the underlying structures while maintaining mucoperichondrial integrity is helpful. Two approaches to this problem may be applicable. If the deformity is located anteriorly, a plane of dissection adjacent to bone can often be found posteriorly; subsequently, careful dissection anteriorly with concomitant dislocation of the cartilaginous septum to the opposite side is frequently successful in exposing this region. This allows removal of the deviated premaxillary crest by using a chisel, heavy scissors, or a rongeur. A second approach to this problem involves identifying the nasal spine and pyriform aperture with subsequent elevation of the mucoperiosteum from the floor of the nose and onto the premaxillary crest. This inferior tunnel is connected to the anterior tunnel adjacent to the septum, allowing direct visualization and removal of the bony deformity (Fig. 40–8).

Large Posterior Septal Spur

Frequently, patients with septal deformities have as part of their abnormality a large sharp septal deformity in the mid- or posterior septal region. This may be associated with intermittent face pain and possibly recurrent sinusitis. The approach favored by the authors is extension of the submucoperichondrial dissection on each side of the septum to the

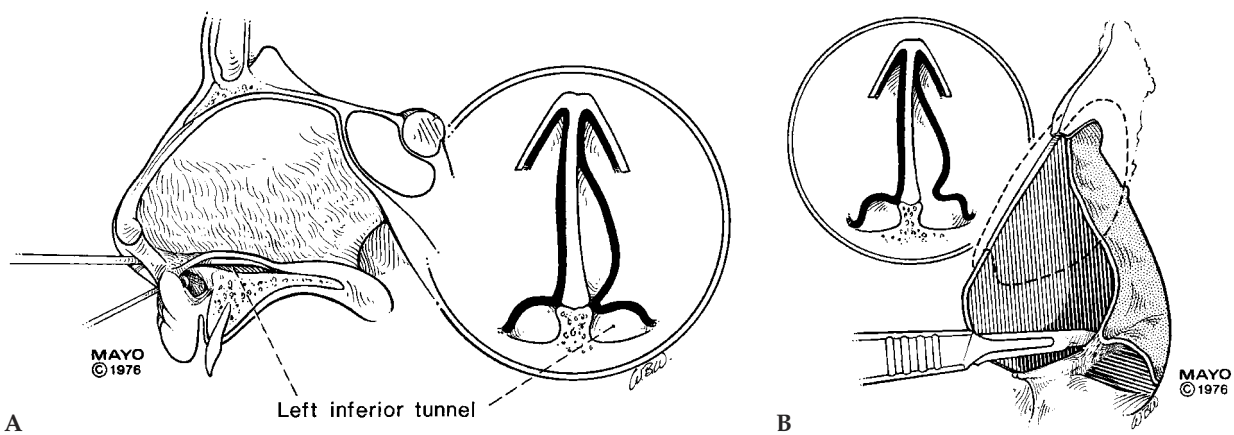

Figure 40–8 Development of a left inferior tunnel. The crest of the pyriform aperture is identified, and a curved Cottle elevator is used to elevate mucosa along the floor of the nose on the left. Three tunnels have now been developed; a left anterior/posterior, a right inferior, and a left inferior. The joining of the left anterior and left inferior tunnels by sharp dissection of the fibrous tissue that binds the mucosa in this area to the crest of the premaxilla. Care is taken not to perforate the mucosa.

anterior margin of the spur and beyond the spur on the side opposite the spur. A similar dissection is performed inferior to the spur, if possible. The bony margins above and below the spur are freed by a bone scissors or an ostetome, and the spur is dissected from the mucosa. In the unusual situation in which a sharp posterior septal spur is the only deformity for which one is performing septal surgery, such as in the case of unilateral facial pain or sinusitis, then an incision just anterior to the spur with subsequent elevation of the mucosa in the region of the spur will allow removal with an osteotome.

Upper Lateral Cartilage Surgery

Surgery on the upper lateral cartilage is best carried out early in the operation, when the field is dry. Hemostasis and precision exposure are the keys to surgery of the upper lateral cartilage. This is probably best done after the septal surgery and before surgery on the tip and pyramid. The intercartilaginous incision is the most commonly used approach to the dorsum of the nose; yet, as pointed out by Anderson,[33] the cartilage-splitting incision (cutting through the lower lateral, i.e., alar or lobular, cartilage) can be used to modify both the dorsum of the nose and the lower lateral cartilages without violating the skin or mucosa of the nasal valve.

Because of the need for accurate surgical technique in this region, the details of technique will be described. Gray[34] deserves credit for first developing this exacting technique. The authors of this chapter favor the intercartilaginous incision in most instances because it affords the most direct approach to the upper lateral cartilage. This incision is made along the caudal end of the upper lateral cartilage from lateral to medial aspects, preferably with a no. 15 blade and with the aid of a four-pronged retractor and the middle finger of the left hand (if the operator is right-handed) (Fig. 40–9A). First, the skin is incised. Then the incision is carried to a depth of several millimeters to the intercartilaginous aponeurosis between the upper and lower lateral (alar or lobular) cartilages. If a hemitransfixion or full-transfixion incision was made for the septal surgery, care is taken not to join the intercartilaginous incision with these incisions; however, should these incisions be inadvertently or deliberately joined (for tip rotation), then accurate suture approximation is required to avoid excessive scarring at the nasal valve angle. The assistant places a weighted, single Joseph skin hook, 16 cm, into the upper lateral cartilage and retracts it downward, while the operator holds either a four-pronged retractor or another retractor to expose upper lateral cartilage in his left hand and holds cotton swabs or suction in his right hand for removal of blood from the field. A no. 66 Beaver knife blade is used to reach the perichondrium of the upper lateral cartilage. This technique not only exposes the upper lateral cartilage but prevents injury to the overlying canopy of neuromuscular and vascular structures (Fig. 40–9B). By this method, the upper lateral cartilage up to and over the nasal bones can be widely undermined in a relatively avascular plane. The upper lateral cartilage may be explored and exposed bilaterally, with minimal injury to any of these overlying structures. The undersurface of the upper lateral cartilage may be exposed, preserving the skin and mucosa, by careful use of the no. 66 Beaver knife blade or a sharp scissors (Fig. 40–9C). The caudal border of the upper lateral cartilage or the mucosa itself can be grasped with a 7-in., curved Gerald dressing forceps. Grasping of the skin or cartilage with a forceps facilitates dissection. Thus, the upper lateral cartilage is freed from the mucocutaneous coverings. The upper lateral cartilage may be evaluated after it has been precisely exposed and after abnormalities have been corrected in an attempt to restore a "normal" nasal valve with a normal nasal valve angle (Fig. 40–9D–F).

Thickening or twisting in this region can be adequately managed by resection. Gray[34] believes that some returning (also termed curling or scrolling) of the upper lateral cartilage may be a normal finding. Yet other workers, including Cottle (cited by Hinderer,[35] believe that returning is almost always a pathologic finding. "Physiologic" returning of the upper lateral cartilage affords some stiffness to resist collapse, whereas "pathologic" and "excessive" returning may interfere with the flexible-valve action of the upper lateral cartilage. In attempting to achieve a normal nasal valve angle and avoiding either increased rigidity or increased collapsibility, the surgeon can use his or her resourcefulness in reconstructing a normal nasal valve. Resection of the upper lateral cartilage (and lower lateral cartilage as part of tip surgery) should be conservative so as to avoid mobile inspiratory collapse. The amount of caudal end of upper lateral cartilage that should be removed is determined, as Hinderer[35] has pointed out, so as to maintain the relationship of the upper lateral cartilage to the caudal end of the septum. Thus, if the septum is being shortened by 2 to 4 mm, then resection of 2 to 4 mm from the caudal end of the upper lateral cartilage should be considered. The amount of the medial portion of upper lateral cartilage that should be removed is determined by resecting the amount needed to reconstruct a normal nasal valve angle of 10 to 15 degrees. Usually the removal of a medial triangular section of upper lateral cartilage (base of triangle is caudal and apex is cephalic) can open the nasal valve angle when the upper lateral cartilage is thickened, deflected, or twisted. In addition, when the valve angle is narrow it may be advantageous to trim the caudal end of the upper lateral cartilage and then to remove a medial triangle of the upper lateral cartilage.

After the medial triangle of upper lateral cartilage adjacent to the septum has been removed and the valve angle opened, several millimeters of the mucocutaneous tissue is separated from the septum (Fig. 40–9G), and a mucosal-relaxing incision is created that extends cephalad from the intercartilaginous incision in the valve apex. The tissue from the cephalic margin of the intercartilaginous incision can be flapped back and trimmed (Fig. 40–9H) and the intercartilaginous incision closed with 4-0 chromic catgut on a curved cutting needle (Ethicon 744) (Fig. 40–9I), thereby opening and widening the valve angle. The upper lateral cartilage is supported in a more dorsal position. Subsequent scar formation aids in maintaining a greater valve angle. We term this flap the *Lopez-Infante flap* because we learned about it from Dr. Fausto Lopez-Infante of Mexico City.

After surgery on the upper lateral cartilage, there are times when widening of the nasal valve angle cannot be satisfactorily accomplished by resection of a triangular portion of the upper lateral cartilage or by creation of the Lopez-Infante flap because of a congenitally narrowed nose or a previous rhinoplasty in which the upper lateral cartilage was

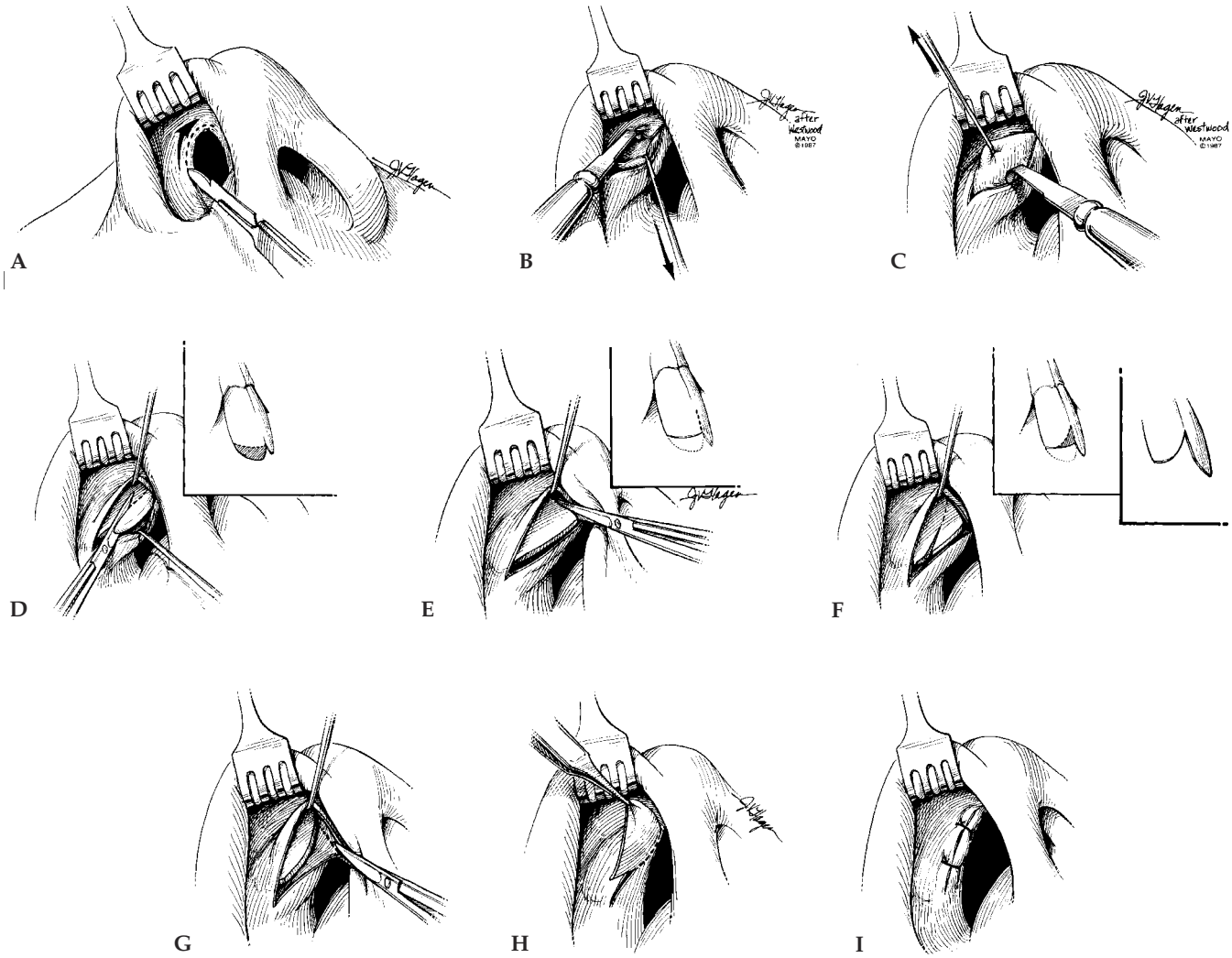

Figure 40–9 **(A)** Intercartilaginous incision with no. 15 blade carried just beneath the skin. **(B)** A weighted hook is applied to upper lateral cartilage for countertraction, and dissection with a no. 66 Beaver knife blade is down to perichondrium. **(C)** Undersurface of upper lateral cartilage may be exposed, preserving skin. **(D)** Resection of caudal end of upper lateral cartilage may be carried out directly, and mucocutaneous tissue can be preserved. **(E)** Upper lateral cartilage can be completely separated from nasal septum medially, and submucosa can be preserved if desired. **(F)** Medial triangle of upper lateral cartilage can be removed submucosally from its attachment to septum. **(G)** After caudal end and medial triangle of upper lateral cartilage have been removed, mucocutaneous tissue is separated from septum. **(H)** Excess tissue is trimmed, and intercartilaginous incision is closed **(I)** thereby opening and widening the apex of the valve angle. (*Courtesy of Mayo Foundation.*)

scarred close to the septum after hump removal and infracture were accomplished. When the upper lateral cartilage is displaced against the septum, two procedures can be used to reopen the nasal valve angle. When a significant mobilization of the upper lateral cartilage is required, medial, lateral, and transverse osteotomies may be necessary, with *outfracture* carrying the upper lateral cartilage away from the septum (Fig. 40–10). If a dorsal hump deformity has been removed, then a roof repair is required in which available tissue is used for grafting.

Special situations or problems may arise that test the surgeon's ingenuity. For example, during nasal septal reconstruction with modification of the external nasal pyramid or during rhinoplasty, modification of the upper lateral carti-

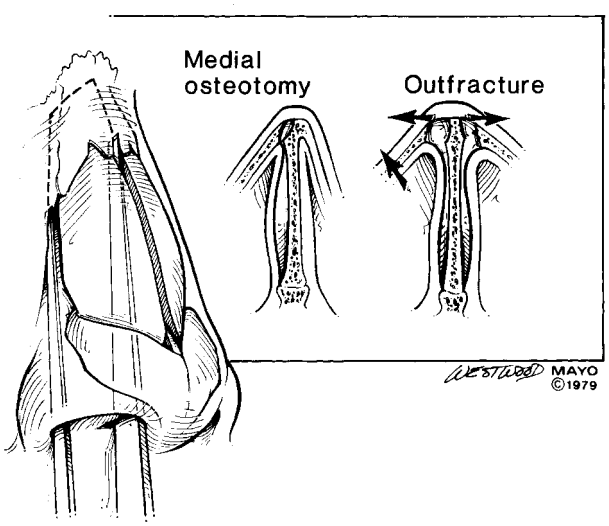

Figure 40–10 Upper lateral cartilage can be completely separated from nasal septum submucosally (intraseptal separation). These medial, lateral, transverse osteotomies, with outfracture on one or both sides as indicated, can be performed to carry the upper lateral cartilage away from the septum to open the nasal valve angle. (*Courtesy of Mayo Foundation*.)

lage may be required before or after the osteotomies and infracture to prevent permanent narrowing of the nasal valve area and closing of the nasal valve angle. Thus, a medial triangle of upper lateral cartilage can be removed for prophylaxis, that is, to maintain a normal nasal valve angle and prevent a fixed collapse of the nasal valve angle. In the situation of mobile collapse of the nasal valve caused by either a nonresilient upper lateral cartilage or previous trauma (surgical or nonsurgical), with partial or complete absence of the upper lateral cartilage, either a conchal (ear) cartilage or septal cartilage autograft, or even rotation of the lower lateral (alar) cartilage over the remnant of the upper lateral cartilage, may be attempted to prevent or lessen an increase in collapsibility of the nasal valve. This subject was covered recently in an article by Goode.[36] He believes that missing cartilage that produces valve collapse is best replaced by a cartilage graft. Scar contraction is repaired by skin graft, and composite loss (skin and cartilage) is probably best reconstructed by composite graft.

During treatment of the severely twisted or smashed nose, if "ballooning" or flaring of the upper lateral cartilage is present, with widening of the valve angle, the upper lateral cartilage may be separated from the septum submucosally, and a section of upper lateral cartilage can be removed to reconstruct and, in this case, narrow the nasal valve angle to approximate normality.

Prior Surgery

Patients with nasal airway obstruction and a history of previous rhinologic surgery present a challenge for several reasons. First, prior surgery produces scar tissue, making surgical dissection difficult. Second, there is a high probability that a significant portion of the cartilage and bony skeleton may be absent, increasing the difficulty of dissection and the likelihood of complications that may require the use of an autograft from a distant site or an allograft for septal reconstruction. These factors not only lead to a more difficult dissection of the mucoperiosteum but increase the risk of tearing of the mucosal flap. Thus, one is operating in a technically more difficult environment with fewer resources available for reconstruction. In addition, both physiologic and psychologic difficulties are more complex, and a thoughtful and thorough preoperative discussion is mandatory.

RECONSTRUCTION

Reconstructive surgery of the nasal septum is truly a reconstruction, with the final steps involving replacement and fixation of the appropriately trimmed cartilage and bone in the septal mucosal envelope. Bone is replaced where bone existed and cartilage is replaced where cartilage existed (Fig. 40–11). Lack of adequate septal cartilage (dorsal or caudal support) will lead to various degrees of saddle deformity, with columellar retraction and even inadequate tip support. Inadequate tip support can be overcome with a caudal cartilaginous strut placed between the medial crura and sutured in place. This strut should span the distance from the spine to the intradomal tip region. If a saddle deformity results, then replacement of the cartilaginous septum, either with autogenous septal structures or with autograft rib, may be required. For the cosmetic defect a dorsal onlay cartilage graft through either the hemitransfixion or an intercartilaginous incision can be considered.

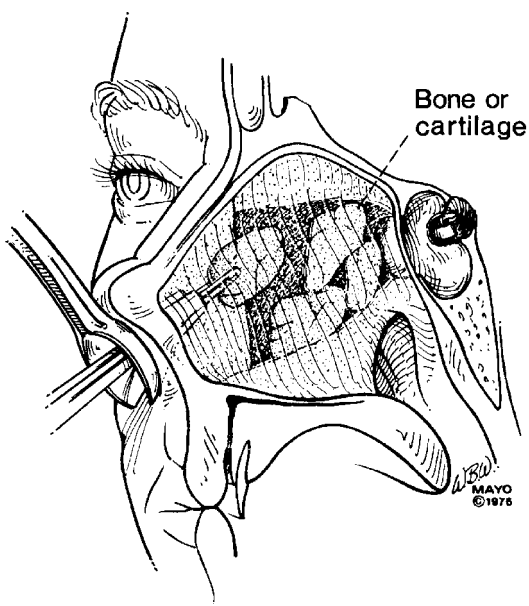

Figure 40–11 Crushed cartilage and bone replaced within septal space.

CLOSURE AND DRESSING

Completion of reconstructive septal surgery includes closure of the hemitransfixion incision and repair of any significant tears (greater than 1 cm) in the mucosa. Absorbable sutures are satisfactory in both situations to close and repair the septal envelope. Mucosal tears are approximated with 4-0 chromic on a G-2 needle (Ethicon no. 798) and a Castroviejo needle holder. If mucosal tears are present at opposing sites, cartilage and gelfilm are placed in the septal space in the hope of providing a surface for mucosal healing.

Closure also includes a mechanism to retain the reconstructed septum in the midline and prevent hematoma formation. Two options are available to accomplish this. Most commonly, the authors utilize plastic nasal stents sutured to the septum with subsequently placed antibiotic impregnated petroleum jelly gauze nasal packing (Fig. 40–12). An alternative method is to mattress-suture the mucoperichondrial flaps with an absorbable suture, thus obviating the need for nasal packing. However, if significant reconstructive efforts have been undertaken or if bone has been transplanted anteriorly in the septal space due to the cartilaginous deformity, mattress suturing would not be advisable. Finally, an external tape dressing is applied. A firm external nasal stent is applied to support and protect the dorsal septal dissection.

POSTOPERATIVE CARE

Reconstructive surgery of the septum frequently is performed on an outpatient basis. The patient is dismissed from the hospital with a small amount of pain medication, antibiotics, and sedatives. Patients are instructed to avoid lifting anything over 20 pounds for 10 days. Lozenges and added humidification to prevent symptomatic drying of the upper airway can be helpful. If packing is placed in the nose to aid in maintaining the septum in its reconstructed position, the timing of the pack removal is variable. Certainly, if there is any history of cardiac disease, significant pulmonary dysfunction, or sleep apnea, then administering oxygen and monitoring arterial oxygen saturation while the packs are in place may be warranted. The timing of pack removal is individualized, with individual surgeons preferring the following day to 4 to 7 days following surgery. Plastic stents are usually removed 7 to 10 days following surgery, depending on the need to protect the mucosa and prevent adhesions.

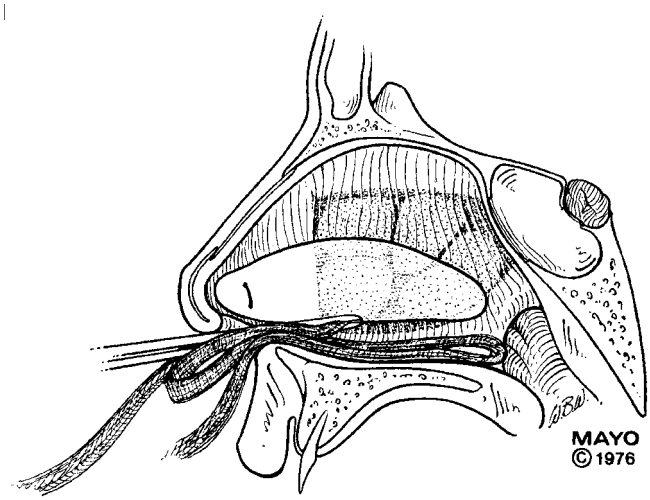

Figure 40–12 Nasal stents are secured on either side of the septum, and nasal packing is introduced to complete the closure of the procedure.

COMPLICATIONS

Intraoperative Complications

The use of local anesthetics either singly or associated with general anesthesia carries an inherent risk of toxicity of the local anesthetics, additives, or a potential interaction of these agents with a general anesthetic. Established safe doses should not be exceeded, and arterial oxygen saturation as well as mental status should be monitored during the procedure. Monitoring the mental status of the patient allows one to be aware of early signs of central nervous system toxicity, whereas monitoring arterial oxygen saturation prompts one to maintain a high P_{AO_2}, which is key in preventing local anesthetic–induced seizures.

Excessive intraoperative bleeding is not common. However, during the course of elevation of the mucoperichondrial and mucoperiosteal flaps, the incisive artery may be encountered and torn. This can be easily handled with electrocautery using steps to protect the integrity of the mucoperichondrial flaps. In addition, a very light electrocautery may be applied to focal sites of hemorrhage that are particularly bothersome. Temporary packs soaked in solutions containing 1:100,000 epinephrine may be helpful.

Broadening of the alar base may be noted following hemitransfixion incision and dissection of the soft tissues near the region of the nasal spine. The preoperative soft tissue relationships can be restored by inserting a base stitch prior to the closure of the hemitransfixion incision utilizing a medium-sized Keith needle and a chromic suture. The Keith needle is placed via the inferior extent of the hemitransfixion incision through the subcutaneous tissues and brought out through the left alar facial groove, and it is subsequently reinserted adjacent to the exit site and passed in the subcutaneous tissues just inferior to the nasal spine and again exiting the alar facial groove on the right. Finally, the Keith needle is again passed through the subcutaneous tissues, entering adjacent to the exit site on the right alar facial groove, and is brought out through the hemitransfixion incision. A nasal speculum placed in the hemitransfixion incision forms a firm back-stop by which the Keith needle can be directed from the hemitransifixion incision atraumatically. The free ends of the suture are then tied, with the tension adjusted so that the preoperative appearance is restored.

It is possible during a hemitransfixion incision for inadvertent lacerations of the alar rim to occur. These should be approximated using 6-0 Prolene with meticulous technique to prevent any notching or residual scarring.

Early Postoperative Complications

Hemorrhage following reconstructive surgery of the nasal septum is rare but requires prompt treatment. If the hemorrhage is minimal, local measures, such as mild pressure, may suffice. If the bleeding is subsequent to removal of the packing, application of a topical vasoconstrictor may be useful. If other measures fail, repacking may be required.

Normally, reconstructive surgery of the nasal septum produces minimal discomfort. Pain in the nose warrants immediate reevaluation due to the possibility of a septal hematoma or abscess. The presence of fever or toxic symptoms requires pack removal and consideration of drainage and intravenous antibiotic therapy, with coverage for *Staphylococcus aureus* due to reported cases of toxic shock syndrome.[36–38] Although not proven to be preventative against toxic shock syndrome, patients are routinely administered an oral antistaphylococcal antibiotic, and nasal packing is impregnanted with antibiotic ointment to prevent bacterial overgrowth.

Late Postoperative Complications

The most frustrating late postoperative complication is recurrence of the septal deformity, although this is uncommon. It can occur due to postoperative scar tissue contracture or nasal trauma. If the patient's nasal breathing is disturbed because of a recurrent deformity, then reoperation is considered. It is usually suggested that 12 months elapse prior to reoperation. This allows scar tissue to contract and mature.

Septal perforations are not common following septal surgery, yet surgical trauma is the most common cause of septal perforation.[39] Factors predisposing to septal perforation include devascularized mucosal flaps (dissection carried out in the incorrect plane), bilateral opposing mucoperichondrial flap tears, hematoma, and infection. To minimize the possibility of developing perforations, an appropriate plane of dissection should be maintained and tears repaired with absorbable suture. Careful attention during closure and packing placement should minimize hematoma formation.

Occasionally, patients may note transient palatal and dental anesthesia. This is most likely due to injury to branches of the nasopalatine nerve, which pass through the incisive foramen. Anosmia is an unusual complication following septal surgery and potentially results if the dissection is carried high in the region of the perpendicular plate of the ethmoid.[40] More significant disruption of structures in this region may lead to cerebrospinal fluid leakage.[41]

SUMMARY

Surgery involving the nasal septum is both challenging and rewarding. The rhinologic surgeon requires extensive knowledge of nasal anatomy, physiology, and pathophysiology to effectively plan therapy that will relieve the patient's often wide-ranging symptoms. Use of nasal septal reconstruction techniques and principles should provide a means to consistently achieve success.

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Chapter 41

Nasal Septal Perforation: Prevention, Management, and Repair

Russell W.H. Kridel and Hossam M.T. Foda

Perforation of the nasal septum presents a difficult surgical challenge to the otolaryngologist/head-and-neck surgeon. Although the most common causes are self-inflicted or iatrogenic, a clear-cut etiology must be established from a long list of potential causes, some of which can be life threatening. Septal perforation repair is technically difficult because the perforation represents a hole in three distinct tissue layers, comprising the right and left septal mucoperichondrial flaps, and the intervening cartilage, all three of which must be distinctly separated and repaired individually. Many procedures have been described to repair septal perforations. Those that are based on an attempt to stretch the septal mucosa through an advancement flap without adequate mobilization generally fail because the septal membrane is relatively inelastic. Those techniques that have the best physiologic result, highest success rate, and best patient acceptance generally require the use of extensively mobilized bilateral intranasal mucosal advancement flaps with the interposition and anchoring of a connective tissue type of graft.

PRESENTATION

Patients who are symptomatic with their septal perforation usually present with complaints about crusting, bleeding, whistling if the perforation is small, nasal obstruction if the perforation is large, pain, and/or rhinorrhea. The more anterior the perforation is on the septum, the more commonly the patient will be symptomatic because this area of the nose is drier than the more posterior portions. Sometimes if the perforation is small and especially if it is posterior, the patient will not have any symptoms and the perforation will be found simply on examination by a physician. Large perforations generally cause more symptoms of nasal obstruction because they disrupt the normal separate lamellar flow.[1,2] The symptom of pain is often more ominous because it suggests the possibility of chondritis, which can occur around the edges of the exposed cartilage at the circumference of the perforation. When normal air flow is not restored by surgical repair or the interposition of a button, the turbulent air flow can change normal respiratory epithelium to dry mucosa, which is often noted by crusting on the mucosa, not at the perforation site, in patients with long-term perforation.

Crusting and bleeding usually occur with septal perforations at the edge of the perforation because of the difficulty for the mucosa to heal over any exposed cartilage. Significant bleeding can occur and must be treated appropriately. In patients with large amounts of crusting and inflammation, one needs to consider a chronic inflammatory process and must rule out cocaine abuse or a granulomatous process.

On examination, the septum should be palpated to ascertain if there is any residual cartilage between the mucosal flaps around the perforation site. In perforations after septoplasty, there is usually very little cartilage left around the perforation, and this makes dissection of the adherent flaps much more difficult (Fig. 41–1). Self-inflicted trauma and previous cocaine use often leave large amounts of intervening septal cartilage and bone, thus making the repair easier. In patients with granulomatous processes or vasculitis, the intervening septal cartilage is usually of poor quality.

Patients often have no understanding of the complexity of a septal perforation or the difficulty of its repair. A great deal of education is important in helping patients understand that the operative repair is not always successful but is often necessary to restore normal physiology. Showing the patient an endoscopic view of the perforation on a monitor is often helpful in this educational process (Fig. 41–2).[3]

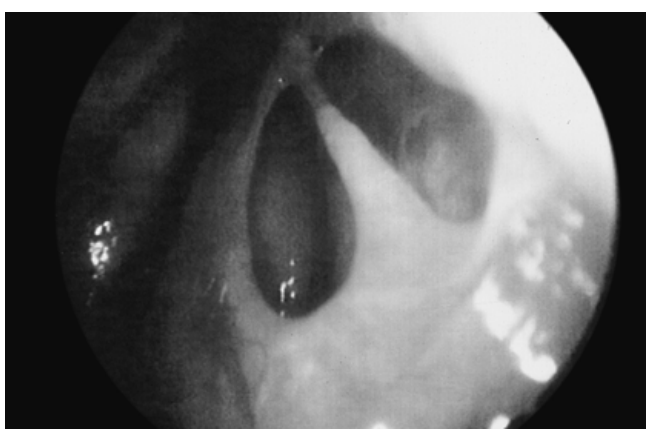

Figure 41–1 An endoscopic view of a septal perforation in a patient who had previous septoplasty with removal of almost all of the septal cartilage and bone. Note the paper-thin adherent flaps with a small bridge of tissue within the perforation.

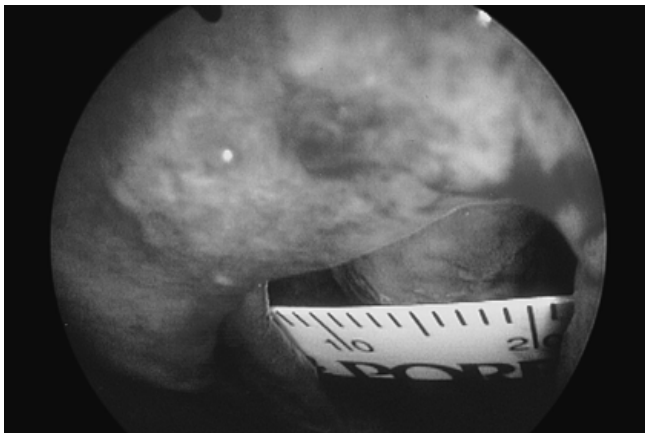

Figure 41–2 A paper ruler is placed in the nose and an endoscopic picture taken to show the patient the size and shape of the perforation.

HISTORY AND ETIOLOGIC FACTORS

Once iatrogenic or traumatic causes for the perforation have been ruled out, a very thorough history and examination are necessary in all patients. The septal perforation may be the first sign of a potentially life-threatening generalized systemic process. Table 41–1 clearly identifies the multiple causes of septal perforation, and the reader of this chapter is directed to a previous paper by R.W.H.K. that delineates these etiologies in detail.[4]

Iatrogenic Causes

Unfortunately, the most common cause of a septal perforation stems from previous nasal surgery, especially septoplasty, and from treatment for epistaxis. During septoplasty, there may have been tears in both septal membranes in a contiguous area where the intervening septal cartilage or bone has been removed. If these are not repaired immediately at

TABLE 41–1 Septal Perforation Causes

Trauma

External
- Fracture
- Septal hematoma
- Piercing injuries

Self-inflicted
- Nose picking
- Foreign bodies

Iatrogenic

Nasal surgery
- Septoplasty
- Sinus surgery
- Turbinate surgery
- Rhinoplasty
- Septal cauterization
- Septal packing
- Septal splinting
- Cryosurgery
- Transsphenoidal hypophysectomy
- Postoperative suctioning
- Nasotracheal intubation

Drugs—legal and otherwise
- Vasoconstrictive nasal sprays
- Steroid nasal sprays
- Cocaine
- Smoking

Chemical irritants
- Chromic, sulfuric, and hydrochloric acids
- Chlorines and bromines
- Agricultural aerosolized dust
- Rice and grain elevator dust
- Chemical and industrial dusts
- Lime
- Cement
- Glass
- Salt
- Dust
- Heavy metal
- Cyanide, arsenicals

Neoplastic causes
- Adenocarcinoma
- Squamous cell carcinoma
- Metastatic carcinoma
- Midline destructive granuloma

Inflammatory causes
- Vasculitides
- Collagen vascular diseases
- Sarcoidosis
- Wegener's granulomatosis
- Renal failure/renal disease

Infections
- Tuberculosis
- Syphilis
- Rhinoscleroma
- Lepromatous leprosy
- Rhinosporidiosis
- Multiple fungal species infection
- *Mucor* infection
- Typhoid
- Diphtheria

the time of surgery, the contraction of healing itself will enlarge the perforation. It is unwise to believe that a perforation will heal on its own; in fact, it is more likely that the perforation will enlarge postoperatively with the contraction of healing. Not only should the membrane tears be repaired but the insertion of intervening cartilage or connective tissue graft as a barrier to perforation is prudent.[5] R.W.H.K., when performing a septoplasty, always places crushed cartilage between the septal flaps and the area where the cartilage has been removed, whether or not there have been tears in the septal membranes. Often the obstructing cartilage that is removed during septoplasty is discarded or sent to pathology. Placing it back between the flaps, after it has been straightened or crushed, makes it act as a barrier against perforation and also, even if it does not survive, against fibrosis between the septal flaps, which may strengthen areas that have been weakened by the removal of cartilage (Fig. 41–3).

The secret to preventing corresponding tears in both mucoperichondrial flaps during septoplasty is to ensure that one has undermined broadly and elevated the mucoperichondrium away from the deviated cartilage or septal spur areas prior to attempting to remove the spur or the deviation. Even when there is a large spur, where penetrating the overlying membrane is common, the opposite mucoperichondrium usually can easily be elevated and maintained intact. If only one membrane is torn, the chance of a through-and-through perforation is markedly decreased. When a large posterior bony spur is encountered, the cartilage is separated from the bony septum and then the mucoperichondrium is elevated over the bony portion of the spur on the opposite side of the spur prior to removal. Becker scissors are used to cut above and below the bony spur, and then the tip of the nasal speculum is used to push the intervening spur closer to the midline as one teases the mucoperichondrium off the protruding portion of the spur prior to its removal.

Bilateral corresponding tears in septal membranes can still cause septal perforation, even if there is intervening cartilage left; therefore, these tears should be repaired. The blood supply to the cartilage comes from the overlying mucoperichondrium, and if this is disrupted bilaterally the intervening cartilage may necrose and ultimately perforate.

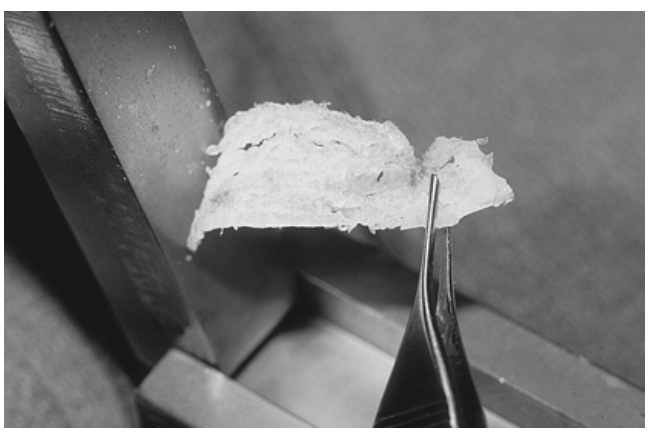

Figure 41–3 A piece of septal cartilage is crushed in a cartilage crusher and then placed back between the mucoperichondral flaps to reskeletonize the septum and help prevent a perforation.

Nasal Sprays and Cocaine Usage

Some steroid nasal sprays can be very irritating to the septal mucosa when used on a long-term basis and can lead to perforation.[6] It is the obligation of the physician who places patients on such sprays to periodically examine the nasal mucosa for any untoward effect of the medication.

Cocaine use has increased dramatically as a major cause of septal perforations. The drug itself causes intense vasoconstriction compromising blood supply to the flaps. As most street cocaine is adulterated with filler substances that can be quite irritating, such as Borax or talc, the insult to the septal membrane can be even worse, and even one-time usage of intranasal street cocaine has been known to cause a septal perforation.[7] Chronic cocaine use can totally destroy the inside of the nose because quite often infection complicates the inflammation, irritation, and lack of blood supply. The necrosis can proceed not only to perforation but also to total nasal collapse, intranasal stenosis and scarring, and dorsal saddling. Because cocaine is so addictive, patients often need to be screened for continued use despite their denial of continued use. It would be useless to attempt to repair a septal perforation in a patient who is still using cocaine.

Disease Processes

Septal perforations can be the sequelae of serious systemic diseases, whether they be neoplastic, inflammatory, or infectious. When no obvious cause has been determined, the physician must rule out potential serious medical illnesses. Renal failure and renal disease, vasculitides, and collagen vascular disorders such as lupus, rheumatoid arthritis, and polychondritis can predispose to septal perforation. Unfortunately, some of these latter conditions may recur following remission. Therefore, prior to repairing such perforations, it is important to touch base with the primary physician who is treating the patient. Patients must be told that even though repair may be successful, recurrence is possible if the disease flares up again at a later date. R.W.H.K. has noted this in several patients with renal and small-vessel disease.[8] Wegener's granulomatosus, sarcoidosis, and other granulomatous diseases are less common causes, but computed tomography (CT) of the nose and paranasal sinuses helps to rule out these conditions. The workup of individuals with no known cause and a negative head and neck examination, and negative CT scans, should include laboratory evaluation for collagen vascular and renal disease. It should also include fluorescent treponemal antibody, absorbed (FTA-ABS), Venereal Disease Research Laboratory (VDRL), cytoplasmic antineutrophilic cytoplasmic antibody (C-ANCA), and Epstein–Barr virus titers. Nasal cultures for fungi and bacteria are helpful in the presence of any inflammatory process. Skin testing for anergy, tuberculosis, and fungal infections may also be helpful. If all of these tests come up negative and no clear cause has been elicited,

then a biopsy of the perforation may be indicated prior to any surgery. Such a biopsy should be taken from the posterior edge of the perforation with a large enough biopsy that enough tissue is included away from the perforation so that the pathologist can get a definitive diagnosis and just not render a report of chronic inflammation. It is important not to biopsy at the superior or inferior edge of the perforation where one would increase the vertical perforation height, which is the dimension of the perforation that is most critical in one's ability to close a perforation. In addition, biopsies at the anterior portion of the perforation should be avoided because that area must be closed preferentially to decrease symptoms.

MEDICAL, NONSURGICAL TREATMENT

Asymptomatic patients with perforations rarely require treatment. Such patients should be advised to keep the nose moist when in dry climates with the use of petrolatum-based ointment. For patients with a great deal of crusting, frequent therapy with a nasal irrigant as well as ointments and emollients is indicated. David Fairbanks recommends an antiseptic wash of 1 teaspoon of table salt dissolved in 1 quart of warm water as a nasal irrigant delivered via a Water Pik–type device with a nasal adapter.[7] Corn syrup or glycerin can be added to the saline mixture as a moisturizing and coating substance, which further reduces nasal crusting. A teaspoon of vinegar or 1 to 3 tablespoons of boric acid powder helps decrease *Staphylococcus aureus* and *Pseudomonas aeruginosa* growth. If there is a chronic infection, antibacterial ointments such as bacitracin or Bactroban may be applied.

Patients often are bothered by such laborious treatment regimens and often opt for other solutions. A silicone grommet prosthesis does not fix the perforation but helps to restore better nasal air flow and keeps the edges of the perforation more moist. The commercially available buttons are not always of proper size to fit larger perforations, in which case a custom silicone button can be fabricated by the local prosthetist once given the proper dimensions. The standard or the custom-made septal buttons usually can be inserted in the office under local and/or topical anesthesia. When these buttons are in place, occasional nasal irrigants may still be needed to keep the obturator clean, and they may have to be removed for more adequate cleaning and integrity check on a yearly or more frequent basis. Such buttons are ideal for patients who are not good surgical candidates for medical reasons and should also be considered for patients with chronic or recurrent disease as well as patients with continued cocaine usage.

SURGICAL GOALS AND OPTIONS

Surgery should not only repair the perforation but should also restore normal nasal function and physiology. The literature is replete with different techniques described for closure, but only those that use intranasal advancement flaps successfully achieve normal nasal physiology because nasal respiratory epithelium is utilized for closure. Methods that use skin grafts or oral buccal mucosal grafts may be successful in closing the perforation but leave the patient with a dry nose that continues to crust as these grafts either shed or dry because normal respiratory epithelium is not present. The normal flow of air through the nose exacerbates the problem as it dries out these grafts.

The surgical method chosen should also facilitate a tension-free closure so that the repair will not break down postoperatively as healing causes contraction. Because there is no elastic tissue in septal mucosa, methods that rely on septal advancement without adequate mobilization usually fail because the graft will not stretch. The open external rhinoplasty approach provides the necessary access and exposure for adequate mobilization and development of mucosal flaps, which are advanced into place without an attempt to stretch the flaps. By using sliding bipedicle or unipedicle flaps, usually from the floor of the nose and under the inferior turbinates, the surgeon can close the mucosal portion of the perforation with normal nasal respiratory mucosa. Because these flaps have a blood supply, their success rate is much higher than that of any composite graft that may not vascularize. In addition to closing the perforation in each mucoperichondrial flap, it is absolutely critical that a connective tissue interposition graft be placed between the flaps at the perforation repair site to prevent recommunication and reperforation, and to act as a continuous surface in which the edges of the sewn perforation can migrate and mucosalize closed. This method of mucosalized flaps with an interposition graft has been described with more than a 90% success rate in perforations of 2 to 3 cm, by several authors, including Fairbanks,[9] Gollom,[10] Wright and Kridel,[11] and Goodman and Strelzow.[12] As perforations increase in size, the chances for their successful closure decrease proportionately and patients need to be so informed. Romo et al[13] described a method of tissue expansion by which to create larger advancement flaps for closure of these more difficult large perforations. Murrell even described a repair utilizing a forearm free flap that was anastomosed with the facial artery.

The anterior to posterior size of the perforation is not very important in closure because the tension of the closure is from the floor of the nose to the dorsum, which is perpendicular to this access. Therefore, the height of the perforation is the most helpful determinant for the possibility and success of repair. Furthermore, the absolute size of the perforation is not as important as the proportion of septal membrane remaining. Perforations that extend all the way up to the nasal dorsum or all the way back to the sphenoid are almost impossible to repair unless there is some small cuff of membrane to which the inferior advance flap can be sewn. A previous septoplasty may make the dissection of the adherent mucosal flaps more difficult if a large amount of septal cartilage has been removed, and such dissection can lead to further worsening of the perforation during envelope separation. Adhesions between the remaining septal membranes and the lateral nasal wall or turbinates may need to be lysed during a separate preceding procedure with the placement of Silastic sheeting on the septum for several weeks to prevent reformation prior to the attempt at perforation repair.

GRAFT SELECTION

Many types of connective tissue grafts have been used to interpose between the repaired septal flaps; these include mastoid periosteum, temporalis fascia, pericranium, septal bone or cartilage, fascia lata, and, most recently, acellular der-

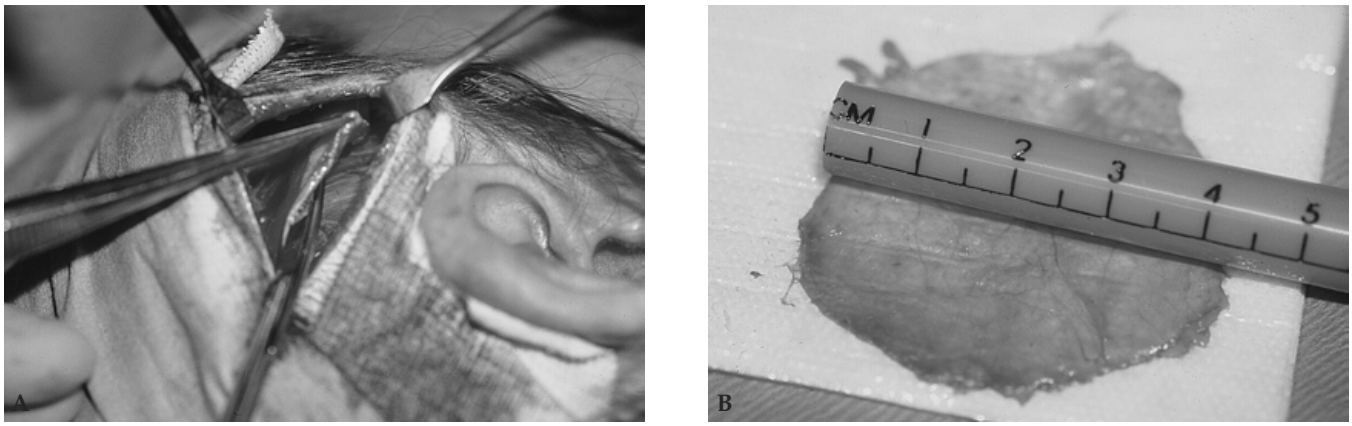

Figure 41–4 **(A)** The temporalis fascia as it is being harvested. **(B)** A 4 × 4 cm piece of temporalis fascia spread out to dry prior to insertion between the mucoperichondral flaps.

mal allografts.[14] Interposing such a connective tissue graft between the repaired septal flaps helps to strengthen the repair and acts as a scaffold for the mucosa to creep on during the healing phase; this is especially important in cases where complete closure of the mucosal defect was not possible. Currently, the most commonly used grafts are the temporalis fascia and the dermal allografts (Figs. 41–4 and 41–5). The temporalis fascia is harvested through a horizontal temporal incision, and the incision is beveled to parallel the hair shafts in order to avoid injury to the hair follicles. Dissection is taken down to the deep temporal fascia. Injection of saline under the deep temporal fascia helps to elevate it off the temporalis muscle. A curved scissor is used to harvest the graft, which should be considerably larger than the septal perforation as the perforation itself may get enlarged during the process of flap dissection. After complete hemostasis is achieved, the temporal incision is closed in two layers and a mastoid-type pressure dressing is applied.

Figure 41–5 AlloDerm is shown being inserted between the mucoperichondral flaps as an interposition acellular dermal graft.

SURGICAL APPROACHES

The endonasal approach to perforation repair has been popularized by David Fairbanks.[7] This method is associated with a high success rate but is extremely difficult, especially in large perforations or in patients with small nostril apertures. When more exposure is needed, Fairbanks does a lateral alotomy, which has the potential for a visible incision. The external rhinoplasty approach is quite advantageous in that it provides access to not only the anterior but also the superior and posterior aspects of the perforation. This provides increased surgical exposure and visualization and avoids distortion that normal intranasal retraction can cause. Furthermore, as no transfixion incision is made, the anterior septal blood and lymphatic supply is preserved, which may improve nasal advancement flap viability. With the external technique, one approaches the caudal end of the septum by totally separating the medial crura from themselves and from the septum. This process cuts the normal fibrous connections between the medial crura, the septum, and the overlying skin, which normally help to support and preserve tip projection. The careful surgeon must reconstitute tip support mechanisms after the perforation is repaired not only by sewing the medial crura back together with interrupted sutures but also at times by placing a columellar strut.

SURGICAL TECHNIQUE

The patient is placed in the supine position. After an adequate level of general oral endotracheal anesthesia is obtained, an oral pharyngeal throat pack is placed to prevent any blood from trickling down into the esophagus and stomach, thus reducing the chance of any postoperative nausea. The nose and septum are then infiltrated with 1% xylocaine with 1:100,000 units of epinephrine. Time is allowed to elapse for the vasoconstrictive and anesthetic effect of the infiltrated solution while the patient is prepped and draped in the usual sterile fashion. Careful intranasal examination is done, and any intranasal synechia or hypertrophied turbinates are dealt with at this stage.

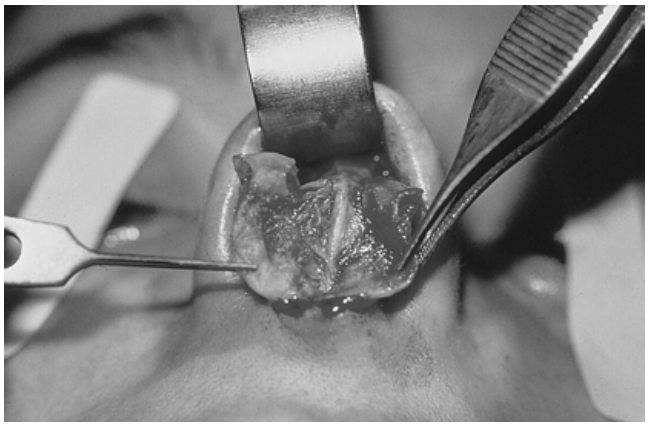

Figure 41–6 Intraoperative photograph showing the dissection and spreading apart of the medial crura to gain access to the caudal part of the septal cartilage.

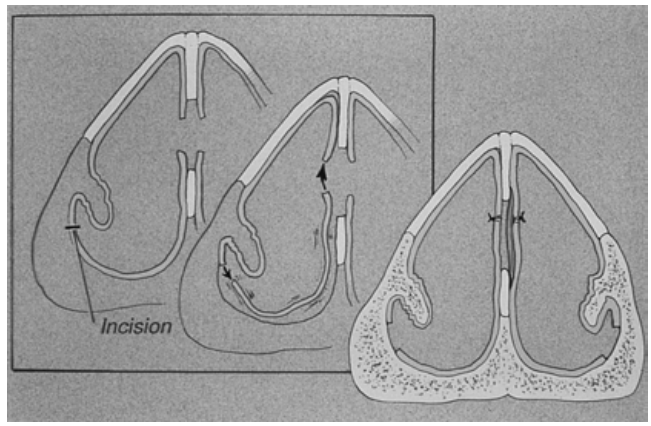

Figure 41–7 The effect of making a floor/inferior turbinate flap with advancement of the mucosal floor flap toward the septum to close the perforation. (From Kridel R. The open approach for repair of septal perforations. *Aesth Plast Surg: Rhinoplasty*, 1993. With permission.)

A classical external rhinoplasty approach is performed whereby bilateral alar marginal incisions are started laterally along the caudal edge of the lateral crus, and dissection is continued medially down the length of the columella where the incisions are connected via an inverted V-shaped transcolumellar incision. The columellar skin is elevated off the medial crura and skin dissection is continued upward, with care taken to stay in the supraperichondrial avascular plane until reaching the nasal bones where the periosteum is elevated using a Joseph-type periosteal elevator. Dissection is performed between the medial crura to gain access to the caudal septal cartilage followed by bilateral caudal septal membrane elevation in a strict submucoperichondrial plane (Fig. 41–6). Septal flap elevation is continued upward until reaching the cartilaginous edge of the perforation where an increased resistance is met during the dissection due to the adherence of the septal flaps to each other with no intervening cartilage. At this stage the dissection is taken downward to elevate the mucosa off the maxillary crest, nasal floor, and laterally until reaching the root of the inferior turbinate. Any bleeding encountered from the penetrating vessels at the maxillary crest should be cauterized using an insulated-tip suction cautery. After completing the nasal-floor flap elevation a posterior-to-anterior back-cut incision is made using a no. 15 blade at the root of the inferior turbinate, thus creating a bipedicled mucosal flap that is attached both anteriorly and posteriorly to preserve its vascular supply (Fig. 41–7). This flap could be mobilized medially and upward on both sides of the nasal septum to facilitate checking the amount of mucosal redundancy provided by the created flaps. In larger perforations, the inferior advancement floor flaps alone cannot provide enough mucosa for closure, and a superiorly based flap may also be needed. In these cases, the septal flap elevation is continued dorsally between the superior edge of the perforation and the upper lateral cartilages. The upper lateral cartilages are then sharply separated from the septum extramucosally (Fig. 41–8). The roof flap that now bridges between the superior edge of the perforation and the undersurface of the upper lateral cartilage could be dropped downward to help in closing the mucosal perforation on each side.

In cases involving large perforations, more length could be added to the roof flap by extending the dissection to include the mucoperichondrium of the undersurface of the upper lateral cartilage. In exceptionally large perforations, a back-cut could be made in the mucosa under the upper lateral cartilage, thus transforming the roof flap into a bipedicled flap allowing more downward advancement. This can only be performed on one side for fear that the dorsal cartilaginous septum would be exposed bilaterally. Loss of cartilaginous viability in the cartilaginous dorsal area may result in dorsal saddling or a high perforation.

Only after completion of the roof and floor flaps can the mucosal perforation be opened into from the front, using a broad exposure technique and careful dissection to avoid enlargement of the existing perforation. Dissection must pro-

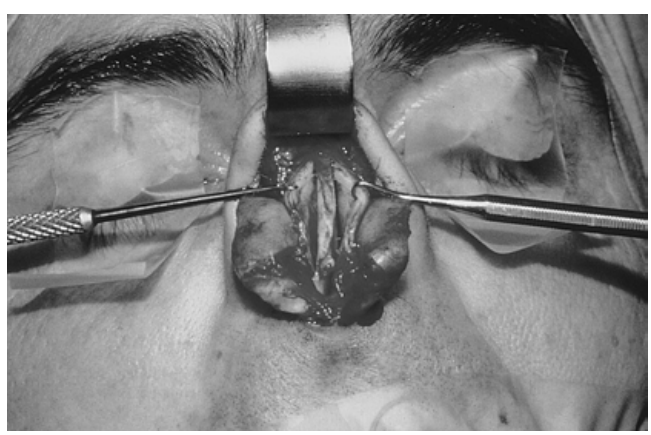

Figure 41–8 The upper lateral cartilages are sharply cut away from the septum to provide improved access to the perforation. The mucoperichondrium is left intact and attached to the undersurface of the upper lateral cartilage.

ceed posteriorly for at least 1 cm back behind the perforation, and any residual bony cartilaginous deviations can be corrected at this time.

Once enough mucosal laxity has been provided by these advancement flaps, the perforation in each mucoperichondrial flap is closed, under no tension, using interrupted sutures of either 4-0 or 5-0 chromic or plain gut sutures (Fig. 41–9). Any granulation tissue or scarring that is present at the periphery of the perforation should be removed prior to suturing to provide fresh edges that would be more likely to heal. At this point, the temporalis fascia graft, the pericranium, or the human acellular dermal graft is utilized. The interposition graft is then placed between the mucoperichondrial flaps and brought back posteriorly at least 1 cm beyond the closed perforation. The graft should then be stabilized to prevent postoperative movement by utilizing a few individual sutures to afix it directly to the septal cartilage remnant. After fixation, the grafting site should be inspected to ensure that the center of the closed perforation is well covered by the graft.

The upper lateral cartilages must then be resutured to the septum. If the perforation was large and required superior advancement flaps, it may be difficult to reattach the upper lateral cartilages to the septum at their original height and at the same time avoid tension on the newly closed perforation site. The surgeon may be forced to resecure the upper lateral cartilages to the septum at a lower level, with the potential cosmetic outcome being a pinched appearance

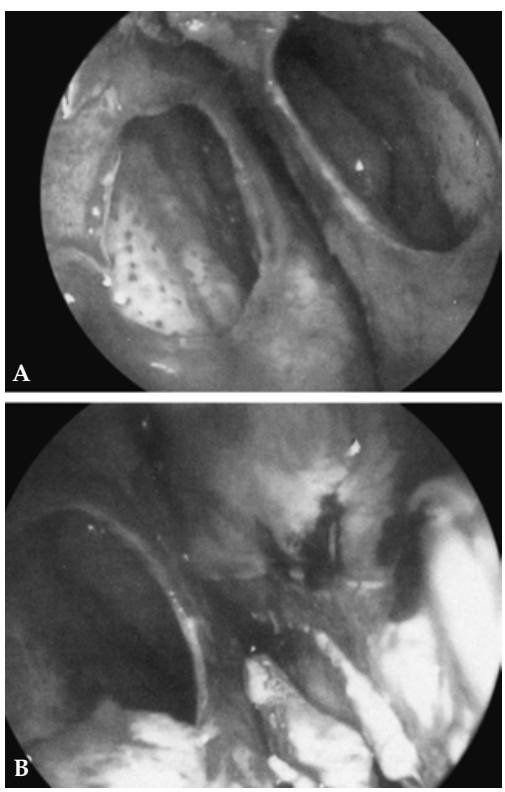

Figure 41–9 **(A)** The mucoperichondral flaps, separated with the perforation in each flap readily seen. **(B)** The perforation sutured closed on one side with dark marks identifying the interrupted sutures.

to the nasal dorsum. The pinched appearance results from the upper laterals being lower than the central septal dorsum. Recognition of this potential problem would necessitate placing cartilaginous onlay grafts over the reset upper lateral cartilages to provide better dorsal symmetry. If a reduction rhinoplasty was carried out at the same time, this problem would be less of an issue.

The intranasal septal flaps must then be mattressed together reapproximating both flaps and sandwiching the interposition graft. Mattressing the septum aids in the healing of the perforation and speeds the revascularization of the graft. It furthermore helps to prevent the occurrence of a postoperative hematoma. The mattress stitch is usually a 4-0 chromic suture and a continuous suture technique is utilized (Fig. 41–10). The needle must be extremely sharp so that it passes freely through not only the flaps, but also the graft and causes little displacement of the interposition graft. Mattress sutures must be used above and below the repaired perforation so that the sutures are placed in a perpendicular plane to that of the perforation repair. This suture technique strengthens and reinforces closure.

As noted previously, resupport of the nasal tip support mechanisms is crucial.[4] The medial crura must be resewn together with or without a columellar strut. The nose should also be evaluated at this time to see if there has been any unwanted rotation of the tip due to tension of the closure, or continuity of the septal flaps with the mucosa of the medial crura. If unwanted rotation and shortening of the nose have occurred, the surgeon may use a caudal septal replacement graft to lengthen the nose or place a large cartilaginous batten in front of the medial crura to camouflage such rotation. A tip graft can also be added that does not extend above the dorsum and so provides extra length to the tip without increased rotation or projection. The dome cartilages must then be sewn together with permanent sutures, reconstructing the dome complex and preventing postoperative bossae. At completion of the rhinoplasty part of the procedure, the nasal skin is redraped to its normal anatomical position and the external rhinoplasty incisions closed. The transcolumellar incision is closed using a deep 6-0 polydioxanone suture to take the tension off the skin edges, which are then approximated using a combination of interrupted 6-0 polypropylene sutures and 6-0 fast-absorbing plain gut in a running locking fashion. The marginal incision is closed on each side using a 5-0 plain suture.

To protect the repaired septal flaps during their healing phase, a 0.020 inch thick polymeric silicone sheeting (Silastic) is placed on both sides of the septal flaps, covering almost all of the septum on each side, and is secured into place by approximately three 5-0 non-absorbable sutures (Fig. 41–11). These sutures should not be overly tight so as not to constrict the blood supply to the septum. Because the polymeric silicone sheets are transparent, the repair site can be visualized postoperatively with monitoring of the healing mucosa. Monitoring of the protected repaired site is especially helpful if the surgeon is unable to close the perforation fully. The sheeting protects the graft site from air flow drying and keeps the area moist to accelerate the healing process. The nose is then very lightly packed with Gelfoam strips underneath the inferior turbinates, followed by a small Telfa pack impregnated with antibiotic cream. If too much packing is placed, vascular

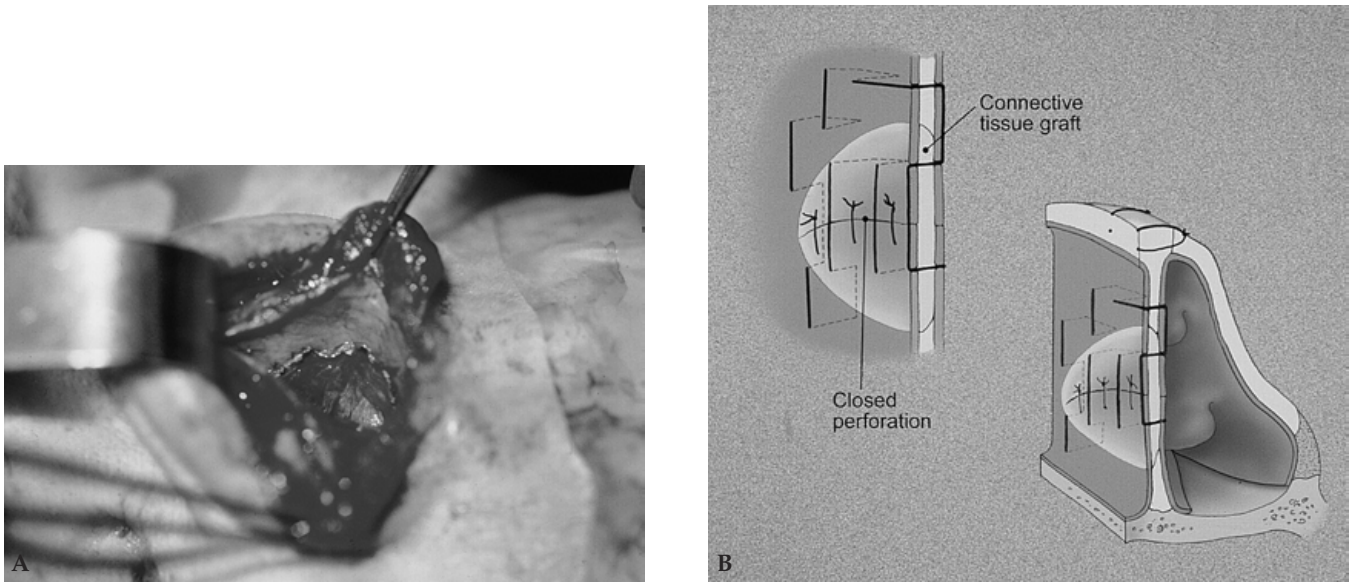

Figure 41–10 **(A)** In this case, the temporalis fascia graft is shown covering over the cartilage perforation and has been sewn to the surrounding septal cartilage to prevent migration. **(B)** The interposition graft is centered under the closed perforation. Mattress sutures go through both mucosal flaps and the graft in order to prevent migration of the graft, to hold the graft in apposition to the flaps as an aid in healing, and to prevent postoperative bleeding or hematoma formation.

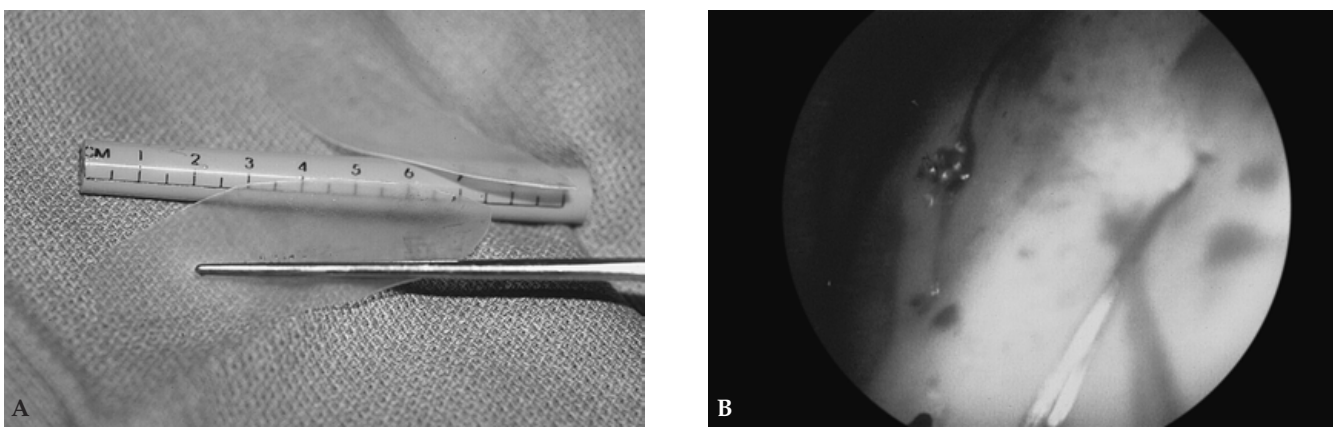

Figure 41–11 **(A)** Clear 0.02-in.-thick silicone soft sheeting that is shaped to cover the perforation repair on each side of the septum. **(B)** The silicone sheeting sewn into place with three through-and-through mattress sutures of 5-0 Prolene suture. Care was taken not to constrict the flaps and compromise the blood supply. One can easily monitor the healing of the septal perforation repair through these transparent sheets.

compromise of the repair site could ensue as nasal swelling develops. The Gelfoam is additionally helpful because it absorbs any bleeding as the result of the development of the bipedicled flaps. The nose is then externally taped and splinted, whether or not any dorsal modifications, osteotomies, or grafts have been used. Elevation of the open rhinoplasty flap creates a potential space for blood accumulation and fibrosis postoperatively, and a standard external splint must be placed for prevention. A drip pad is placed, and the patient is then extugated by anesthesia.

POSTOPERATIVE CARE

All patients are told that there will probably be some bloody discharge postoperatively because of the raw areas underneath the inferior turbinates. This nasal discharge often subsides after the first 24 hours.

On the first postoperative day, the Telfa packs are removed and the Gelfoam is usually left in place. No attempt is made to remove all of the Gelfoam on the first operative day.

The patient is instructed to use saline nose drops three to four times per day. This helps to keep the Gelfoam moist and allows easier suctioning over the next 7 to 10 days. Using cotton-tipped applicators, the patient is encouraged to place antibacterial ointment in the nose to prevent postoperative crusting. The external nasal splint is usually removed about 5 to 7 days later, and then the nose is usually retaped for another 5 days. The nonabsorbable columellar sutures are removed on about the fifth day.

Careful examination of the site of the previous perforation is carried out through the clear Silastic sheeting at each visit. In most cases, we leave the sheeting in place for 3 weeks, but will prolong that time if the perforation does not appear to be fully healed. If upon removal of the Silastic sheeting we discover a small area that is unhealed, the patient is instructed to keep this area moist, using antibacterial ointment three to four times per day in addition to a saline mist.

The patient is instructed not to use any vasoconstrictive sprays, to refrain from smoking, and to avoid noxious fumes during the postoperative phase. Blowing of the nose is also to be avoided for the first month postoperatively.

If the patient had a temporalis fascia graft harvested, the drain is removed on the first day, the pressure dressing is maintained for 2 or 3 additional days, and the sutures are removed in about 7 to 10 days.

OUTCOMES

The successful outcome of this operation is dependent on many factors, including the cause of the perforation, size and location of the perforation, surgical skill of the operating physician, and cooperation of the patient postoperatively. If one has not been successful in totally closing the perforation, it is usually made smaller with this surgery. If complete closure is not likely, all perforations should be closed from an anterior-to-posterior direction, moving the perforation more posteriorly, thus decreasing the patient's symptoms. A repeat operation can be attempted in about 6 months, if necessary.

After the perforation has healed completely, the patient can experience the same satisfaction as the physician in the successful closure. Photographic documentation once again can assist the patient in understanding this difficult and complex problem and in seeing the successful outcome. It is remarkable to observe how well the septum heals with little or no evidence of previous perforation.

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Reconstructive Surgery of the Face and Neck

Section

IV

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Chapter 42

Cutaneous Malignancies: Diagnosis and Treatment

John D. Hendrix, Jr. and Craig L. Slingluff

Cutaneous malignancies, which are the most common cancers in the world, include melanoma and nonmelanoma skin cancers, principally squamous cell carcinoma (SCC) and basal cell carcinoma (BCC). These tumors originate from the upper layer of the skin, called the *epidermis*. Many factors can play a role in the development of skin cancer, but exposure of the epidermis to ultraviolet (UV) radiation—principally from sunlight—is the most important factor. Less common cutaneous malignancies can arise from the deeper layers—the dermis and subcutaneous fat or from other structures, such as hair follicles, sebaceous glands, eccrine glands, blood vessels, and nerves. Sometimes skin cancers are misdiagnosed because they mimic benign growths that arise from these structures in the skin.

The incidence of skin cancer in the United States is approaching epidemic proportions. Currently, one in five Americans will develop a skin cancer during his or her lifetime.[1] There are now over one million cases of nonmelanoma skin cancer in the United States annually.[2] It is predicted that 1 in 75 individuals in the United States will develop melanoma by the year 2000.[1] It is postulated that the increase in incidence of skin cancer may be explained by changes in lifestyle or depletion of the ozone layer, which filters out the carcinogenic UV radiation from sunlight.[3] Epidemiologic studies suggest that an individual who develops a skin cancer is more likely to develop not only additional skin cancers but other internal malignancies, such as lung cancer.[4–6] An individual who develops one nonmelanoma skin cancer has an estimated risk of developing one or more additional skin cancers of 35% at 3 years and 50% at 5 years.[7]

In this chapter, we will focus on the diagnosis and treatment of skin cancer, particularly SCC and BCC. The biology and histology of these neoplasms will be included when relevant to management. Other unusual cutaneous malignancies will also be reviewed.

SQUAMOUS CELL CARCINOMA

Epidemiologic and Etiologic Factors

Cutaneous SCC, a malignant tumor of keratinizing epidermal cells, is the second leading cause of skin cancer death after melanoma and the second most common type of skin cancer after BCC.[8] The incidence of SCC, and all skin cancer, is increasing. SCC has been found to occur on all cutaneous surfaces but most often occurs on the sun-exposed areas of the head and neck. In the United States, one study estimated a 4-fold increase in SCC incidence in men and a 15-fold increase in women from 1977 to 1994.[9]

The cause of SCC is multifactorial. Exposure to sunlight, fair skin, and reduced immunity are major risk factors. Certain environmental exposures and medical conditions are associated with an increased risk of SCC. When many predisposing elements are present in a patient, such as high cumulative sun exposure, fair skin, and immunosuppression (which many organ transplant patients have), the likelihood of developing SCC is extremely high.

The principal cause of SCC is ultraviolet (UV) radiation from sunlight. The majority of SCCs occur in elderly, fair-complexioned Caucasians who have had years of sun exposure.[10] Pigmentation plays an important role in protecting the skin from UV radiation; therefore, skin cancer is uncommon in individuals with dark pigmentation. Clinical signs of chronic sun exposure that can be used to identify those at risk for SCC and skin cancer in general include freckling, telangiectasia, atrophy, rhytides, and precancerous lesions.[11,12] People who are engaged in an outdoor occupation or recreation, live close to the equator (where the sun is more intense), or are elderly (with more cumulative exposure to UV radiation) are at higher risk for the development of SCC.[13] Both epidemiologic and experimental evidence points to UV-B as the major component in sunlight responsible for causing cutaneous SCC.[14–16] UV-A may also play a role in the development of SCC, particularly when a photosensitizer is used.[14]

Chemical exposure to organic hydrocarbons, pesticides, and arsenic (most commonly in contaminated well water) can be associated with the development of SCC.[17–19] Ionizing radiation can be associated with SCC.[20] Cigarette smoking has also been shown to be a risk factor for development of SCC.[21] Certain genetic disorders and syndromes (such as xeroderma pigmentosum and albinism) are also associated with the development of SCC.[22–24] Chronic skin conditions, such as draining sinuses, burn scars,[25] ulceration, and infection, can also be associated with the development of SCC.[18]

Impaired cell-mediated immunity (either drug- or disease-induced) is linked with the development of cutaneous SCC. Organ transplant patients requiring chronic immunosuppressant medications, such as cyclosporine, azathioprine, and prednisone, are at increased risk for SCC. T-cell depletion (particularly CD4+ T cells) is associated with increased risk of skin cancer in long-term renal transplant recipients.[26] The incidence

of malignancy increases with time after transplantation. One study showed the overall risk for a transplant patient to develop a first skin cancer increased from 10% after 10 years to 40% after 20 years of graft survival.[27] In one study of heart transplant patients, SCC was the predominant skin malignancy, constituting 90% of the lesions. Another study showed the mean number of skin malignancies per transplant patient to be greater than 4, with some patients having more than 100 cutaneous cancers.[28,29] Development of SCC is also more common in diseases with impaired cell-mediated immunity, such as lymphoma or leukemia,[30,31] autoimmune disease,[32] and epidermodysplasia verruciformis (a rare hereditary immune deficiency in which human papillomavirus is associated with SCC).[33]

Clinical Characteristics and Precursors

The most common precursor to SCC is the actinic keratosis (AK). AKs, also called solar keratoses, are sun-induced precancerous lesions. These scaly, circumscribed, rough, erythematous lesions are often better recognized by palpation than inspection. They are typically found on the head and neck of many middle-aged and elderly individuals (Fig. 42–1). They are usually asymptomatic, but the patient may occasionally complain of itching or tenderness. Size varies from pinpoint size to large plaques but they usually are 3 to 6 mm in diameter. AKs are clinical markers of long-term sun exposure, a major risk factor for nonmelanoma skin cancer, and may be the most significant predictor for a person's developing cutaneous SCC.[34] Although AKs are biologically considered to be premalignant, histologically they appear to represent early SCC in situ.[35] About 20% of AKs will spontaneously involute.[36] An AK can evolve into SCC with the potential for metastases when there is active growth with invasion into the dermis. Malignant conversion has been estimated to be on the order of a 1 in a 1000 chance per year and may involve p53 mutations.[37,38] Hyperkeratotic AKs may have a higher rate of malignant transformation.[39]

Another less common precursor to invasive SCC often associated with AKs is Bowen's disease (SCC in situ). Histologically one sees malignant cells filling the epidermis but not invading the dermis. Clinically, Bowen's disease most often appears as a single erythematous, slightly scaly, minimally indurated patch that can be mistaken for eczema, fungus, or psoriasis (Fig. 42–2). There can sometimes be multiple areas on a background of sun damage and AKs. The lesions measure from millimeters to centimeters. Bowen's disease is most commonly found on the trunk. Any induration or hyperkeratotic thickening should alert the clinician to the possibility of invasive SCC in that area and a biopsy should be done.

Invasive SCC typically presents on the sun-exposed areas of the head, neck, and arms. They can arise de novo or from preexisting AKs. Clinically, SCC most often presents as a hyperkeratotic growth or a crusted indurated papule that on removal of the crust reveals a friable, red granular base. SCCs often have elevated and rolled edges with central ulceration. Pearliness and telangiectasia (found in BCC) are often absent. The tumor is firm, although more advanced cases can be soft and friable. Erosion and ulceration are more common with SCC than BCC. Histologically, SCC may show a wide spectrum of differentiation from cells showing complete keratinization (well-differentiated) to spindle-shaped cells that can only be distinguished from other tumors by special histologic methods (poorly differentiated). Well-differentiated SCC is likely to present as a firm erythematous nodule of variable size, sometimes with an area of central hyperkeratosis (Fig. 42–3). Poorly differentiated SCC is more apt to present as a faintly erythematous nodule or plaque that is not well

Figure 42–1 Severely sun-damaged skin and multiple actinic keratoses on the left side of the face [see Fig. 42–1 (c)].

Figure 42–2 Bowen's disease (squamous cell carcinoma in situ) on the trunk. These lesions could be mistaken for psoriasis, eczema, or fungus.

Figure 42–3 Keratoacanthoma on the left dorsal arm.

defined and in which erosion and ulceration is common (Fig. 42–4). Keratoacanthoma has traditionally been thought to be a benign growth that resembles SCC clinically and histologically. The most unique clinical characteristic is its rapid growth. Over the period of a few weeks, the lesion can grow to several centimeters, then suddenly involute over several additional weeks. Classically, keratoacanthoma manifests as a smooth shiny papule or nodule with telangiectasia and a central kera-totic plug, sometimes with ulceration (appearing similar to the well-differentiated SCC shown in Fig. 42–3). A keratoacanthoma may resemble a miniature volcano during the active growth phase. Unfortunately, the distinction of SCC from a solitary keratoacanthoma often is difficult. There are expert dermatopathologists and clinicians who regard solitary keratoacanthoma as a well-differentiated variant of SCC deserving of equivalent treatment.[40–42] One would be well advised to treat any keratoacanthoma in the same way as SCC because misdiagnosis could lead to inadequate treatment.

Biologic Behavior and Risk Factors

In most cases, SCC is a locally growing neoplasm of sun-exposed skin that is easily diagnosed and treated. In some cases, SCC may infiltrate the surrounding skin and adjacent structures, making treatment more difficult and recurrence after treatment more likely. If growth continues, metastasis may occur. Histology (differentiation, thickness, depth of invasion, perineural involvement), clinical size (diameter), etiology, immune status of the patient, and anatomical site of the tumor all have a role in predicting the risk of recurrence and metastases (Table 42–1). SCCs that recur locally are more likely to metastasize.[43] The most common route of spread for metastatic SCC is lymphatic. In a study of skin cancer mortality in Rhode Island from 1979 to 1987, there were 51 deaths from nonmelanoma skin cancer. Fifty-nine percent of deaths were due to SCC, most of them due to metastases. The mean age was 73 years and 47% of these SCCs arose on the ear. No deaths were due to refusal of treatment by the patient.[44]

Figure 42–4 Large ulcerated squamous cell carcinoma on the left temple/cheek [see Fig. 42–4 (c)].

TABLE 42–1 Squamous Cell Carcinoma Prognostic Factors for Local Recurrence and Metastasis (%)

Factor	Local recurrence	Metastasis
Clinical Presentation		
Diameter		
<2 cm	7.4	9.1
>2 cm	15.2	30.3
Location		
Sun-exposed skin	7.9	5.2
Ear	18.7	11.0
Lip	10.5	13.7
Previously treated	23.3	30.3
Immunosuppression	N/A	12.9
Scar carcinoma (non-sun-exposed)	N/A	37.9
Histology		
Thickness		
<4 mm/Clark I–III	5.3	6.7
>4 mm/Clark IV, V	17.2	45.7
Differentiation		
Well differentiated	13.6	9.2
Poorly differentiated	28.6	32.8
Perineural invasion	47.2	47.3

From Rowe DE, Carroll RJ, Day CL. Prognostic factors for local recurrence, metastasis, and survival rates in squamous cell carcinoma of the skin, ear, and lip. *J Am Acad Dermatol* 1992;26:976–990. With permission.

Figure 42–5 Ulcerated recurrent squamous cell carcinoma on the right forehead with perineural invasion of supratrochlear nerve that extended through the foramen, resulting in CNS involvement. The temporal branch of the facial nerve is also affected, which resulted in right forehead paralysis.

Increased tumor thickness and depth of invasion are the most consistent histopathologic features of cutaneous SCC that recur and metastasize. Invasion into the deep (reticular) dermis, subcutaneous tissue, or below (Clark's level IV and V) is strongly associated with the development of recurrence or metastases.[45–48] In general, the more poorly differentiated the tumor, the higher the risk of recurrence and metastases, but SCCs of any grade can metastasize. A particularly ominous sign is SCC with perineural invasion; there is a high risk of recurrence and metastasis, and direct intracranial extension along nerve fibers is a possibility (Fig. 42–5).[43,49–51] Larger-diameter lesions also have an increased likelihood of recurrence and metastasis.

Anatomical site appears to play an important role in behavior for SCC. Both the ear and the lip are consistently reported to have elevated recurrence and metastasis rates. Other locations that have increased risk for recurrence and metastasis are the nasolabial creases and, periorbital and preauricular regions.[43] Direct invasion of the parotid gland by cutaneous SCC has been reported to have a 50% metastatic rate.[52]

Conditions in which the SCC develops can also affect risk of recurrence and metastasis. SCCs arising in scars, on the edges of ulcers, and in skin damaged by ionizing radiation have substantial potential for metastasis.[43] SCC in organ transplant patients can be more aggressive because host immunosuppression can also increase the risk of metastasis.[29,53]

BASAL CELL CARCINOMA

Epidemiologic and Etiologic Factors

BCC is the most common malignancy in humans. Estimates predict one million cases of nonmelanoma skin cancer in the United States this year and at least three fourths of these will be BCC.[2] Lifetime risk for a Caucasian developing a BCC has been estimated to be 28 to 33%. BCCs can be highly destructive but are almost always characterized by slow growth and by rare metastasis (less than 1%).[9]

BCCs arise from the basal keratinocytes of the epidermis and associated adnexal structures such as hair follicles.[54] Like SCCs, the most common factor involved in the pathogenesis of BCC is UV radiation. In normal individuals a long latency period of 20 to 50 years is typical between the time of UV damage and clinical onset of BCC. Intense, intermittent sun exposure has been implicated in the development of BCC (as opposed to chronic steady exposure with SCC).[55]

Other factors associated with the development of BCC are the same as with SCC. These are environmental factors, such as ionizing radiation and arsenic exposure. Medical conditions associated with BCC development include immunosuppression (in organ transplant patients) and genetic disorders (such as nevoid basal cell carcinoma syndrome).[18] Nevoid basal cell carcinoma syndrome (also called basal cell nevus syndrome or Gorlin's syndrome) is an autosomal dominant condition characterized by continued appearance of many BCCs at an early age.[56] Odontogenic keratocysts, palmoplantar pitting, intracranial calcification, and rib anomalies may also be seen with nevoid basal cell carcinoma syndrome. UV radiation–induced mutations in the human *PATCHED* gene have also been implicated in sporadic cases of BCC as well as nevoid basal cell carcinoma syndrome.[57]

Clinical Characteristics and Precursors

There is no common clinical precursor to BCC as there is with SCC. BCC typically occurs on sun-exposed areas, especially the head and neck and in particular the nose. Patients often present with a nonhealing "sore" of varying duration. Bleeding on slight injury is a common sign. Some BCCs heal spontaneously and form scar tissue as they extend. The lesions are sometimes itchy but often asymptomatic. There is gradual enlargement, with the tumor roughly doubling its 6-month volume at 1 year and quadrupling it at the end of 2 years.[58]

BCC can have a variety of clinical appearances, such as nodular, pigmented, cystic, or superficial. Nodular BCC is the most common variety and is usually composed of one or a few small, waxy, semitranslucent "pearly" papules or nodules that sometimes form around a central depression (Fig. 42–6). The tumor may be eroded, ulcerated, crusted, or bleeding. The trauma necessary for ulceration is usually slight, and patients frequently insist that the lesion is a scratch or razor nick. The edges of larger lesions have a characteristic rolled or raised border and are well circumscribed. Telangiectasias are visible coursing through the lesion. BCC may also be pigmented with brown or black pigmentation. Pigmented BCCs are seen more commonly in dark-skinned individuals and can mimic a mole or even a melanoma (Fig. 42–7). Cystic BCCs (Fig. 42–8) are filled with fluid that makes them look translucent blue-gray. These cystic nodules may mimic benign cystic lesions, especially around the eye where they may be confused with hidrocystomas. Superficial BCCs (Fig. 42–9) usually are pink to reddish brown scaly macules or plaques, seen occasionally with central clearing. Ulceration is less common than in nodular BCC. Superficial BCCs are more common on the trunk where they can be multiple. There is little tendency to become invasive. Superficial BCC may mimic psoriasis, fungus, or eczema. Occurrence of numerous superficial BCCs may be a clue to arsenic exposure.

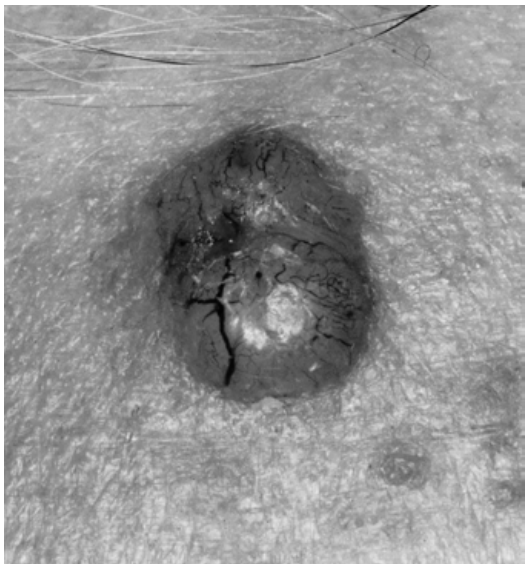

Figure 42–6 Nodular basal cell carcinoma on the left forehead. Note the pearliness, well-circumscribed border, and telangiectasia [see Fig. 42–6 (c)].

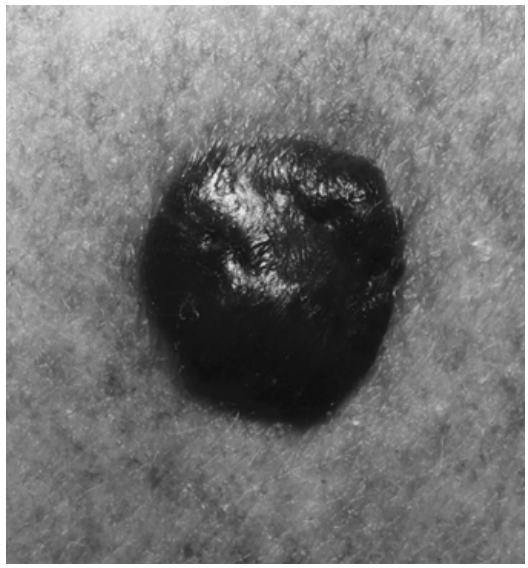

Figure 42–7 Pigmented basal cell carcinoma on the trunk. One might mistake this growth for a melanoma [see Fig. 42–7 (c)].

BCCs can also have the appearance of pale, flat, smooth-surfaced plaques or macules that are typically ill defined (Fig. 42–10). They are usually referred to as "aggressive" BCCs because they have ill-defined borders with deeper extension of tumor that cannot be detected clinically. They are also called "sclerosing" BCCs because they can masquerade as a scar. Telangiectasia, ulceration, erosion, scaling, and crusting are often absent. Clinically this tumor appears as a yellowish white, indurated plaque with ill-defined borders. This is in contrast to nodular BCCs, which usually have well-defined borders. Oftentimes this deeper growth of aggressive BCC goes undetected for a long period and there is enormous destruction of normal tissue by the time the tumor is discovered. This hidden growth is referred to as subclinical extension. Subclinical extension refers to the portion of a tumor that is present histologically but cannot be detected clinically. Even if the border is seemingly well defined, a tumor can invisibly extend far beyond clinically apparent margins. BCCs with subclinical extension may appear yellowish white when the skin is stretched and be firm to the touch

Figure 42–8 Cystic basal cell carcinoma on the left medial canthus/nose.

Figure 42–9 Superficial basal cell carcinoma on the trunk, which could be mistaken for a patch of eczema, fungus, or psoriasis. Note the scaly crusted surface, pearliness, and well-defined borders [see Fig. 42–9 (c)].

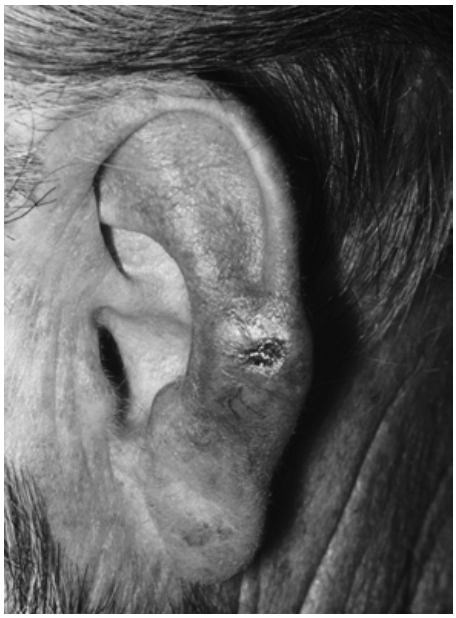

Figure 42–10 "Aggressive" basal cell carcinoma (infiltrative histology) on the left helix. Note the ill-defined border and white, scar-like appearance [see Fig. 42–10 (c)].

Figure 42–11 The same basal cell carcinoma as shown in Figure 42–10. Note that the clinical extent of tumor becomes more evident when the skin is stretched [see Fig. 42–11 (c)].

(Fig. 42–11). Significant subclinical extension is most commonly seen with the morpheaform, infiltrating, and micronodular histologic subtypes, to be discussed under "Biologic Behavior and Risk Factors."

When examining possible skin cancers, it is best to use good lighting and magnification. The affected skin should be stretched, squeezed, and palpated to better estimate the tumor size and depth (Figs. 42–10 and 42–11). Oblique illumination of the tumor can highlight surface changes, such as a "rolled" border. A gentian violet pen can be used to mark the clinical margin of the tumor. Occasionally, the true extent of the tumor can be grossly underestimated because of subclinical extension (Figs. 42–12 and 42–13).

Figure 42–12 A basal cell carcinoma (nodular-infiltrative histology) on the left ala (before Mohs micrographic excision). Gentian violet dots outline the extent of tumor that could be detected clinically.

Figure 42–13 The same basal cell carcinoma in Figure 42–12 but after Mohs micrographic excision. Note the great quantity of tumor that could not be detected clinically (subclinical extension).

Biologic Behavior and Risk Factors

Like SCC, BCC is a locally growing neoplasm that is usually easily diagnosed and treated. In some cases, BCC may infiltrate the surrounding skin and adjacent structures. Although the clinical appearance of the BCC can alert the clinician to the possibility of subclinical extension, the histologic appearance of the BCC obtained from a generous skin biopsy (see biopsy techniques discussed with melanoma) can more accurately predict which BCC will have a greater chance of incomplete surgical removal (and subsequent recurrence).[59] The micronodular, infiltrative, and morpheaform histologic subtypes of BCC can be more difficult to detect clinically and to eradicate than the nodular histologic subtype of BCC because of the patterns of growth within the skin. Micronodular, infiltrative, and morpheaform BCCs grow in a dispersed pattern, enlarging beneath the epidermis by small diffuse finger-like extensions that can permeate through tissue without much displacement of normal tissue. Extension from the epidermis is minimal so that there is little surface change to reveal the tumor during skin examination. In contrast, nodular BCCs have an aggregated pattern that enlarges in a circumscribed expansile manner, displacing more tissue and becoming more raised and clinically evident with time. BCC of any histologic subtype can have malignant extension that is invisible to the eye, but micronodular, infiltrative, and morpheaform types are consistently deceptive and actually much larger than they appear clinically in comparison with nodular BCC.[60–63] Micronodular, infiltrative, and morpheaform BCCs often need larger excision margins to effect complete removal of these subtypes.[64] The invisible portion of tumor may invade deeply into subcutaneous tissue, bone, and cartilage, causing extensive local destruction and mutilation.[65,66]

Death from BCC is uncommon. Metastatic BCC is rare but more cases are being reported.[67,68] In a study of skin cancer mortality in Rhode Island from 1979 to 1987, there were 51 deaths from nonmelanoma skin cancer. Of these deaths, 20% were due to BCC, the mean age was 85 years, and refusal of surgical intervention was documented in 40%. BCCs that metastasize have almost always been subjected to repeated incomplete excisions or represent lesions that have been so neglected as to reach extremely large size without the benefit of treatment.[44] A BCC that metastasizes has an extremely poor prognosis; according to the English literature, the median survival of patients with metastatic basal cell carcinoma is 10 months.[68]

TREATMENT OPTIONS FOR SCC AND BCC

Superficially destructive measures provide adequate treatment for AKs. Cryotherapy or the application of liquid nitrogen (with a temperature of −195°C) to the skin is most commonly used to destroy AKs. Other treatments include topical 5-fluorouracil cream, electrodesiccation and curettage, CO_2 laser, dermabrasion, and chemical peel. If the AK is markedly hyperkeratotic and raised, then a shave or punch biopsy should be done to rule out the possibility of SCC. Those patients who develop AKs have had sufficient chronic photodamage to produce skin cancer, and regular skin cancer checks are recommended. Use of sun screen has been shown to prevent the development of actinic keratoses and, possibly, future skin cancer.[69] Interestingly, a low-fat diet has been shown to reduce the incidence of AK.[70]

The choice of therapeutic modalities is the same for SCC and BCC (Table 42–2). Selection of the most appropriate therapy depends on many factors, including size of the tumor, location, whether the tumor is primary or recurrent (or incompletely treated), histology, and individual patient factors. Careful consideration of the options should be undertaken—especially with SCC, given the greater potential for morbidity and mortality. Standard treatment can be divided into *excision* and *field therapy*. Excision of the tumor is followed by permanent or frozen sectioning of the specimen to check the margins. Field therapies destroy tissue in an area within and around the tumor, and the tissue is not evaluated

TABLE 42–2 Treatment Options for Basal Cell Carcinoma and Squamous Cell Carcinoma

If one or more of these factors are present, then consider **Mohs micrographic excision**:
- *Recurrent tumor*
- *Tumor size* >2 cm in diameter
- *Tumors with an aggressive histology (such as morpheaform, infiltrative, micronodular BCC or poorly differentiated SCC)*
- *Tumors with ill-defined margins*
- *Tumors that are incompletely excised*
- *Tumors with perineural invasion*
- *Tumor location where maximal conservation of normal tissue is important (such as eyelid, nose, ear, lip, digit, genitalia)*

Otherwise consider **standard excision** and use at least:
- *4- to 6-mm margins to a depth of mid- to deep subcutaneous tissue if small (<2 cm) primary BCC/SCC with clinically well-defined borders and nonaggressive histology* ***OR*** *7-mm margins to a depth that includes all of the subcutaneous tissue if factor(s) are present for consideration of Mohs but Mohs is unavailable or patient refuses Mohs.*

Radiation therapy should be considered if patient is a poor surgical candidate or refuses surgery. If Mohs or standard excision shows perineural invasion or positive margins, then radiation therapy should be considered as postoperative treatment.
- *Consider therapies other than radiation therapy if the patient has connective tissue disease (i.e., lupus/scleroderma) or patient is younger than 50 years.*

Less commonly used modalities to consider if none of the above factors are present (these modalities are primarily used for superficial BCC and SCC on the trunk and extremities):
- *Cryosurgery*
- *Curettage and electrodesiccation*
- *Laser*
- *Photodynamic therapy*

BCC, basal cell carcinoma; SCC, squamous cell carcinoma.

TABLE 42–3 Long-Term (5-Year) Recurrence Rates for Treatment of Primary and Recurrent Basal Cell Carcinoma (BCC)

	Recurrence rate (%)	
	Primary BCC	Recurrent BCC
Treatment modality		
Surgical excision	10.1	17.4
Curettage and electrodesiccation	7.7	40.0
Radiation therapy	8.7	9.8
Cryotherapy	7.5	None reported
All non-Mohs modalities	8.7	19.9
Mohs micrographic surgery	1.0	5.6

From Rowe DE, Carroll RJ, Day CL. Long-term recurrence rates in previously untreated (primary) basal cell carcinoma: implications for patient follow-up. *J Dermatol Surg Oncol* 1989;15:315–328, and Rowe DE, Carroll RJ, Day CL. Mohs surgery is the treatment of choice for recurrent (previously treated) basal cell carcinoma. *J Dermatol Surg Oncol* 1989;15:424–431. Reprinted by permission of Blackwell Science, Inc.

histologically for margins. Commonly used field therapies include radiation therapy, cryosurgery, and curettage and electrodesiccation.

Excision is the treatment of choice for most SCCs and BCCs. A standard excision is usually done under local anesthetic, and the tumor is removed with a margin of clinically normal-appearing skin. Selected vertical sections (either frozen or permanent) from the specimen are then examined microscopically to determine if margins are free of tumor. Unfortunately, this method samples less than 1% of the true surgical margin, leaving the possibility that the examined sections may not include areas in the specimen where there are tumor extensions. Despite this disadvantage, cure rates greater than 90% can be obtained in many cases with standard excision for SCC and BCC.[43,71] Although it is potentially dangerous to assign a "standard" margin, current surgical recommendations call for margins of 4 mm of healthy tissue in excision of nodular BCC and more than 7 mm in aggressive BCC.[60–62,72] For SCC, one study proposed minimal margins of excision of 4 to 6 mm around the clinical borders.[73]

Mohs micrographic excision (MME) uses horizontal frozen sections and intraoperative tumor mapping to provide a higher cure rate for SCC and BCC than standard excision while leaving a smaller wound. When compared with other modalities, MME obtains higher cure rates—as high as 99% for primary BCC and SCC[43,74] (Table 42–3). The reason for the high cure rate is that 100% of the surgical margin (deep and peripheral) is examined microscopically in combination with precise mapping of the surgical site and histologic specimen.

At the beginning of Mohs excision (Fig. 42–14) the skin is anesthetized and the tumor is excised just beyond the clinical margin. The tissue is frozen and very thin sections are mounted on microscope slides. The tissue is oriented so that the sections are made horizontally across the deep and lateral margins of the specimen instead of vertically (the usual method). The surgeon then reads these sections, looking for remaining tumor cells by examining the entire periphery. By mapping the tumor site, the surgeon can pinpoint the location of residual disease and remove only the area that contains cancerous tissue. One or more layers may need to be excised and inspected before all residual cancer cells are found. A more detailed description can be found elsewhere.[75]

MME should be very seriously considered for SCCs or BCCs that are recurrent, large (greater than 1 cm), or that have indistinct margins or are in critical locations. A critical location may be defined as one where tissue sparing is paramount (e.g., nasal tip, eyelid, concha) or recurrence is com-

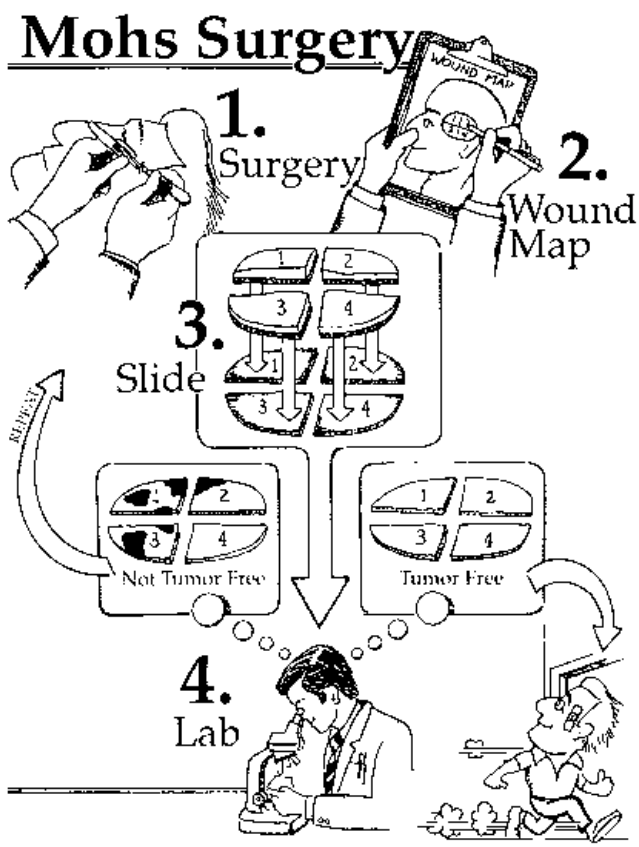

Figure 42–14 Steps in Mohs micrographic surgery.

mon (e.g., nose, ear, periocular). MME should also be considered for the more difficult histologic patterns, such as poorly differentiated SCC or BCC with morpheaform, infiltrative, micronodular, or mixed morphology or tumors with perineural involvement. If positive margins are reported after standard excision with no obvious clinical tumor, then MME should be considered. The need for MME increases when a number of these factors are present (i.e., recurrence, infiltrative histology, perineural invasion, etc.).

Cryosurgery, a field therapy, destroys tissue by freezing (usually with liquid nitrogen) to a tumoricidal temperature. In most cases, cryosurgery is best limited to small, superficial SCCs and BCCs. In skilled hands, cryosurgery will give a cure rate in excess of 95% on selected SCCs and BCCs.[76] Wounds heal with second intention and leave hypopigmented, soft, sometimes depressed scars. The technique for freezing skin cancers is distinctly different from the light freeze for AKs.[77]

Curettage followed by electrosurgery is indicated only for the smallest, most superficial, and well-circumscribed SCCs and BCCs. The curette has a sharp edge that scrapes away soft tumor tissue followed by electrodesiccation of the wound base. The cosmetic appearance is usually minimally satisfactory. In one study, for sites at low risk for recurrence (neck, trunk, and extremities), BCCs of all diameters responded well to curettage and electrodesiccation, with an overall 5-year recurrence rate of 3.3%.[78]

Radiation therapy, another field therapy, can be used as a primary therapeutic alternative to surgery if the case dictates, or as an adjunctive therapy to surgery.[79] The latter approach should receive consideration when dealing with high-risk cutaneous SCCs and BCCs (e.g., an SCC that is poorly differentiated, large, recurrent, deeply penetrating, or perineural). In high-risk SCCs, radiation therapy is sometimes employed to treat the nodal basin prophylactically after the primary tumor has been excised.[80–82] Radiation therapy is a proven field therapy that achieves cure rates in excess of 90% for appropriately selected patients with SCC and BCC. It is an excellent choice for patients who are not good surgical candidates or do not wish to have surgery.[83]

In summary, SCCs and BCCs are the most commonly encountered skin cancers in the world. Clinicians should be familiar with their clinical appearance so that diagnosis and treatment can be initiated early. When treatment is delayed significant morbidity and mortality can ensue. Many therapies obtain reasonable cure rates, but Mohs micrographic excision remains the gold standard.

MELANOMA

Epidemiologic and Etiologic Factors

Melanoma is a malignancy arising from melanocytes, the pigment-producing cells of the skin. It accounts for approximately 4% of skin cancers, with more than 41,000 new invasive melanomas, 21,000 new melanomas in situ, and approximately 7300 melanoma deaths annually in the United States.[2] Usually, it arises in sun-exposed areas. Commonly, melanomas in women arise on the lower extremities. In men, they commonly arise on the trunk and the head and neck region (Fig. 42–15). The primary cause of melanoma is believed to be exposure to UV radiation from the sun.[84] Experimental data from a possum model suggest that exposure of animals to UV light early in life can lead to metastatic melanoma in later life.[85] Other studies suggest that UV-B irradiation of human skin engrafted on mice leads to the development of nevi and melanomas.[86] However, the exact etiologic role of UV light is not entirely understood, and there are melanomas that arise in areas not exposed to the sun. The association between melanoma and sun exposure is based on a number of observations, including studies showing that people with severe burns in childhood seem to be at higher risk for developing melanoma later in life.[84] It is of interest that people who have been exposed to the sun on a regular basis appear not to be at increased risk of melanoma. Chronic sun exposure in people who tan well does not appear to be associated with increased risk and may even be protective.[87] Persons at highest risk for melanoma are those with fair complexions who have had intermittent sun exposure and severe sunburns. In particular, the skin type most associated with melanoma is a Celtic complexion, including pale skin, freckles, blond or reddish hair, and light eyes. Melanoma is uncommon in Caucasians with dark skin and even more uncommon in people of Asian or African American background.

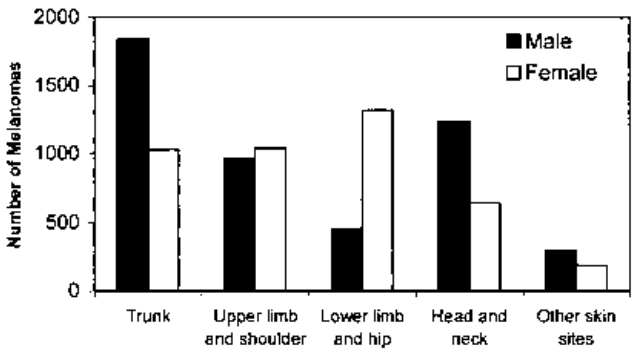

Figure 42–15 In a population-based registry, there is association between patient gender and body site of primary melanoma. Women are much more likely to develop melanomas of the lower extremity, whereas men are more likely to develop melanomas of the trunk and of the head and neck. (Adapted from data in Norris SLW. Melanoma in Virginia 1970–1996. In: Pugh AM, Slingluff CL Jr, and Woolard D (eds). Virginia Cancer Registry, Virginia Department of Health, 1999.)

Clinical Characteristics

Many melanomas arise from preexisting nevi, though most probably arise de novo. Usually they have irregular borders and variations in color. Often they are raised above the skin surface. Occasionally, they are black without any other coloration. Any skin growths with these characteristics should be evaluated by a physician, and if there is any doubt a biopsy should be performed. A mnemonic useful for identifying melanomas is: A (asymmetry), B (border irregularity), C (color variation), D (diameter greater than 6 mm). Lesions that are also elevated are of even greater concern. All of these

Figure 42–16 A thick melanoma on the upper chest that is characterized by asymmetry, border irregularity, color variations, diameter greater than 6 mm, and marked elevation. The black, flatter portion measured 11 × 14 mm across. The raised reddish nodule was 1 cm across and 4 mm high. The Breslow thickness was 4.3 mm. (From Slingluff CL Jr. Pigmented skin lesions. In: Schirmer B, Rattner DW (eds). *Ambulatory surgery*. Philadelphia: WB Saunders, 1998:386–392. With permission.)

Figure 42–17 An intermediate-thickness melanoma was diagnosed on the right temple on a woman in her mid-30s with fair skin and red hair. It was Breslow thickness 2.9 mm, with a raised nodule in the center.

features are evident in the melanoma shown in Figures 42–16 and 42–17. Realizing, however, that the goal is to diagnose melanoma early; small and flat lesions that satisfy the A-B-C criteria or are totally black should be considered suspicious. The lesion in Figure 42–18 is extensive but was almost totally flat. Excision revealed the lesion to be a dysplastic nevus containing a 3-mm-wide melanoma, only 0.8 mm thick. His prognosis is good and can be attributed to early diagnosis. If a melanoma is diagnosed and removed when very thin, cure is likely. If it is diagnosed when thick, metastasis may have occurred and cure is less likely. Signs that are particularly worrisome in a primary lesion would be itching, bleeding, ulceration, and the presence of satellite lesions.

Unfortunately, some melanomas do not have brown or black pigment, and look very much like normal skin. These can be very difficult to diagnose, even by an experienced physician. Among these amelanotic melanomas, there are a disproportionate number that fit into an uncommon histologic group: the desmoplastic melanomas.[88] Given the variable presentations of melanoma, any pigmented skin lesion that has changed should be evaluated for possible biopsy.

Though melanoma arises in defined cutaneous sites in approximately 90% of cases, it can also arise from mucous membranes, from the eye, from unknown sites, or, rarely, from viscera. These presentations are uncommon but well described, and familiarity with each is important in the management of patients with melanoma.

Approximately 1 to 2% of melanomas arise from mucous membrane sites, and these are distributed equally among three different body areas: the mucous membranes of the

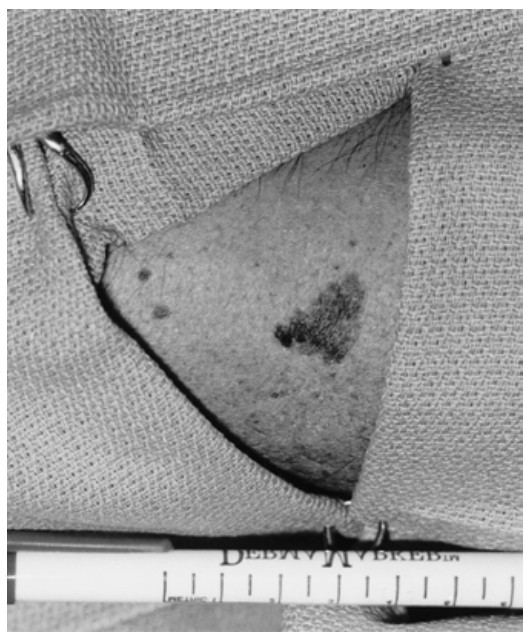

Figure 42–18 The melanoma arising in this large dysplastic nevus was in the more darkly pigmented portion and was only 3 mm across and 0.8 mm deep. The remainder of the lesion was benign. The entire lesion was excised with a 1-cm margin. (From Slingluff CL Jr. Pigmented skin lesions. In: Schirmer B, Rattner DW (eds). *Ambulatory surgery*. Philadelphia: WB Saunders, 1998:386–392. With permission.)

head and neck (oropharynx, nasopharynx, and sinuses), the anorectal region, and the female genital tract.[89] These lesions are usually large when diagnosed because they are in areas not readily visible to the patient or to family. They are usually associated with a very poor prognosis.[90] Though up to 10 to 20% of patients may be alive at 5 years, the vast majority of patients will ultimately succumb to the disease. Radical resection does not appear to improve patient survival, compared with wide excision, but it may improve local-regional control.[91]

Ocular melanomas account for 2 to 5% of melanomas, and they may arise from the retina, the iris, the ciliary body, or other sites in the eye. These melanomas are often identified as small lesions as they may be visible or may affect vision. Often they can be treated by radiation, but advanced lesions require enucleation. Though these tumors share many phenotypic features with cutaneous melanomas, they behave in a distinct pattern. Nodal metastases are rarely seen, presumably because of the lack of ocular lymphatics.[92] Instead, the first site of metastasis is almost always the liver. In many cases, it is the only site of metastasis and the liver metastases are the cause of death.

Very rarely, melanomas arise primarily in viscera, such as esophagus and lung. The esophagus contains normal melanocytes in 3% of normal individuals, and these can transform into melanoma.[93] These, like mucosal melanomas, are usually diagnosed when they have become large.

In 5 to 10% of patients who present with metastatic melanoma, no primary melanoma can be identified. These most commonly present as melanoma in a lymph node or in cutaneous sites.[94] In some cases, a history of a pigmented lesion that spontaneously regressed can be elicited. In some cases, it is believed that the immune system may have destroyed the primary melanoma. Another hypothesis for melanoma in a lymph node without a known primary is that the melanoma may have arisen there primarily, as isolated nests of nevus cells can be found incidentally in some lymph nodes. However, most cases remain unexplained.

Biologic Behavior

Although wide excision of melanoma is curative in some cases, all invasive melanomas have some risk of metastasis; the risk correlates well with the maximal thickness (Breslow thickness) of the primary melanoma.[95] Melanomas typically metastasize through lymphatic channels, usually to the regional nodes draining the primary melanoma. If a melanoma arises on an extremity, the most common place for metastases to be found is in the axillary or inguinal nodes, respectively. However, when a melanoma arises on the trunk or on the head and neck, lymphatic drainage patterns can be less predictable.

A total of 80 to 90% of first metastases of melanoma can be found on physical examination, either in the skin or in lymph nodes. Metastases in the skin typically appear as nodules that are either black or dark blue, but they may appear without any color. When melanoma metastasizes to lymph nodes, the nodes usually appear round and hard, resembling marbles. Usually there is no tenderness or pain associated with them. Surgery often permits complete removal of cutaneous and isolated nodal metastases, and some patients treated surgically for nodal or cutaneous metastases survive for years without distant disease.

Unfortunately, however, melanoma is also prone to metastasize to visceral sites through hematogenous dissemination. Often little can be done to effect cure in those cases, but some treatments may be helpful, including chemotherapy and cytokine therapy. There are novel experimental immunotherapy approaches available in certain circumstances, including several melanoma vaccine approaches. In rare cases, durable complete responses occur after systemic therapy with chemotherapy or with immunotherapy, including administration of interleukin-2.

Biopsy Techniques

The diagnosis of a skin lesion can be made easily with a simple biopsy. It is important to realize that there can be a difference between removing a skin lesion and making a diagnosis. Shave biopsies are often performed for the easy removal of benign skin lesions, such as keratoses, but significant diagnostic and prognostic information can be lost if a shave biopsy is performed for a lesion suspected to be melanoma. In particular, there are difficult diagnostic dilemmas for pathologists that can be made more difficult without complete tissue excision. One of these is distinguishing a melanoma from a Spitz nevus.[96,97] Spitz nevi are much more common in children but can be found in adults. Because some of the distinction is based on the architecture of the entire lesion, a shave biopsy that does not encompass the entire lesion may result in an inaccurate diagnosis or a delayed diagnosis. A more common problem is that a shave biopsy may not include the base of the lesion, thus preventing an accurate assessment of the tumor thickness. This limits the prognostic information available to patients and may affect the extent of subsequent surgery and the candidacy for adjuvant therapy. The goals, if melanoma is suspected, should be to (1) make a diagnosis, (2) collect the most prognostic information possible, and (3) facilitate subsequent therapy.

The principles that will ensure fulfillment of these goals are as follows: (1) always take full-thickness biopsies; (2) include a rim of normal skin in the biopsy; and (3) on extremities, orient the incision longitudinally. A full-thickness biopsy should, by definition, include all layers of the skin, so that the subcutis is entered during the biopsy. Excision of a small ellipse of skin with a scalpel is usually done for a full-thickness biopsy. Normal skin included in the biopsy need not be extensive. A 1 to 2-mm margin of normal skin permits the pathologist to examine the junctional changes that are critical to identifying melanoma and to determine if it is a primary or a metastatic lesion.

These biopsies are easily performed in the outpatient or ambulatory setting. No preoperative laboratory studies are needed. Under local anesthesia, the lesion is then excised with a 1- to 2-mm margin, lifting the skin up with an Adson forcep. Hemostasis can usually be achieved without electrocautery by a combination of gentle pressure and suture closure. The incision is closed, in many cases, with a subcuticular 4-0 absorbable suture and sterile strips. If there is significant tension, a few interrupted nonabsorbable 4-0 sutures will suffice. The wound can be covered with a sterile dry dressing for 2 to 3 days.

In some cases, the lesion of concern is large enough that even simple excision would leave a large wound, with concern for functional and cosmetic implications. In those cases, excision of the portion of the lesion of greatest concern may be adequate for a diagnosis. Again, some normal skin should be included at a margin. It is important that the full thickness of the lesion be evaluated in the biopsy. Because wide reexcision is always performed after the biopsy, partial excision of a melanoma is not generally thought to compromise subsequent therapy; however, the possibility of effects on prognosis has not been ruled out.[98] Thus, it is wise to perform complete excisional biopsy when feasible.

In some cases, a punch biopsy technique may be useful, such as with small nevi. A punch biopsy instrument is a disposable circular blade on a handle that can be used to excise a small circle of full-thickness skin. Punch biopsy instruments for excisions 4, 5, or 6 mm in diameter are useful for quick excisions of small nevi. It is important when using a punch to be certain the lesion can be completely excised with a 1- to 2-mm margin and also to be careful not to crush the lesion when excising it. After punching out the skin, the circle of skin containing the lesion must be excised with scissors just below the dermis. A fine forcep can be used to elevate the skin circle while cutting underneath it. After excision, the lesion should be placed in formalin and sent for histologic evaluation. Lesions larger than 2 to 4 mm should not be excised with a punch biopsy because evaluation of the junctional zone at the edge of the lesion can be very important for a definitive diagnosis.

At least as important as the instructions listed previously is the choice of skin incision. Especially on extremities, the orientation of the initial skin biopsy is a critical determinant of the subsequent therapy. If the pigmented lesion is melanoma, a wide excision will be needed, the orientation of which is determined largely by the orientation of the initial excision. It is difficult to close a transverse incision on an extremity primarily; thus, a transverse incision is more likely to require a skin graft. Also, because the innervation to skin surfaces runs longitudinally, a transversely oriented excision will interrupt more of the innervation to skin distal to the lesion. On the other hand, an incision that crosses a joint may lead to a contracture that limits range of motion; so extremity excisions near a joint may need to be oriented transversely or closed with a Z-plasty across the joint. On the head and neck region, the orientation of a biopsy incision should be selected with consideration of how it may affect subsequent reexcision or node dissection incisions.

Prognosis and Staging

The pathologist looks for several characteristics when a primary melanoma is diagnosed in a skin biopsy. The most important of these is thickness (Breslow thickness), which is measured in millimeters. Melanomas thinner than 0.76 mm have classically been considered thin melanomas and are unlikely to recur once removed.[99,100] Currently, thin melanomas include lesions up to 1 mm thick. Melanomas thicker than 4 mm are considered thick melanomas and have a greater than 50% chance of recurring or metastasizing to other organs.[101] Melanomas that are intermediate in thickness have a likelihood of recurrence that averages roughly 30 to 40%. As examples, the patients with the melanomas pictured in Figures 42–16 and 42–18 developed axillary nodal metastases and systemic metastases, respectively, within 3 years of diagnosis.

Several additional histologic features of melanomas can be important in considering the overall prognosis. These include the Clark level, growth phase, ulceration, mitotic rate, lymphovascular invasion, satellite lesions, and the presence or absence of tumor-infiltrating lymphocytes. Clark level refers to the depth of invasion of the lesion, relative to the anatomic layers of the skin.[102] A Clark level I lesion is a melanoma in situ, confined to the epidermis, with no significant metastatic potential. A Clark level II lesion involves the superficial (papillary) dermis and is usually associated with a good prognosis. A Clark level III lesion fills the papillary dermis, and a Clark level IV lesion invades the reticular dermis and is associated with a poor prognosis. A Clark level V lesion invades full thickness into the subcutaneous fat and is generally associated with a very high mortality risk. Although these measures are useful, distinction between levels III and IV is not always reproducible among good pathologists, and the Breslow thickness is a more reproducible prognostic factor. Also, in multivariate analyses, Clark level adds little to Breslow thickness in determining prognosis.

Most melanomas go through two growth phases, the first being a radial growth phase (RGP), when the tumor cells proliferate at the dermal–epidermal junction and the tumor expands radially. This may include lesions confined to the epidermis and those with superficial dermal involvement. Subsequently, the lesion begins to invade more deeply into the dermis, with expansile nests of cells growing vertically. This is often associated with the development of a palpable nodule in the lesion, and this is considered the vertical growth phase (VGP). A common presentation of melanoma in the head and neck region is Hutchinson's melanotic freckle (lentigo maligna), which is a form of melanoma in situ commonly arising on the face, more commonly in women. A VGP is that portion of the tumor associated with metastatic risk. In some cases, a desmoplastic melanoma may arise from a lentigo maligna. Similar patterns of radial and vertical growth also occur with superficial spreading melanomas and acral lentiginous melanomas. The exception to this sequence of growth phases involves the nodular type of melanoma, which only has a VGP. Some lesions are excised early, while still in the RGP, and there are data to suggest that these lesions have no metastatic potential.[103–105] Usually, patients with thin melanomas have an excellent prognosis, but a small percentage go on to develop metastatic disease, and it appears that part of the explanation for this may be attributed to thin VGP lesions that do have metastatic potential. Most of the thicker melanomas are in VGP.

Ulceration is a poor prognostic sign and is more common in thicker lesions.[101,106] A high mitotic rate is also associated with a poor prognosis, with lesions containing more than 6 mitoses/mm^2 being at higher risk than those with fewer mitoses. Similarly, lesions with microscopic satellites or lymphovascular invasion appear to be at higher risk. A protective feature may be the presence of a cellular immune response to the tumor, as evidenced by lymphocytes infil-

trating into the tumor mass itself. When tumor-infiltrating lymphocyte response is brisk, there is a significantly improved prognosis.[105,107]

When a patient presents for definitive therapy following initial diagnosis, it is important to make an initial assessment of the stage of disease. The vast majority of melanomas present with clinically localized disease, but occasionally patients have clinically evident nodal or visceral metastases. The first step in evaluation includes a history and review of systems, looking for evidence of bone pain, mental status changes, cough, headaches, weight loss, or other new systemic symptoms that may suggest metastases to bone, lung, liver, or brain. A careful physical examination should focus on evaluation of the regional nodal basins for lymphadenopathy, as the first site of metastasis is usually to those nodes. The examination should also include a detailed evaluation of the skin and subcutis between the primary site and the regional nodes, as in-transit metastases are also common. In addition, distant skin metastases should be sought, as they are fairly common metastatic sites and are best identified by physical examination. A chest x-ray and a serum lactate dehydrogenase are reasonable screening studies to identify patients who may have metastases to lung and liver, though the yield is low in patients without clinical evidence of metastases.[108–110] Routine CT scans or bone scans are not indicated if these evaluations are all negative. However, specific studies to evaluate worrisome symptoms or physical findings may be indicated.

If a patient has evidence of distant metastases, then aggressive management of local and regional disease is not indicated. Instead, systemic therapy must be considered. Fortunately, this is uncommon, and most patients will present without evidence of metastasis. In these patients, the focus of definitive therapy will be on wide excision of the primary lesion and consideration of surgical staging of the regional nodes.

American Joint Council on Cancer (AJCC) staging for melanoma is based on the TNM system. The T stage is based on the tumor thickness (T1: <0.76 mm or Clark II; T2: 0.76–1.5 mm or Clark III; T3: 1.5–4 mm or Clark IV; T4: >4 mm or Clark V). Stage I includes T1 N0 M0 and T2 N0 M0. Stage II includes T3 N0 M0 and T4 N0 M0. Nodal metastases or intransit metastases qualify for N1 status. Bulky nodes are graded as N2. Stage III includes T_{any} N1 M0 and T_{any} N2 M0, and stage IV includes T_{any} N_{any} M1. Recommendations in 1999 for changing the AJCC staging criteria are being formally considered, and they likely will be adopted. With these changes, ulceration will be included as a part of staging the primary lesion, and the N staging will also take into account the number of positive nodes, which is well documented as the single most important prognostic factor in patients with nodal metastases.[106]

Treatment

The definitive treatment of melanoma of the skin includes wide excision of the initial biopsy site. The goal is to remove an area of normal skin around the primary melanoma to remove dermal or subcutaneous micrometastases that often occur as a result of lymphatic spread. By doing so, we reduce the chance of the melanoma recurring locally. For melanomas in situ (Clark level I, confined to the epidermis and epidermal–dermal junction), a 5-mm margin is adequate. Thin melanomas, up to 1 mm in thickness, should be excised with a 1-cm margin.[111] Thicker melanomas are usually managed with a 2-cm margin. In many locations on the body, this can be accomplished with an elliptical skin incision and the wound can be closed primarily. In some locations, a skin graft may be required. This is particularly true on the face, hands, and feet but may be true on other parts of the body as well. In some of these locations, concern for appearance or function may require taking smaller margins to permit primary closure.

The basis for the current recommendations for wide excision margins is clinical experience with 2-cm margins showing good local control in thick lesions. Also, randomized clini-cal trial data from the Intergroup trial show that 2-cm margins provide the same local control and survival as 4-cm margins for melanomas 1 to 4 mm thick.[101,112,113] Furthermore, 1-cm margins provide the same local and distant control as 2-cm margins for melanomas up to 1 mm in thickness.[114] For melanomas 1 to 2 mm thick, a slight increase in local recurrence (less than 5% of patients) was observed, without impact on survival.[114] Thus, for some lesions up to 2 mm in thickness it is reasonable to perform excisions with a 1-cm margin.[115] It is common in the head and neck region for cosmetic concerns and anatomic constraints to prevent excisions larger than 1 cm in some cases, and these data justify use of narrower margins in certain cases.

Wide excisions can generally be performed easily in the outpatient or ambulatory setting but require more time than a simple skin biopsy. The goals of the wide excision are to (1) obtain an adequate margin of normal tissue radially, (2) resect full-thickness skin and subcutaneous tissue in the area of concern, and (3) minimize morbidity. This is usually best performed in an operating room using local anesthetic (lidocaine 1%, with epinephrine 1:100,000 to slow systemic distribution and sodium bicarbonate 0.084% to decrease patient discomfort) and intravenous sedation. In most cases, a complete excision has been performed prior to the wide excision; however, in cases where residual melanoma is present, it may be wise to cover the lesion with an adherent plastic barrier to prevent possible transfer of melanoma cells to the wound edges. An incision is planned, first by measuring the appropriate margin of excision around the initial scar or residual melanoma, then by extending the ellipse in the direction that will best permit primary closure under the least tension. After the planned ellipse of skin has been marked out, a field block can be performed with the lidocaine, being careful to anesthetize deeply through the full thickness of the subcutaneous tissue. The incision is then made with a scalpel and deepened through full thickness of subcutis, down to the muscle fascia with electrocautery in all directions. The attachments to the fascia are divided with electrocautery as the specimen is lifted from the wound. An Allis clamp is useful for grasping one end of the skin as the dissection progresses. When large cutaneous nerves are encountered deep to the subcutis along the surface of the deep fascia, they can be preserved. When they run through the superficial subcutaneous tissue or innervate the excised skin, they should be sacrificed.

Closure of the wide excision can usually be accomplished, under some tension, in two layers, using interrupted

3-0 absorbable sutures to reapproximate the subcutaneous fascia, followed by 3-0 nonabsorbable monofilament sutures in a full-thickness vertical mattress pattern to reapproximate the skin and to reinforce the subcutaneous closure. Where the subcutaneous tissue is not substantial, vertical mattress sutures in the skin will suffice. The closure will usually heal well, and the skin and scar will stretch with time, much as is observed with tissue expanders; so the tension will resolve over a few weeks to months. When there is significant tension, the sutures generally should be left in place for 2 weeks.

Where the wide excision wound does not close easily, some limited undermining of the skin can permit closure. If this fails or is not feasible, a skin graft may be needed. Large myocutaneous flaps are not usually recommended because of the difficulty of evaluating for early local recurrences in that setting. However, split-thickness skin grafts, harvested from areas distant from or contralateral to the primary site, can be used to cover a defect. In body sites where cosmesis is a major concern, a full-thickness skin graft may be harvested from the inguinal area, neck, abdomen, or inferior gluteal region and used in a fashion similar to that of a split thickness graft. A graft placed near a joint will heal better if the limb is immobilized in a splint. The dressing and splint may be removed after 5 days and the surgical site cared for in a routine fashion. With 1 to 2 cm margins of excision, skin grafts are rarely required on the back or proximal extremities. However, wide excisions are often difficult to close on the distal extremities and on the face and scalp; therefore, these areas are more likely to require skin grafts.

Melanomas of the head and neck can arise in many different locations, and for many of them there are special considerations related to the wide excision (Fig. 42–19). For these melanomas, the deep margin of excision often is not muscle; the extent of resection must be individualized depending on the location and the extent of the lesion. Melanomas of the external ear, unless very superficial, often require wedge resection of the cartilage and primary closure. In patients who wear glasses, preservation of the upper portion of the external ear is particularly important. Amputation and reconstruction of the external ear is generally reserved for patients with very extensive local disease. For melanomas of the nose, the perichondrium often can be spared unless there is gross involvement of the subcutaneous tissue with tumor. Scalp melanomas tend to have a particularly poor prognosis, and they should be excised with the underlying fascia but not with periosteum. Melanomas overlying the parotid gland should be excised down to the parotid fascia. In cases where the deep or lateral margins are expected to be close to important anatomic structures, it is reasonable to perform the excision and to leave the wound open until the final pathology report is available. At that point, reexcision or coverage can be performed as a separate procedure. This approach can permit sparing of critical structures while ensuring adequate margins before any local flaps or grafts are applied.[116]

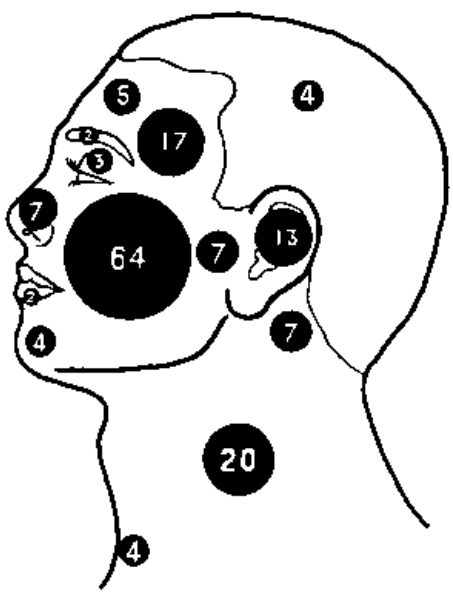

Figure 42–19 The number of melanomas arising in each area of the head and neck, based on experience in Queensland. (From Harris TJ, Hinckley DM. Melanoma of the head and neck in Queensland. 1983;5:197–203. With permission.)

For melanomas of the scalp, appropriate methods of closure include local advancement flaps, pinwheel flaps, or split-thickness skin grafts. The hair will usually cover these areas well. On the face and neck, the cosmetic concerns are more substantial. Alternatives to free skin grafts include simple advancement flaps or rotational or free vascularized flaps. Free flaps or large rotational flaps are generally discouraged for closure of melanoma wide-excision wounds because of the difficulty in following these areas in the event of local recurrence and because some patients will have unsuspected satellite lesions at or near the margins. Creation of a large complex wound puts the patient at risk for a local recurrence that extends over a large area and that may be very difficult to manage. However, small rotation flaps and simple advancement flaps can be used with good cosmesis. It is critical to ensure adequate margins of excision prior to any major reconstructive effort, especially where local recurrence may threaten adjacent structures.

Surgical Management of Clinically Negative Regional Nodal Basins

One of the most debated issues in the management of melanoma has been the appropriate surgical management of clinically negative regional lymph node basins. Evidence is accumulating that elective lymph node dissections (ELND) do not provide a survival advantage over selective dissections of nodal basins when palpable nodal metastases are evident. Though subset analysis of the recently published data from the Intergroup trial has been interpreted to show that for a subset of patients there is a survival advantage to ELND, when reasonable statistical principles are applied to these subset analyses the differences are not statistically significant.[117] More recent follow-up data suggest that there may in fact be a small improvement in survival for melanomas 1 to 2 mm thick when elective node dissection is performed (Balch CM, abstract presented at Society of Surgical Oncology meeting, March 1999). However, an earlier World Health Organization study and a Mayo Clinic study found no evidence for a survival advantage with ELND when compared with delayed, selective lymphadenectomy in patients with isolated nodal metastases.[118–120] Even the Intergroup data, when considering the entire popu-

lation of patients with melanomas 1 to 4 mm thick, show no difference in survival with ELND. The only studies that show a significant improvement in survival after ELND were retrospective nonrandomized studies.[121,122] More recent reviews from the same institutions, with longer follow-up, found that patients with ELND had the same likelihood of survival as patients managed with wide excision only.[123,124]

Independent of the potential effects of ELND on patient survival, there is strong prognostic value in knowing the status of the regional nodes in patients with melanoma. Also, knowing the status of regional nodes can affect therapeutic decisions. Interferon-alfa is FDA-approved for the adjuvant therapy of melanoma patients with thick melanomas or with positive nodes, and there are numerous experimental trials of melanoma vaccines for which the status of the regional nodes is required for entry in those trials. Unfortunately, the morbidity of lymphadenectomy can be significant, especially for inguinal nodes. An approach that permits accurate staging of the regional nodes without complete lymphadenectomy is sentinel lymph node biopsy. The technique for sentinel lymph node biopsy was first described by Dr. Donald Morton in the early 1990s[125] and has been widely adopted since for the management of melanoma. It has been demonstrated that the node (or nodes) draining a primary tumor site can, in the vast majority of cases, be identified either by lymphatic mapping using a vital blue dye or a technetium-labeled sulfur colloid injected into the skin. Current estimates are that the sentinel node reflects the status of the entire nodal basin in 98 to 99% of cases.[126] Thus, if 20% of patients with intermediate-thickness melanomas have nodal metastases, 1 to 2% of these metastases may not be detected by sentinel node biopsy. This represents approximately 5 to 10% of persons with positive nodes. On the other hand, the application of serial sectioning and immunohistochemistry on the sentinel nodes may identify nodal metastases that would have been missed on routine evaluation of one face of each node using hematoxylin and eosin (H&E) stains. In one large series, 26% of nodal metastases detected in the sentinel nodes were found by serial sectioning and immunohistochemistry only.[127] Thus, the net sensitivity of sentinel node biopsy may exceed that of standard complete node dissections because the pathologist can examine the sentinel nodes more carefully than is practical for an entire node dissection (i.e., by serial sectioning and immunohistochemistry).

After a negative sentinel node biopsy, 4.1% of patients may develop palpable nodal metastases in that basin.[128] This compares favorably with the 4% rate of nodal recurrences following a negative elective complete node dissection.[123]

The attractiveness of sentinel node biopsies is that reliable staging information can be obtained with minimal morbidity, using a technique that requires only local anesthesia and that can be performed at the time of wide local excision. This procedure can generally be performed on an outpatient basis, and it often requires only a local anesthetic. If metastatic melanoma is found in the nodal basin, then a complete node dissection can be scheduled electively. The finding of a positive sentinel node upstages a patient to stage III, making him or her eligible for adjuvant therapy with high-dose interferon-alfa or for inclusion in experimental tumor vaccine protocols. It is reasonable to consider sentinel node biopsy in patients with melanomas thicker than 1 to 1.5 mm. Some patients may be offered sentinel node biopsy in the setting of more minimal disease. It can be argued that the risk of metastatic disease is so low in patients with melanomas in situ or with radial growth phase melanomas that sentinel node biopsy is not indicated in those cases.

Most surgeons use technetium-99-labeled sulfur colloid to identify the draining nodal basin and to localize the sentinel nodes preoperatively. A hand-held gamma camera can then be used intraoperatively to localize the sentinel nodes definitively prior to and after excision. Simultaneous injection of vital blue dye can further confirm the identity of radiolabeled nodes as sentinel; some surgeons use both techniques together. The use of technetium-99-labeled sulfur colloid for intraoperative localization has been found to be effective without blue dye[129] and can improve the accuracy of intraoperative mapping better than to blue dye alone.[130]

Routine use of lymphoscintigraphy has permitted a detailed understanding of the variability of lymphatic patterns among individuals. In 34 to 84% of patients with head and neck melanomas, the draining nodes are in basins that would not have been predicted clinically.[131,132] The impact of sentinel node biopsy techniques on patients with head and neck melanoma is that it permits accurate staging without performance of a complete neck dissection and without parotidectomy in the majority of cases. This may spare many patients the substantial morbidity of that surgery while still permitting detailed staging.

Surgical Management of Palpable Nodal Metastases

When melanoma recurs in a regional nodal basin, complete resection of the nodal basin is associated with regional control in the vast majority of cases and with long-term survival in a significant minority (Fig. 42–20). For patients with a single

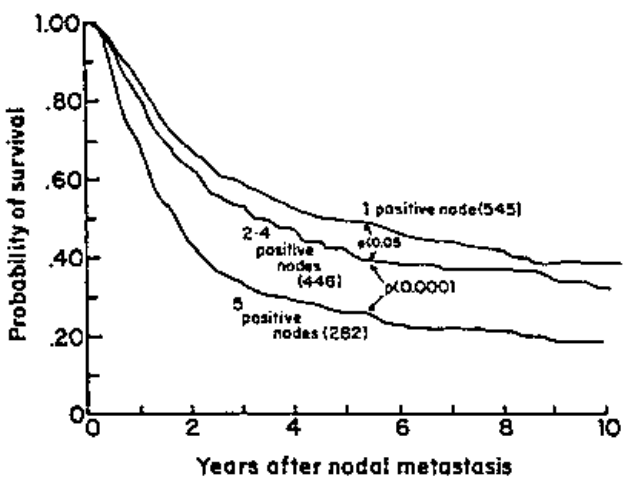

Figure 42–20 The 10-year survival of patients treated with lymphadenectomy for regional nodal metastases of melanoma is demonstrated for patients with one positive node and for groups of patients with a larger number of positive nodes. (From Slingluff CL, Vollmer R, Seigler HF. Stage II malignant melanoma: presentation of a prognostic model and an assessment of specific active immunotherapy—1273 patients. *J Surg Oncol* 1988;39:139–147. With permission.)

nodal metastasis, 10-year survival is approximately 40% after complete node dissection, and for patients with more nodes, there still is a significant chance of long-term survival.[133] Thus, resection of nodal metastases is pursued aggressively in the absence of detectable systemic disease. It is recommended that CT scans of the chest, abdomen, and pelvis be obtained prior to node dissection.[134] In patients with nodal metastases from an unknown primary, survival after surgical resection is as good as or better than survival of similar patients with a known primary.[133,135]

In the case of cervical metastases, the extent of the neck dissection does not appear to affect recurrence or survival; thus, preservation of function with a modified neck dissection is advocated.[136] There has been some experience with adjuvant radiotherapy to the surgical site after neck dissection for nodal metastases of melanoma. Though there has been some suggestion of increased regional control, the differences are not significant and there is no evidence that survival is affected.[137] Randomized prospective trials are under way to determine if any significant differences in patient outcome can be detected with radiation therapy after therapeutic lymphadenectomy. Patients with many positive nodes or with extracapsular extension are at higher risk of regional recurrence, so that radiation therapy, if beneficial, may have the greatest impact in these patients.

Adjuvant Systemic Therapy for Melanoma

In patients with thick melanomas (T4 N0 M0) or nodal metastases (T_{any} N1 M0), the risk of systemic recurrence is greater than 50%. Interferon-alfa is FDA-approved for the adjuvant therapy of melanoma in these patients, based on a randomized trial (ECOG 1684), which showed a modest improvement in survival in patients treated with high dose interferon.[138] The toxicity has been high with this therapy, limiting its acceptability to patients and to physicians. A repeat trial (ECOG 1690) has also been completed, but no difference in survival was seen in this larger trial (presentation at ECOG meeting in November 1998). Interferon-alfa does have some activity in melanoma, but these conflicting results have further diminished the willingness of patients to accept this therapy. Experimental adjuvant therapies are being investigated in this same patient group, primarily using melanoma vaccines.

Systemic Disease

Only about 20% of patients diagnosed with melanoma are expected to die of their disease. However, the progression of melanoma can be relentless and can be associated with great morbidity. Melanoma can metastasize to any site, but common visceral sites include the lung, liver, bone, and brain. It may also metastasize to the gastrointestinal tract, to adrenal glands, and to soft tissue sites. Cytotoxic chemotherapy is associated with a modest response rate of 20 to 40%, with the single most active agent being dacarbazine (DTIC). However, durable complete responses occur in only 1 to 2% of patients at most. High-dose interleukin-2 therapy has been associated with response rates of 15 to 20% but with 5 to 10% durable complete responses.[139,140] Combination therapy with cytotoxic chemotherapy and biologic therapy (interleukin-2 and interferon-alfa) has been associated with higher response rates (60 to 70%), but to date has not been associated with improved survival compared with dacarbazine alone.[141] Similarly, the addition of chemotherapy to interleukin-2 and interferon appears to increase response rates but also does not improve long-term survival.[142,143]

An area of active clinical investigation is immunotherapy. Melanoma expresses numerous antigens recognized by cytotoxic T cells and numerous antigens recognized by antibodies. Attempts to treat melanoma with immunotherapy are not new and date back to the work of W. B. Coley at the end of the nineteenth century, and even earlier. However, these approaches are being revolutionized by new knowledge about the molecular nature of melanoma antigens, about the role of cytokines in modulating immune responses, and about the critical role of antigen-presenting cells called dendritic cells.[144] Many clinical trials of tumor vaccines for melanoma are now under way; these include peptide-based vaccines, DNA vaccines, carbohydrate-based vaccines, adoptive cellular therapy, and cytokine therapy.[145,146]

Monitoring of Patients after Therapy

Follow-up of patients with melanoma focuses on detection of treatable recurrences. Primarily this includes local recurrences, in-transit metastases, and nodal recurrences. The vast majority of these are evident on physical exam; therefore, physical examination should be the primary focus of follow-up visits. Various schedules of follow-up are used in different treatment centers, depending in part on the level of risk for individual patients. A reasonable schedule for follow-up exams is every 3 to 4 months for 2 years, then every 6 months for the next 3 years, and then annually after 5 years.

Follow-up should also include a history focused on identifying any signs or symptoms of systemic disease. Any suspicious symptoms should be evaluated in detail. In the absence of clinical evidence of recurrence, it is reasonable to perform screening chest x-rays and a serum lactate dehydrogenase and complete blood count annually.

In summary, the surgical management of early melanoma can usually be handled on an ambulatory basis for most procedures, from initial diagnosis by biopsy of a suspicious lesion to wide excision and sentinel node biopsy. Keys to optimal management include early diagnosis, aggressive resection of the primary lesion with attention to the orientation of the incision, and complete staging of patients with intermediate and thick melanomas by sentinel node biopsy, where appropriate. Aggressive surgical therapy for nodal metastases is the standard of care and can lead to long-term survival or cure in many patients. Unfortunately, visceral disease or distant metastatic disease is difficult to manage and can only rarely be cured with existing therapy. New hope for advances in this field include ongoing studies of novel therapy directed at modulating the immune response to melanoma.

UNUSUAL CUTANEOUS MALIGNANCIES

Angiosarcoma

Cutaneous angiosarcoma (AS), a highly malignant soft tissue sarcoma of vascular origin, accounts for less than 0.1% of all head and neck cancers. Half of all ASs occurs on the scalp and face, most often in elderly Caucasian men. Sun exposure does not appear to play a role in development of AS.[147] Chronic lymphedema, usually on the edematous arm of women with a radical mastectomy and axillary node dissection for carcinoma of the breast, can be associated with AS (Stewart-Treves syndrome).[148] Rarely, AS can develop following radiation therapy for breast or cervical cancer.[149]

AS typically presents as painless enlarging purple-blue macules, plaques, or nodules and can be mistaken for infection or bruising (Fig. 42–21). They can range in size from a quarter to a softball. Lesions often have ill-defined borders and may be solitary or multiple. Ulceration and bleeding can occur in advanced cases.

AS frequently presents with multifocal disease. There is propensity for both local recurrence and distant metastasis. The rate of lymph node metastases is 13% for AS—the highest of all soft tissue sarcomas of the head and neck.[150] Elective lymph node dissection is not routinely done. Distant metastases occur in up to 50% of patients with AS—most commonly involving lung and liver.[151,152]

Figure 42–21 Angiosarcoma on the anterior scalp with noduloulcerative appearance.

The prognosis of patients with AS is poor. A recent study reported an overall survival rate of 33%.[147] If an extremity is involved, amputation probably offers the best chance for survival.[152] Mohs micrographic excision may offer some treatment benefit with improved margin control in the treatment of AS.[153] The literature suggests that aggressive combined-modality therapy with surgery, radiation, and chemotherapy offers the best chance for long-term control in patients with AS.[151] Unfortunately, the rareness of this tumor is why no large controlled studies to evaluate treatment have been done.

Atypical Fibroxanthoma

Atypical fibroxanthoma (AFX) is an uncommon spindle cell neoplasm that usually presents as an innocuous-appearing skin growth on the head or neck of elderly men (Fig. 42–22). UV radiation appears to play a role in the development of AFX because it appears most often on actinically damaged skin, such as the ear and nose.[154]

AFX most commonly appears as a solitary, nickel-sized erythematous nodule. It is often mistaken clinically for BCC, SCC, or amelanotic melanoma. The nodule can enlarge quickly over a period of weeks. Oftentimes the lesion is friable and there is ulceration with bleeding and pain. The term "atypical" refers to the bizarre, malignant-looking giant cells sometimes seen histologically in AFX. AFX is usually only locally aggressive, sometimes recurring after excision but rarely metastasizing.[155,156] Management of AFX should be similar to that of cutaneous SCC with wide local excision. In advanced cases, radiation has been combined with surgery to manage AFX.[156] Mohs micrographic excision has been associated with a lower recurrence rate than wide local excision.[157] Because of its histologic appearance, AFX is felt by some to be a superficial form of malignant fibrous histiocytoma (which carries a poor prognosis).

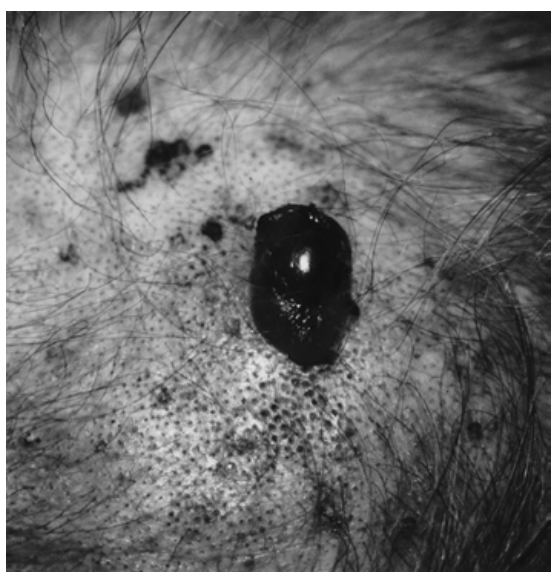

Figure 42–22 Atypical fibroxanthoma on the vertex scalp. Note typical nodular appearance with an eroded glistening surface [see Fig. 42–22 (c)].

Dermatofibrosarcoma Protuberans

Dermatofibrosarcoma protuberans (DFSP) is an intermediate-grade sarcoma thought to arise from fibroblasts in the dermis.[158] DFSP usually occurs in early to middle adult life. Occasionally, there is a history of antecedent trauma.[159] There is no racial proclivity, although there is a slight male predominance. Rarely, DFSP occurs in childhood.[160]

DFSP initially presents as a solitary, asymptomatic, firm, half-dollar-sized plaque that is usually violaceous to reddish brown in color. DFSPs arise most often on the trunk or proximal extremities and occasionally on the head and neck. The tumor enlarges slowly over months to years and gradually develops small raised nodules within the plaque (Fig. 42–23). The growth is usually fixed to overlying skin but not underlying structures. The initial lesion can sometimes be confused with a scar, lipoma, cyst, or neurofibroma. The patient becomes aware of the lesion when there is a sudden change in size or it becomes tender.

Although DFSP is known to be locally aggressive, it metastasizes only rarely. Clinically DFSP may appear to be well circumscribed, but beneath the skin the tumor diffusely infiltrates the dermis and subcutaneous tissue with rootlike projections. In the past, this large subclinical spread caused physicians to underestimate the extent of the tumor and use narrower margins for removal than required. In part, this underestimation explains the high rate of recurrence after excision, as much as 60%, in one study.[161] After multiple recurrences, invasion into fascia, muscle, bone, and even brain has occurred.[162] Metastases are usually preceded by two or more local recurrences. One recent review of 913 cases of DFSP reported that only 1% of patients had regional lymph node metastases, and approximately 4% had suspected distant metastases, principally in the lung. Most patients with metastases died within 2 years.[163]

DFSP is best treated by wide surgical excision. A minimal margin of 3 cm of surrounding skin, including the underlying fascia, is recommended.[163] Radiotherapy has been useful in selected cases.[164,165] Treatment of primary and recurrent DFSP by Mohs micrographic excision has been shown to result in a lower recurrence rate than wide local excision.[166,167]

Extramammary Paget's Disease

Paget's disease is an adenocarcinoma that can develop not only around the breast but also at other apocrine gland–bearing extramammary sites, such as vulva, scrotum, and perianal area (Fig. 42–24). Extramammary Paget's disease (EP) occurs primarily in elderly Caucasians and is seen more frequently in women than in men. EP occasionally is associated with an underlying adenocarcinoma or internal malignancy, in contrast to mammary Paget's disease, which almost always is associated with an underlying intraductal carcinoma of the breast.[168]

EP presents most often as an ill-defined erythematous patch or plaque in the anogenital area. In women the site most often affected is the labium majora and in men the scrotum.[169] Size can range from a few millimeters to the entire anogenital area. Itching and burning are common symptoms. Scaling and crusting can occur, as can ulceration. EP can easily be mistaken for psoriasis, eczema, seborrheic dermatitis, or fungal infection, delaying diagnosis.

Figure 42–23 Dermatofibrosarcoma protuberans on the right upper back. Elevated firm papules and nodules could be mistaken for cystic acne and scarring.

Figure 42–24 Extensive extramammary Paget's disease of the left labium majora and inguinal crease that could be mistaken for a yeast infection of the skin.

Most cases of EP are superficial, confined to the epidermis without invasion. However, one study found that 24% of patients with EP have an associated underlying cutaneous adnexal adenocarcinoma. The mortality rate of EP with an underlying carcinoma was 46% and dropped to 18% without an underlying carcinoma. Concurrent internal malignancy, such as bladder carcinoma or prostate cancer, was found in 12% of patients with EP.[170] The location of the underlying internal malignancy appears to be closely related to the location of the EP, so that a finding of perianal EP should trigger a search for carcinoma of the digestive system and genital EP an investigation of the genitourinary system.[171,172] The risk of an underlying neoplasm is highest with perianal EP (especially rectal carcinoma), resulting in the poorest prognosis of any location.[173,174] Of patients with EP disease, 26% will ultimately die of it or of associated internal malignancy.[170]

Therapy consists of wide local excision with frozen section margin control, preferably followed by permanent section margin control.[175] Excision may be very difficult or even impossible if the disease is widespread or located in a critical anatomical site. Recurrences after excision are notoriously common—probably because the tumor almost always extends beyond clinically apparent margins and can be multifocal.[176,177] Mohs micrographic excision of EP can provide tissue sparing of critical anatomic structures.[178] Field-destructive modalities, such as radiotherapy, laser, and 5-fluorouracil cream, have been used as adjuvant or primary therapy with varying success.[179–182]

Kaposi's Sarcoma

Kaposi's sarcoma (KS) is a relatively indolent vascular neoplasm that is most often seen in AIDS patients, sometimes as the presenting sign of HIV infection (epidemic KS).[183] Less commonly, KS is seen in HIV-negative individuals—usually on the lower extremities in elderly men of eastern European or Mediterranean descent (endemic KS). There is also an African variant. KS can also be observed in immunosuppressed patients, such as organ transplant recipients. Recently, human herpesvirus type 8 has been shown to be involved in the pathogenesis of AIDS-related KS.[184,185]

KS most often appears as bilaterally symmetrical, bruise-like, violaceous to brown macules, plaques, and nodules on the lower extremities. Involvement of the ears, lips, nose, mucous membranes, and trunk can also be observed. Most cases are asymptomatic. The lesions can be solitary or multiple (Fig. 42–25), and multiple lesions can coalesce. Gradually, the lesions of KS darken and become thickened and raised. Advanced lesions can become painful, ulcerated, and edematous, especially on the extremities.

Immunosuppression, brought on either by drug therapy (e.g., cyclosporin in organ transplant patients) or by infection (e.g., HIV), appears to play a role in the development of KS. Cessation of immunosuppressive therapy in organ transplant patients or improvement of CD4+ cell counts in AIDS patients may result in regression of the KS.[186,187] Oftentimes KS remains indolent and is not a threat to a patient's general health. Internal organ involvement in patients with KS is common but without consequence unless gastrointestinal or pulmonary bleeding or obstruction occurs.[188]

Asymptomatic KS may not require treatment. Cosmetic improvement can be accomplished with cryotherapy, radiation therapy, or intralesional injection of a substance such as vinblastine sulfate.[189–191] Systemic chemotherapy, with a cytotoxic agent such as etoposide or an antiviral agent such as cidofovir, can be administered if KS becomes life threatening.[192,193]

Merkel Cell Carcinoma

Merkel cell carcinoma (MCC) is a highly malignant neoplasm derived from neuroendocrine cells thought to function as touch receptors.[194] Most MCCs occur in elderly Caucasian men and women on the head and neck. MCC is often associated with other skin neoplasms, the most common of which is squamous cell carcinoma. This suggests that UV radiation may have an etiologic role in the development of MCC.[195]

MCC appears as a rapidly growing purple to red nodule with telangiectasia. The nodule is usually painless, firm, raised, and red, pink, or occasionally blue (Fig. 42–26). Advanced

Figure 42–25 Extensive Kaposi's sarcoma on the chest and arms of an HIV-positive young man.

Figure 42–26 Merkel cell carcinoma on the right ala.

lesions may be ulcerated. The tumors range in size from a few millimeters to many centimeters; they average 2 cm.

The recurrence and metastatic rate for MCC is high. One review reported a 40% local recurrence rate, 55% nodal recurrence rate, and a 36% incidence of distant metastases.[196] One study found an overall median survival of 24 months, with 65% of patients succumbing to metastatic disease.[197] There are no reliable microscopic features that differentiate MCC from metastatic oat cell carcinoma; therefore, it is always necessary to rule out oat cell carcinoma metastatic from the lung to the skin by radiologic studies.

There is currently no standardized treatment for MCC due to the rarity of this neoplasm.[198] Most authors recommend wide local excision.[199] Prophylactic lymphadenectomy is controversial.[200] MCC is chemosensitive, and a wide variety of chemotherapeutic agents have been used for palliation.[201,202] MCC is also a radiosensitive tumor, and postoperative radiation therapy has been recommended for all patients.[203,204]

Microcystic Adnexal Carcinoma

Microcystic adnexal carcinoma (MAC) most likely originates from sweat ducts.[205] It usually occurs on the head and neck in middle-aged to older Caucasian men and women. The tumor is sometimes associated with a history of previous radiation therapy.[206] Diagnosis of MAC is often delayed because of its slow growth, innocuous clinical appearance, and lack of symptoms. A patient's report of sensory changes, such as pain, numbness, or paresthesias, should alert the physician to the perineural involvement that can be seen with MAC. The incidence of perineural invasion has been reported to be as high as 80%.[207] Clinically, MAC presents as an indurated white to yellow smooth-surfaced plaque or nodule, most often on the upper lip, eyebrow, or, occasionally, the scalp (Fig. 42–27).[208,209] MAC is a locally destructive tumor with a high rate of recurrence (as high as 47% after conventional surgical excision).[205] Frequently MAC is deeply infiltrating, invading muscle and bone, and the tumor often extends far beyond clinically apparent margins.[210,211] MAC has rarely been reported to metastasize.[212] The clinically inapparent extension and perineural involvement of MAC make Mohs micrographic excision the treatment of choice.[213] MAC has been reported to be radioresistant in many cases.[207,208,210]

Sebaceous Gland Carcinoma

Sebaceous gland carcinoma (SGC) may arise from any sebaceous gland in the body but most commonly arises from the sebaceous glands of the eyelid [usually the meibomian glands (51% of cases) or, less commonly, the glands of Zeis (10% of cases)].[214] Extraocular SGC most often occurs on the head and neck.[215] SGC has been associated with ionizing radiation.[216] Mutational inactivation of p53 may be involved in the progression of sebaceous carcinoma.[217]

SGC most commonly arises in elderly women as a slowly growing, indurated, painless, yellow to red nodule on the conjunctival surface of the upper eyelid. The upper eyelid is involved more often than the lower eyelid (Fig. 42–28).[215] SGC is often mistaken for a benign inflammatory condition of the eyelids (such as chalazion), and delay in diagnosis is common.[218]

SGC has a propensity for recurrence and metastasis. Both ocular and extraocular SGCs often recur after treatment, with approximately one third of all patients having local recurrences.[219] Metastasis occurs in 14 to 25% of cases and is most often to the regional lymph nodes.[215] Orbital invasion occurs in 6 to 17% of cases.[220] Delay in diagnosis and increased tumor size of ocular SGC correlate with increased mortality.[214] SGC of the lower eyelid reportedly has a better prognosis, however, prognosis is poor if both eyelids are involved, with a mortality of 83%.[214,215] Extraocular SGC has a better prognosis than ocular involvement. A patient with an SGC occurring in association with a gastrointestinal malignancy should alert the physician to the possibility of Muir-Torre syndrome, an autosomal dominant genodermatosis.[221]

Wide surgical excision with 6-mm surgical margins controlled by frozen section or permanent section is the primary

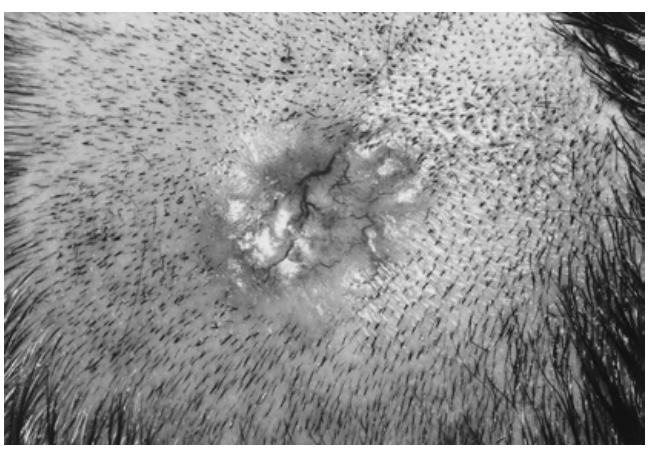

Figure 42–27 Microcystic adnexal carcinoma of the scalp. Note typical ill-defined whitish plaque with central depression and telangiectasia.

Figure 42–28 Sebaceous gland carcinoma on the right lower eyelid. Note the margin irregularity, subcutaneous nodule, and eyelash loss.

management for SGC.[215] Orbital exenteration for ocular SGC has been recommended for orbital disease, extensive intraepithelial neoplasia, tumors greater than 2 cm in diameter, or lesions present for more than 6 months.[220] Better margin control and tissue sparing have been obtained with Mohs micrographic excision, but the multicentricity and pagetoid spread of SGC may still allow tumor to be missed and thereby lower the cure rate.[222,223] Cryosurgery for conjunctival pagetoid spread of SGC may have a role in treatment and may preclude exenteration.[224] Although radiotherapy has been used with some success for treatment of SGC, it is usually reserved for treatment of patients who cannot undergo surgery, for palliation, or as adjuvant therapy after surgery.[223,225]

SUMMARY

Unusual cutaneous malignancies often have unusual clinical presentations. For many, the prognosis is usually poor because of failure to discern the true diagnosis. Unusual cutaneous malignancies should always be included in the differential of a suspicious skin growth. If in doubt, a generous biopsy should always be performed. Unfortunately, treatment of many of these unusual cutaneous malignancies is not optimal not only because diagnosis is delayed but because their rarity precludes any standardized approach to examination.

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Chapter 43

Minimally Invasive Options and Skin Grafts for Cutaneous Reconstruction

David B. Hom and Whitney D. Tope

Conservative options for cutaneous facial reconstruction comprises healing by second intention, primary closure, and the use of skin grafts. Oftentimes, minimally invasive techniques for facial reconstruction are the best choice in reconstructing facial defects. This chapter focuses on these minimally invasive reconstructive options for facial repair. In treating patients requiring facial reconstruction, the major objectives and time course for healing should be carefully discussed with the patient and family so that a mutual agreement is made regarding the reconstructive goals.

ASSESSMENT OF THE FACIAL DEFECT

To determine the optimal method for reconstruction, one must fully define the given defect. The complexity of the defect is defined by the tissue layers that are missing, location, surface area of involvement, and its relationship to the aesthetic subunits.

The initial wound assessment involves determining the size, location, and depth of the facial defect while being cognizant of the possibility that underlying neurovascular or glandular structures, might also be missing. Evaluating the depth of the defect (subcutaneous space, facial musculature, cartilage, and bone) is crucial for planning the appropriate repair. By palpating the wound and its surrounding structures, the structural support of the area is determined. If structural support is missing, computed tomography (CT) may be helpful in determining if additional underlying support is required. The extent of the tissue loss and orientation of the wound in proximity to surrounding mobile facial structures (eyelids, nasal alae, nasal tip, auricle, vermilion, commissures, and philtral ridges) should also be evaluated.

The major reconstructive goal is to reestablish functional structural support and soft tissue coverage, maintaining the most aesthetic appearance with minimal distortion. Ideally, the absent tissue should be repaired with like tissue that is similar in color, texture, and thickness. Absent supporting structures (bone and cartilage) should be replaced to obtain appropriate projection and contour. Wound healing should be optimized to avoid infection, excessive contraction and scarring.

PLANNING GUIDELINES AND FACIAL SUBUNITS

The extent of the missing facial subunits should be evaluated. If the contralateral face is normal, it can be used as a visual template for guidance. Dividing the face into six major facial aesthetic units (forehead, eye/eyebrow, nose, lips, chin, and cheek) is helpful in reconstructive planning (Fig. 43–1). Aesthetic units of the face represent anatomical boundaries, and scars lying on these boundaries appear more concealed. This is because the borders of the aesthetic units are defined by light reflections and shadows of the facial contours. Within some aesthetic units, additional anatomical boundaries can be divided into subunits. This boundary division is applicable to the nose, which can be divided into the subunits—nasal dorsum, nasal tip, columella, nasal alar, soft tissue triangles, and nasal sidewalls.[1]

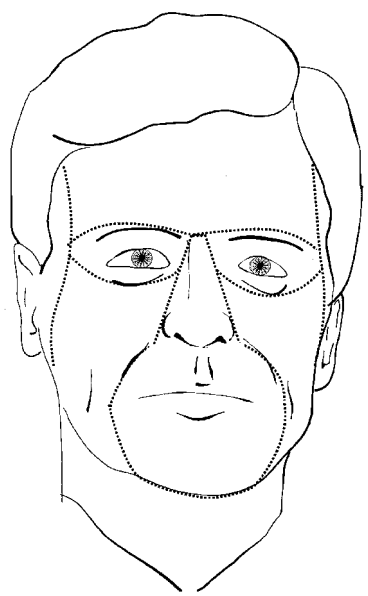

Figure 43–1 Aesthetic units on the face (forehead, eye/eyebrow, nose, cheek, mouth, and chin). (From Hom DB, Odland RM. Prognosis for facial scarring. In: Harahap M (ed). *Surgical techniques for cutaneous scars revision*. New York: Marcel Dekker, Inc.; 2000:25–37. With permission.)

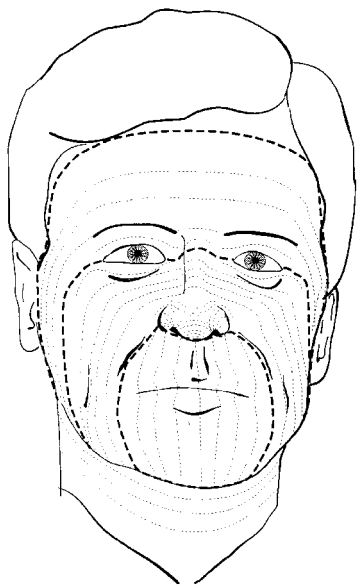

Figure 43–2 Facial relaxed skin tension lines. The long axis of fusiform excisions should lie parallel to the relaxed skin tension lines. (From Hom DB, Odland RM. Prognosis for facial scarring. In: Harahap M (ed). *Surgical Techniques for Cutaneous Scars Revision.* New York: Marcel Dekker, Inc.; 2000:25–37. With permission.)

Scars are concealed maximally by adhering to techniques of tensionless wound closure, wound edge eversion, and planning to have the wound lie within the relaxed skin tension line (RSTL) of the face (Fig. 43–2) or at the border of facial aesthetic units.

With any wound, the proximity of the tissue loss with respect to nearby mobile facial structures (eyelids, nasal alae, nasal tip, auricle, vermilion, commissures, and philtrum) should be recognized. This is to avoid distortion of these neighboring structures during closing of the wound, which can make the scar much more noticeable.

When a wound from tissue loss cannot be adequately closed primarily without undue tension or vital structure deformity, planning for reconstruction is required. Reconstructive options include healing by second tension, local skin flaps, skin grafts, regional flaps, or free flaps. For wound sites having the majority of a facial aesthetic unit missing, considerations can be made for removal of the remaining aesthetic skin unit followed by local skin flaps or skin grafting. This technique can maintain uniformity of skin color and contour of the facial unit and make scars less visible by having them lie on the aesthetic unit boundaries. For defects encompassing more than one facial aesthetic unit, the units can be reconstructed independent of one another.

PRIMARY CLOSURE

Tensionless closure of each layer (mucosa, muscle, subcutaneous tissue, and skin) should be achieved. To avoid distortion of nearby structures, differential undermining of the wound edges in the subcutaneous plane may be necessary. Differential undermining signifies dissecting in the subcutaneous plane only on one side of the wound. This is performed only to advance the undermined side of the wound edge to avoid distorting the nonundermined side of the wound. The deeper layers can be closed individually with buried absorbable suture to avoid transmitting tension to the skin surface. With dermal closure, eversion of the skin edges can then be performed. To minimize a "trap door" deformity with a beveled wound edge, excessive dermal tissue can be conservatively excised in a tangential fashion to the wound surface to create a more vertical skin edge. When a defect cannot be adequately closed primarily, other conservative options include healing by second intention, local flaps, or skin grafts.

HEALING BY SECOND INTENTION

Introduction and History of Second-Intention Healing

It is easy to overlook the fact that the healthy human body possesses the capability to repair damaged or lost tissue without surgical intervention. This phenomenon of complete tissue restoration[2] of soft tissue defects occurs through processes of replacement of lost tissue volume (granulation), reestablishment of defect surface integrity (reepithelialization), and reduction of wound volume (wound contraction). However, the healing of full-thickness dermal wounds does not transform into an intact layered integument complete with adnexal structures. Hence, second-intention healing results in an appearance and scar texture different from that of normal adjacent skin.

It is interesting that even in the preantiseptic, preantibiotic, and preanesthetic eras, healing of wounds by surgical reconstruction was judged to be the surgeon's first intention. In first-intention healing, surgical apposition of the wound's edges allows healing without the intervention of exposed granulation tissue. Advances in surgical technique have expanded the scope of first-intention healing beyond linear closures to include use of local, regional, and free flaps, and skin grafting.

These improvements led to a mindset that surgeons could create results superior to those afforded by "natural" healing. Thus, healing achieved through the natural processes of granulation, reepithelialization, and wound contraction was judged to be the surgeon's second intention. Fortunately, observant physicians who felt compelled to allow second-intention healing in a variety of clinical situations rediscovered the positive attributes of this approach, it being the most conservative form of wound management.

Perhaps foremost among the early observers of second-intention wound healing was Dr. Frederic E. Mohs. While a University of Wisconsin medical student, Mohs created a surgical technique combining in situ tissue fixation and complete microscopic margin examination for the treatment of skin cancer. Similar to wounds created by cryosurgery and electrosurgery, residual devitalized tissue present in the postoperative wound bed fixed by Mohs' zinc chloride paste precluded immediate wound closure. Thus most wounds created through

the original Mohs micrographic technique, known as the fixed-tissue technique, were allowed to heal by second-intention. Any reconstruction performed typically awaited slough of the devitalized fixed wound tissue, usually within a week on facial skin. By 1948, Mohs was able to report 5-year follow up of 577 cases of primary and recurrent basal cell carcinoma (BCC) and squamous cell carcinoma (SCC), largely managed by second-intention healing.[3] Over the next three decades, several authors reported the adequacy of second intention healing, particularly after surgical treatment of lower eyelid and medial canthal BCC[4] and in large traumatic or surgical defects of the central face.[5]

In 1978, Mohs reported his 30 years of experience in treating cutaneous malignancies by his micrographic technique.[6] Well over 10,000 cutaneous BCCs and SCCs had been followed through wound healing with a final 5-year follow-up. Mohs noted that "healing by granulation yields surprisingly good cosmetic and functional results.... In some areas the results are superior to those obtained by standard surgical or radiation procedures. Prime examples are the forehead, temples, scalp, eyelid margins, canthi, nasal root and alae, ears, fingers, hands and plantar surfaces of the feet. The good results partly are attributable to the saving of maximal amounts of normal tissues as a consequence of microscopic control, but much is also attributable to the surprisingly good healing that can occur by granulation."[6] Again, other authors also advocated second-intention healing to prevent hypertrophic scar formation[7]; to produce smaller, more manageable facial defects for delayed flap or graft reconstruction[8]; and to manage medial canthal and lower eyelid margin defects.[9,10]

In the 1970s, Mohs' fixed-tissue technique was supplanted by the fresh-tissue technique. Whereas Mohs reported use of tumor excision using frozen tissue sections and without application of zinc chloride fixative for eyelid tumors,[6,11] it was later advocated for virtually all cutaneous tumors using Mohs technique. Today widely practiced by surgeons trained in Mohs' technique the fresh-tissue technique avoids the pain and tissue slough associated with situ tissue fixation and allows immediate reconstruction. Despite the wound's readiness for reconstruction and their confidence in tumor-free margins, Mohs surgeons commonly employ second-intention healing of selected clean surgical wounds. Certainly, wounds with clear margins as assessed by "frozen section control" or those confirmed by permanent sections may be allowed to heal by second intention as well.

Factors in Considering Second-Intention Healing

In addition to tumor-free wound margins, other factors suggest that second-intention healing may or should be considered. Clinical factors include the shape and contour of the wound, potential for compromised healing of flaps or grafts, patient at high risk for local tumor recurrence, patient ill suited to undergo surgical reconstruction, and a wound requiring a granulation tissue bed for receiving grafts. In addition, a desire to decrease the initial size of large facial wounds prior to reconstruction may give an early option for second-intention healing. Finally, the expected function and cosmesis resulting from second-intention healing may be superior to that expected from first-intention healing.

Mohs surgery involves creation of a beveled wound edge. Microscopic margin examination allows the surgeon to track out subclinical tumor extensions. Mohs defects typically are gently rounded and concave. Such beveled curvilinear wounds lend themselves to second-intention healing with less contraction than that seen with angulate wounds.[12,13]

Second-intention healing is an excellent option to manage compromised wound healing. Compromised vasculature increases the risk of graft or flap failure. Compromised wound beds occur in persons with previously irradiated skin, in diabetics, in users of tobacco, and in persons with contaminated wounds. Hemorrhagic diatheses may cause hematoma and failure of flaps or grafts while not greatly interfering with second-intention healing. In particular, aspirin, nonsteroidal anti-inflammatory agents, ticlopidine, heparins, coumarins, α-tocopherol, garlic, and ethanol should be avoided preoperatively. Still, many patients may be unable to or fail to discontinue these agents, making immediate reconstruction more difficult.

Despite careful performance of Mohs micrographic surgery, some patients remain at high risk for local tumor recurrence. Such tumors may manifest perineural, perivascular, muscular, cartilaginous, or osseous invasion, or possess an inherently aggressive histopathologic growth pattern. This is especially true of sclerosing, morpheaform, and keratinizing (metatypical) BCC, poorly differentiated SCC, microcystic adnexal carcinoma, extramammary Paget's disease, and sebaceous carcinoma. In fact, some authors advocate against immediate reconstruction of recurrent basal cell cancers.[5,14] Reconstruction in such patients may obscure and delay diagnosis of clinical tumor recurrence. Also, photodamaged, field-cancerized skin imported for reconstruction may harbor a subclinical tumor, leading to pseudo-recurrence.

Certain patients are ill suited to surgical reconstruction. They may be unable to cooperate with appropriate local anesthesia, may be at significant medical risk for general anesthesia, or may not want more surgery.

Second-intention healing may effectively aid rather than supplant reconstruction. Deep wounds amenable to full-thickness skin grafting may benefit from filling of the defect with granulation tissue prior to grafting. This approach can reduce graft depression and poor postoperative tissue contour. Large facial wounds healing by second intention may contract sufficiently to make possible delayed reconstruction[5,8] or create smaller scars than the original. Finally, second-intention healing can be used concurrently with flap or graft reconstruction. Especially in a setting of complex facial wounds involving two or more facial cosmetic subunits, one can select second-intention healing for one appropriate subunit while reconstructing the adjacent one (Fig. 43–3). Use of certain flaps may allow a defect to shift to an area more likely to heal better by second intention. Upper forehead wounds resulting from donor site defects of paramedian forehead flaps used in nasal reconstruction often heal by second intention with very satisfactory cosmesis. Full-thickness skin defects at the posterior auricular sulcus and midhelical rim usually heal with minimal scarring by second intention (Fig. 43–4 and 43–5).[15] Linear closures with dehiscence or necrotic areas on flaps or grafts should be allowed to heal by second intention before corrective techniques are considered.[5]

Second-intention healing should be given serious consideration for anatomic locations in which excellence in both

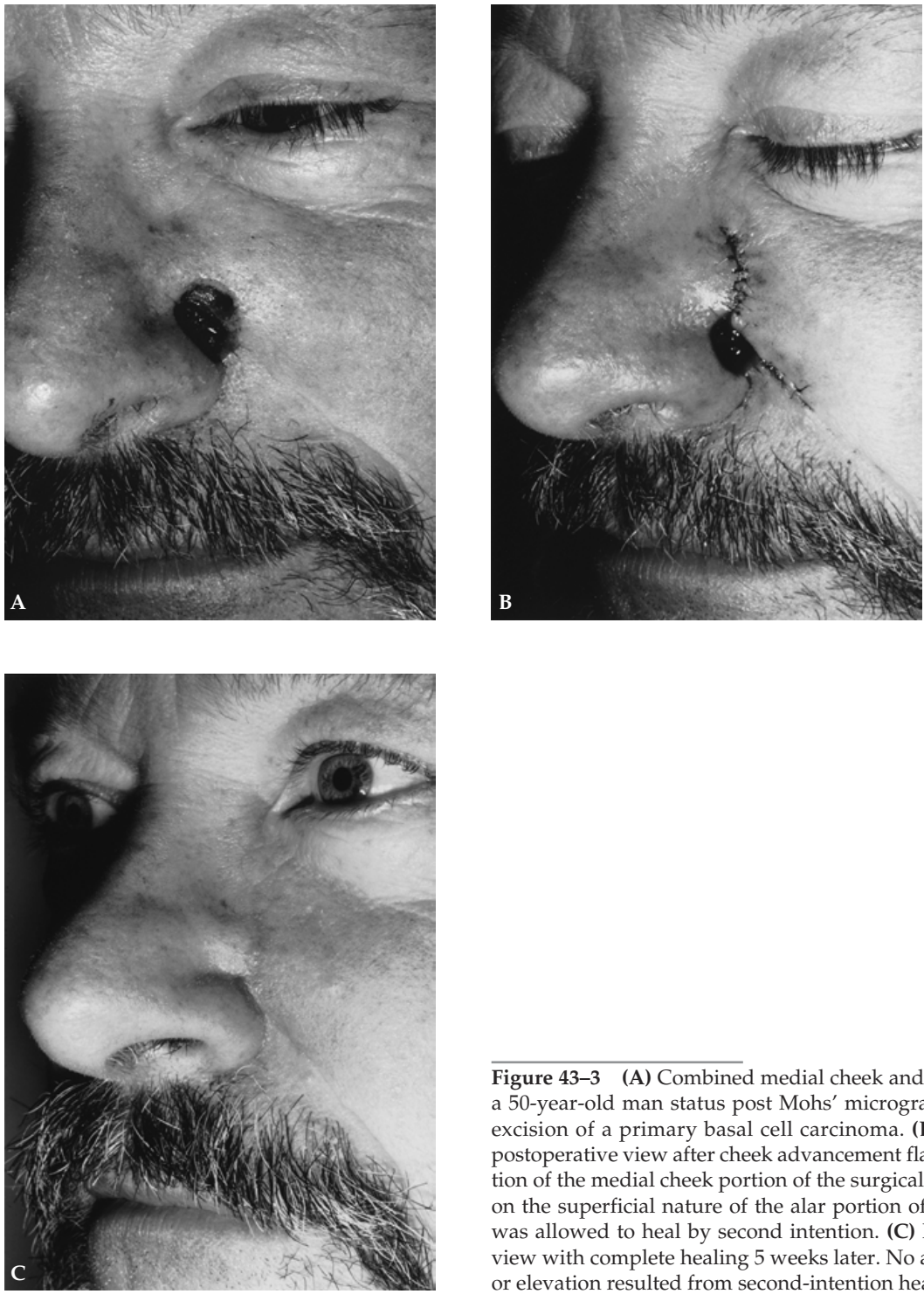

Figure 43–3 **(A)** Combined medial cheek and alar defect in a 50-year-old man status post Mohs' micrographic surgical excision of a primary basal cell carcinoma. **(B)** Immediate postoperative view after cheek advancement flap reconstruction of the medial cheek portion of the surgical defect. Based on the superficial nature of the alar portion of the defect, it was allowed to heal by second intention. **(C)** Postoperative view with complete healing 5 weeks later. No alar retraction or elevation resulted from second-intention healing.

function and cosmesis are expected. Second-intention healing most frequently leads to poor function when wounds are large or deep and involve or lie in proximity to anatomic free margins, lip, ala, eyelid, and, occasionally, the external ear canal. The process of wound contraction literally pulls on free margins distorting position and creating dysfunction. Tension on the lip, eyelid, and nasal ala will cause distortion. Defects involving a significant portion of the circumference of the auditory meatus may cause meatal stenosis. Except for these situations, which are prevented by appropriate reconstruction, second-intention healing usually does not result in anatomic dysfunction. Doctor John Zitelli first classified expected cosmesis of second intention healing by facial regions[16,17] based on his observation of several thousand

Figure 43–4 **(A)** Posterior view of a helical rim defect in an 87-year-old man status post Mohs' micrographic surgical excision of a recurrent invasive squamous cell carcinoma. Second-intention healing was selected based on the defect size, location, and the tumor's recurrent nature. **(B)** Healing of helical defect from second intention 2 months later.

Figure 43–5 **(A)** Posterior auricular sulcus defect in an 82-year-old man following Mohs' micrographic surgical excision of a squamous cell carcinoma in situ. **(B)** Healing by second intention 8 weeks later.

patients. He observed that healing in anatomic sites characterized by concave surfaces (on the nose, eye, ear, and temple—or NEET—areas) produced superior cosmetic results. Convex surface defects (on the nose, oral lip, cheeks, chin, and helix—NOCH—areas) healed with obvious scars. And flat surface defects (on the forehead, antihelix, eyelids "I," and remainder of the nose, lips, and cheeks—FAIR—areas) healed with satisfactory cosmetic results (Fig. 43–6). Several other factors contribute to the expected cosmetic result of second-intention healing. The pallor of mature scars stands out more in patients with darker pigmentation (Fitzpatrick phototypes III to VI). In a given anatomic subunit, smaller and more superficial wounds leave less noticeable scars, particularly when the defect retains appendages that recreate the pore pattern of normal skin. Skin with large and numerous sebaceous glands (distal nose, medial cheeks, or in early rhinophyma) are more prone to have visible scarring (Fig. 43–7).[16,17]

Figure 43–6 Aesthetic result of facial areas healing by second intention. Dark gray (**NEET** area, concave surfaces of the nose, eye, ear, and temple) – excellent results. White (**FAIR** area, forehead, antihelix, eyelids [I], and rest of the nose, lips and cheeks)—satisfactory results, could result in hypopigmented scars. Light gray (**NOCH** area, convex surfaces of the nose, oral lips, cheeks, chin and helix)—variable results, superficial wounds acceptable to some patients but deeper wounds heal with depression or potential for hypertrophic scars. (From Zitelli JA. Wound healing by secondary intention: a cosmetic appraisal. *J Am Acad Dermatol* 1983;9:407–415. With permission.)

First- versus Second-Intention Healing

Second-intention healing possesses distinct advantages over first-intention reconstruction. Tissue defects reconstructed with flaps have greater skin tension, which contributes to postoperative pain. Second-intention healing also obviates the possibility of nerve injury during reconstruction and the creation of a second wound at graft donor sites. Contrary to popular and "informed" opinion, open healing wounds are universally not painful. Whereas desiccated wounds can be uncomfortable, second-intention healing within a moist healing environment typically is not painful,[18] rarely requiring analgesia stronger than acetaminophen. Significant pain may

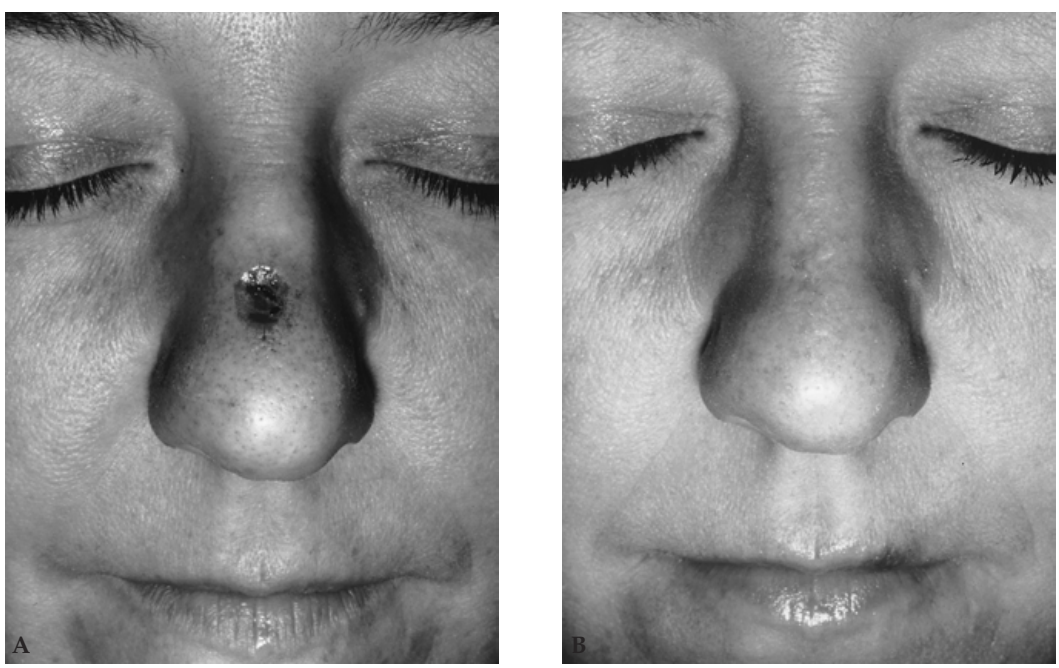

Figure 43–7 **(A)** Full-thickness nasal dorsal defect in a 38-year-old woman following Mohs' micrographic surgical excision of a primary nodular basal cell carcinoma. Second-intention healing was selected. **(B)** The wound reepithelialized over 6 weeks, and at 3 months some residual scar telangiectasia is evident.

suggest the presence of infection. Even irradiated wound beds heal well, though more slowly. Postoperative hemorrhage easily drains away from the wound, avoiding hematoma and seroma formation. The wounds of patients at risk for hemorrhage are easily treated with topical hemostatic agents, such as oxidized cellulose (OxyCel, Becton Dickinson, Franklin Lakes, NJ). Devitalized tissue from electrocautery readily sloughs from the wound, and no suture is present to incite a foreign-body reaction. Wounds healing by second intention are no more likely to develop infection than reconstructed wounds if kept clean.[6]

Selection of Wounds for Second-Intention Healing

When does the surgeon select second-intention healing for a patient? First, the final decision of repair should be based on an agreement between the surgeon and the patient. For education purposes, the patient should view the wound to be aware of the amount of tissue removed to eradicate the tumor. The expected appearance of the scar, time for wound healing, and the patient's (family's or home nurse's) role in wound care are discussed. If the patient is willing to consider second-intention healing, the surgeon must assess the whole patient as well as the specific wound characteristics. During second-intention healing, one must rely on published criteria, such as Zitelli's guide, for advice on appropriate wound management.[16,17]

Wound Preparation and Care for Second-Intention Healing

We practice the following routine in managing wounds selected to heal by second intention. To optimize wound healing, the tenets listed in Table 43–1 are followed. The patient or caregivers, if available, are involved in initial dressing application. If a significant amount (≥1 cm) of periosteum is removed, decortication of bone to expose the diploic layer is required for adequate granulation tissue formation.[19] This may be achieved using a rotating bone burr, rongeur, CO_2 laser,[20] or an erbium:YAG laser.[21] Bone decortication should create exposed bone segments smaller than 1 cm or be carried out to the soft tissue periphery. Bone exposed in this manner, if not kept moist, may become devitalized and impede wound healing. Hydrogen peroxide should not be consistently applied to exposed cartilage or bone due to its desiccating effects.[19] Wounds with exposed bone should be reviewed regularly to remove devitalized tissue until a complete granulation tissue bed has formed.[19] The presence of significant infection (chondritis or osteomyelitis) in either of these settings is unusual.[19]

Residual clot or cautery debris is removed and adequate hemostasis achieved in the wound bed. Sufficient antibiotic ointment (bacitracin zinc) is applied to prevent tissue desiccation. If the patient has known contact allergy to bacitracin, then another antibiotic agent or white petrolatum may be used. Next, a pressure dressing (composed of a layer of nonadherent gauze dressing; packing of cotton gauze, dental rolls, or cotton balls to overfill the wound; and paper tape) is applied. Adherent (Medipore, 3M Health Care, St. Paul, MN) or nonadherent elasticized materials (Coban, 3M Health Care, St. Paul, MN) can be used for additional pressure, if required. Three-dimensionally complex areas, such as external ear sites, may require a mold such as heat-sensitive plastic (Aquaplast, WFR Aquaplast Corp., Wyckoff, NJ) and suture to achieve a rigid, well-conformed dressing. If contact allergy to tape components exists, Aquaplast or Coban avoids irritation or allergy. The patient is sent home with written wound care instructions and contact telephone numbers.

Patients are instructed to remove pressure dressings after 24 or 48 hours. Wounds are cleansed with tap water, normal saline, or H_2O_2 soaks or cotton-tipped applicators to remove crust and debris from the wound and surrounding skin. We encourage patients to attempt to remove soft fibrinous material from the wound bed, but not so vigorously as to cause more than pinpoint bleeding. The wound is blotted dry. Antibacterial ointment and a lighter dressing of nonadherent gauze (Telfa, Kendall Healthcare Products, Mansfield, MA) and paper tape (Micropore, 3M Health Care, St. Paul, MN) are applied. Patients are specifically cautioned to ensure a moist environment and not to allow dry scabs to form because dry eschars dramatically slow wound healing[22] and contribute to postoperative pain. Wound cleansing is performed and new dressings applied twice daily for the first week, then decreased to once daily until complete healing has occurred. To help determine the kind of dressing to use, Tables 43–2 and 43–3 describe the types of dressings available and their reasons for use.

TABLE 43–1 Major Tenets for Optimal Local Wound Care Management

Debride necrotic tissue—Removal of necrotic tissue minimizes bacterial growth.
Identify and treat infection—Infection inhibits all stages of wound healing.
Pack dead spaces lightly—Tightly packed spaces hinder wound cavity contraction.
Divert any salivary drainage away from the wound—Salivary seepage increases bacteria wound load.
Drain any excess fluid collection—A fluid collection becomes a reservoir for infection.
Absorb excess exudate—Excess wound exudate macerates surrounding skin.
Maintain a moist wound surface—Moist surfaces enhance granulation tissue formation and epithelial cell migration.
Maintain open fresh wound edges—Closed, well-epithelialized wound edges prevent epithelial migration across the wound surface.
Protect the wound from trauma and infection—Trauma and infection cause damage to new tissue.
Insulate the wound—Warmth maximizes blood flow and cell function, thus optimizing wound healing.

Reprinted with permission from Bryant R. Science and reality of wound healing. In: *Wound healing: state of the science*. 1997 Program of the Wound Healing Society and the Wound, Ostomy, and Continence Nurses Society, Nashville, TN, June 12, 1997.

TABLE 43–2 Dressing Purpose and Product Classifications

Purpose of product	Wound product classifications
Cleanse topically	Normal saline Commercial wound cleaners
Absorb exudate	Absorption beads, pastes, and powders Alginates Composite dressings Foams Gauze Hydrocolloids Hydrogels
Cover a wound to allow autolytic enzymes of the wound fluid to self-digest eschar and fibrinous slough	Absorption beads, pastes, and powders Alginates Composite dressings Foams Hydrated gauze Hydrocolloids Hydrogels Transparent films
Topically debride devitalized tissue chemically	Enzymatic debridement agents
Mechanically debride devitalized tissue	Wound cleansers Gauze (wet to dry)
Add moisture to the wound	Gauze (impregnated or with saline) Hydrogels Wound care systems (two-part)
Maintain a moist wound environment	Ointments Foams Gauze (impregnated or with saline) Hydrocolloids Hydrogels Transparent films Wound care systems (two-part)
Fill dead space	Absorption beads, pastes, and powders Alginates Hydrocolloid pastes, powders Foam Gauze
Cover and protect wound	Composites Compression bandages/wraps Foams Gauze dressings (covers/wraps) Hydrocolloids Hydrogels (with covers/borders) Transparent film dressings
Protect surrounding skin from moisture and trauma	Moisture barrier ointments Foams Hydrocolloids Securement devices Skin sealants Transparent film dressings

Reprinted with permission from Krasner D. Dressing decisions for the twenty-first century. In: Krasner D, Kane D (eds). *Chronic wound care.* 2nd ed. Wayne, PA: Health Management Publications, 1997:139–151.

TABLE 43–3 Tailoring Wound Dressings to the Particular Characteristics of the Wound

Type	Wound description	Dressings to consider	Objective
Necrotic	Wound cavity with excessive yellow exudate, slough, dark eschar (black to tan)	Calcium alginate rope, hypertonic saline gauze, hypertonic gel, enzymatic debriding ointment	To absorb exudate and promote debridement
Granular	Granulating wound, minimal or moderate exudate	Hydrogel gauze, calcium alginate	To provide a moist environment
Requiring reepithelialization	Pink, shallow	Hydrogel sheet, hydrocolloid, foam when wound is moist	To maintain moisture, promote resurfacing, and protect new epithelium

Adapted and reprinted with permission from Krasner D. Dressing decisions for the twenty-first century. In: Krasner D, Kane D (eds). *Chronic wound care.* 2nd Ed. Wayne, PA: Health Management Publications, 1997:139–151.

Wounds are reexamined within a week to judge the adequacy of wound care, provide coaching technique, and perform surveillance for adverse events. Wound examinations then occur monthly until the wound has healed completely. Once healing has taken place, patients are seen annually, or as dictated by changes in status, for surveillance of recurrence or development of new suspicious lesions. Wounds managed by second intention often heal initially with an indurated, red or violaceous central papule or ridge. This resolves with time or its resolution may be accelerated by twice-daily digital massage with lotion or ointment. Massage enhances blood flow and speeds scar tissue remodeling. Oral antibacterial agents are used only in patients judged to have a clinically significant propensity for infection, a strong history of prior wound infections, or a need for antibiotic prophylaxis to protect artificial valves, prosthetic joints, and so forth. In our experience, the occurrence of wound infection in second-intention healing is a rarity, even in immunosuppressed individuals. We do find that an occlusive hydrocolloid dressing (DuoDerm, ConvaTec, Princeton, NJ) may adhere well, retain drainage, require less frequent dressing changes, and provide an excellent environment for second-intention wound healing. Use of hydrocolloid dressings allows serum enzymes to perform painless autolytic debridement of fibrinous eschar. Some patients prefer this wound dressing to those described previously, especially for wounds on an alopecic scalp or difficult-to-reach areas of the trunk.

Wound Healing of Second Intention

Wound healing is dependent on the following physiologic steps: hemostasis (occurring over minutes), inflammation (occurring over 3 days after injury), proliferation (occurring from the third to twelfth day after injury), and remodeling (occurring over months after injury). In open wounds healing by secondary intention, contraction plays a critical role. All of these components must be present in a coordinated sequence for optimal healing to occur.

When one healing step is delayed, all subsequent healing steps are affected. When one or more of these steps is impaired, delayed healing becomes apparent, resulting in more scarring. Wound remodeling is the last and longest phase of soft tissue wound healing. During this period, granulation tissue recedes, collagen remodels, and a mature scar forms. Scar maturation takes place over years, with gradually increasing tensile strength. However, the strength of healed tissue never reaches that of uninjured skin.

As long as a wound remains open, inflammation persists. This is because in an exposed wound, continual exposure to microorganisms and foreign material acts as an inflammatory stimulus. For inflammation to resolve, this stimulus must be eliminated. The epithelium is the key barrier that protects the wound from the external environment. After a wound becomes reepithelialized, the underlying tissue is further protected and inflammation is curtailed.

It is believed that something in the epithelium suppresses inflammation. Clinically, this is supported by observing that closing a wound primarily or covering a wound with a graft reduces the inflammation. If an open wound fails to reepithelialize within 2 to 3 weeks, the likelihood of a hypertrophic scar developing increases.[23]

Complications of Second-Intention Healing

Significant hemorrhage following Mohs' surgery may rarely occur, typically in the first 24 hours. Most commonly, diffuse oozing occurs in patients with an organic or iatrogenic bleeding diathesis. This may be sufficient to soak through the initial pressure dressing but should be controllable through direct pressure, application of new dry dressings, rest, and wound elevation. Occasionally, arteriolar bleeding manifests within several hours of surgery when the epinephrine effect wanes. The presence of exposed large vessels dictates management by tissue coverage. Slow wound healing may be expected to occur in previously irradiated skin (Fig. 43–8) or may develop concurrently with bacterial colonization or wound infection. Wounds suspected of microbial colonization or infection should be cultured, any dry eschar removed (often revealing purulent foci), appropriately aggressive

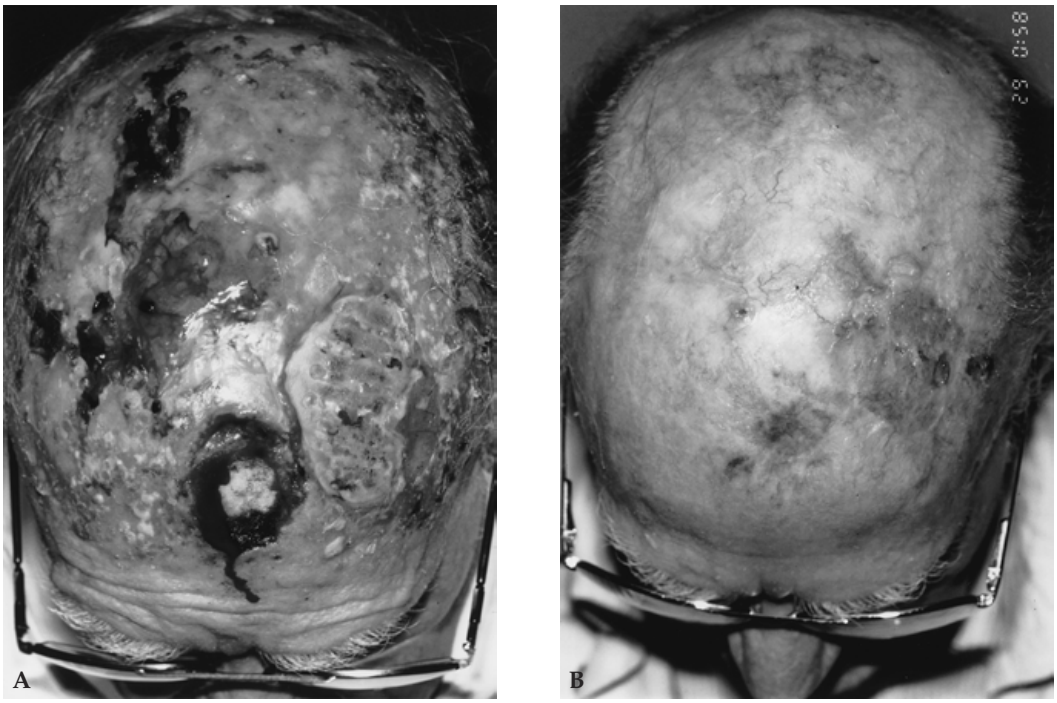

Figure 43–8 An 82-year-old man who presented with a persistent, chronic, nonhealing full-thickness wound on his scalp of 2 years' duration following excision of a squamous cell cancer 2 years previously. Ten years previously he had received radiation to his scalp. He had no evidence of tumor recurrence by multiple biopsies. **(A)** Inadequate granulation tissue and bare calvarial bone exposed. **(B)** After the outer table of skull was burred down and the scalp kept moist with antibiotic ointment, new granulation tissue formed to allow for later coverage with a split-thickness skin graft.

wound care reemphasized, and gram-positive antibacterial coverage begun. If necessary, antibiotic coverage is later adjusted based on culture results. Rarely, even in healthy-appearing wounds, nonhealing may be observed. In this instance, one observes granulation tissue formation followed by only partial reepithelialization. Such wounds should be cultured to rule out colonization by yeast or bacteria and antibiotics employed as necessary. A recent clinical report[24] suggests that wound healing arrest may be reversed by topical or oral corticosteroids or oral ibuprofen in combination. Provided that sufficient granulation tissue has developed, grafts may be placed or flaps constructed to cover the wound. Development of proud flesh, an exuberant growth of granulation tissue, that overfills the wound bed, may impede wound healing. Proud flesh has been associated with the presence of foreign bodies, such as hair shafts on hair-bearing skin, which should be removed to allow regression of abundant granulation tissue. Regression may be induced by application of chemical cautery (silver nitrate sticks), electrocautery, topical steroids,[25] pulsed laser irradiation targeting oxyhemoglobin (532 nm, 577 to 600 nm), or CO_2 laser targeting tissue H_2O. Alternatively, proud flesh may be sharply debrided, particularly if pedunculated or overgrowing the wound edges.[16,17] Ironically, the moist wound environment, which promotes wound healing in some cases, may contribute to the formation of proud flesh. If other treatment modalities fail, use of less occlusion (less ointment, more gas-permeable dressings) or astringent wound care (acetic acid wet-to-dry dressings) can bring about regression of proud flesh. In a wound created by removal of a skin malignancy, failure of proud flesh to respond to common measures should prompt a biopsy to rule out recurrence.

Once reepithelialized, second-intention wounds may still not achieve complete healing. Inadequate filling of the wound to a level that recreates the normal tissue contour commonly occurs on convex surfaces, making scars more noticeable and less cosmetically appealing. In addition, some scars may heal with a shelf-like drop-off at the periphery. This contour abnormality readily casts a shadow and brings attention to the scar. Hypertrophic scarring is unusual but may follow second-intention healing. Hypertrophic scar tissue is marked by significant red or violaceous erythema, induration, pruritus or pain, and progressive growth. Common facial sites include the cutaneous and vermilion lip, upper medial canthi, and central cheeks. Hypertrophic scarring diagnosed early may be treated with topical or intralesional corticosteroids, intralesional 5-fluorouracil, intralesional interferon-α, topical silicone gel sheeting, or pulsed dye laser irradiation (585 nm). Tissue contraction associated with second-intention healing may distort surrounding normal anatomic structures. Appropriately placed guiding sutures can alter contraction force vectors to minimize or prevent distortion of adjacent structures.[26] Finally, second-intention healing of wounds deep to the pilosebaceous units can

leave alopecic scars on hair-bearing skin. This can make second-intention healing a relatively poor choice on the male beard area or on hair-bearing scalp.

A successful approach to wound management is based on an appreciation for the expected outcome of wounds managed by both first and second intention. One should consider that the choice of second-intention healing need not produce inferior results and therefore should not be a secondary consideration.

SKIN GRAFTS

A skin graft consists of a segment of dermis and epidermis that has been completely separated from its blood supply and donor site and transferred to a recipient location. Skin grafts are classified as split-thickness skin grafts (STSGs) and full-thickness skin grafts (FTSGs) (Fig. 43–9).

Skin grafts are often considered when local skin flaps are not feasible. Compared with skin flaps, skin grafts give less optimal color match and texture on the face. STSGs (0.010 to 0.018 in.) can provide temporary coverage of soft tissue defects if adjacent soft tissue viability is uncertain or if a large amount of soft tissue coverage is required. However, they give poorer color and texture match than full FTSGs, giving a lighter, more atrophic, and glistening appearance. They also have less skin durability to infection and to future trauma with increased wound contracture. FTSGs give more acceptable facial color and texture match in comparison with STSGs if they are taken from the preauricular, postauricular, upper eyelid, nasolabial, or supraclavicular donor areas.

When obtaining skin grafts, one should be aware that skin thickness varies with age, sex, and region of the body. Skin is 3.5 times thinner in newborns than in adults. By 5 years old, the skin thickness in children is close to that of adults. Females have thinner skin than males. By body region, skin is thinnest at the eyelids (0.017 in.) and thickest over the soles of the feet and palms (0.150 in.).[27]

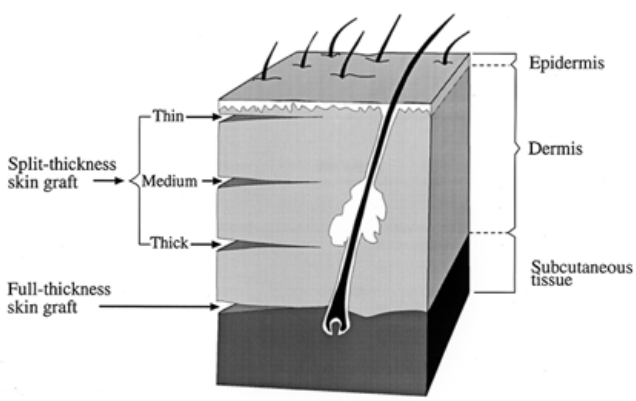

Figure 43–9 Various skin graft thicknesses taken from the skin.

STSGs can be used to cover any wound that has a blood supply sufficient to support its survival. Areas that cannot furnish enough blood supply to a graft are on cortical bone without periosteum, cartilage without perichondrium, tendon without paratenon, nerve with perineurium, and any surface with stratified squamous epithelium intact. In addition, a previously irradiated recipient site has a lower blood supply and results in a decreased "take rate" than a nonirradiated site.

Wound Healing of Skin Grafts

Immediately after a skin graft is brought in contact with its recipient bed, it begins to absorb the plasma wound fluid like a sponge by capillary action (plasmatic imbibition) during the first 48 hours. In addition, over the first 24 hours, a fibrin layer forms underneath the graft, keeping the graft adhered to the wound bed to allow for vascular budding to occur. Within 4 to 7 days after transplantation, the skin becomes revascularized by three major mechanisms. One mechanism is the direct connection of vascular buds from the bed with preexisting vessels in the graft (inosculation). The second method is ingrowth of the host vessels through preexisting endothelial channels of the graft. The third method is random ingrowth of vascular buds into the graft, thus forming a new vascular network.[28] Thin STSGs (less than 0.014 in.) are thought to revascularize faster than thicker skin grafts. This is because penetrating blood vessels travel shorter distances through the dermis in thinner skin grafts. In addition, thin STSGs have a lower metabolic rate; thus, plasma imbibition is able to maintain the graft survival longer, before revascularization occurs.[28]

Split-Thickness Skin Grafts

STSGs contain epidermis and a portion of the dermis. They can be further defined by their thickness: thin (0.008 to 0.010 in.), medium (0.011 to 0.015 in.), and thick (0.016 to 0.018 in.). Thin STSGs contract more than thick STSGs. Thin STSGs do not grow hair at the recipient site. The advantages of using STSGs for reconstruction of facial defects are as follows: (1) they can be an expedient technique for covering soft tissue defects if adjacent soft tissue viability is uncertain and (2) they can cover large defects when close surveillance is required of the site for tumor recurrence. Disadvantages of partial thickness skin grafts are as follows: (1) they have poor color and texture match with the surrounding skin, giving a lighter, more atrophic, and glistening appearance; (2) they result in decreased skin durability to future trauma; (3) there is increased wound contracture; and (4) there is a donor site scar.

Donor Sites

Common donor sites include thigh, abdominal wall, and buttock. If a larger amount of STSG is required, the scalp can be used repeatedly in 7-day intervals because its dermis is so thick with dense hair follicles and a robust blood supply. Up to five or six harvestings can be taken from the same site.[29]

Technique

Common instruments used in obtaining a STSG are the Brown electrical or air-driven dermatome, the Padgett-Hood dermatome, or the Humby knife. The choice of instrument is

based on the surgeon's preference. To obtain the preferred STSG thickness using the electrical dermatome, adjust the pitch of the blade in the instrument by closing the knobs down completely and use this reading as the zero point on each side. After the preferred thickness and width have been set, it is recommended that the space between the blade and the instrument be double-checked to ensure that a consistent and proper thickness is obtained. The skin is cleaned with bactericidal solution and dried, then treated with sterile mineral oil. The dermatome is set between 0.008 and 0.018 in. with the desired STSG thickness. The dermatome is operated so that its flat surface lies against the skin with even pressure.

After the graft has been placed at the recipient site, it is immobilized for 5 to 7 days to prevent hematoma formation and shearing. A pressure dressing using a bolster or stent with tie-over sutures is helpful. Cotton balls, dental rolls, fluffed gauze, or sponges are effective as bolus materials to secure even pressure over the graft site. A heat-sensitive mold splint (Aquaplast) is used to conform and secure the bolus material in place for 5 to 7 days. The skin graft donor site can be covered with an occlusive dressing (such as Opsite) for several days and changed when needed until adequate reepithelialization has occurred. A moist donor area will heal more rapidly than a dry area (Fig. 43–10).

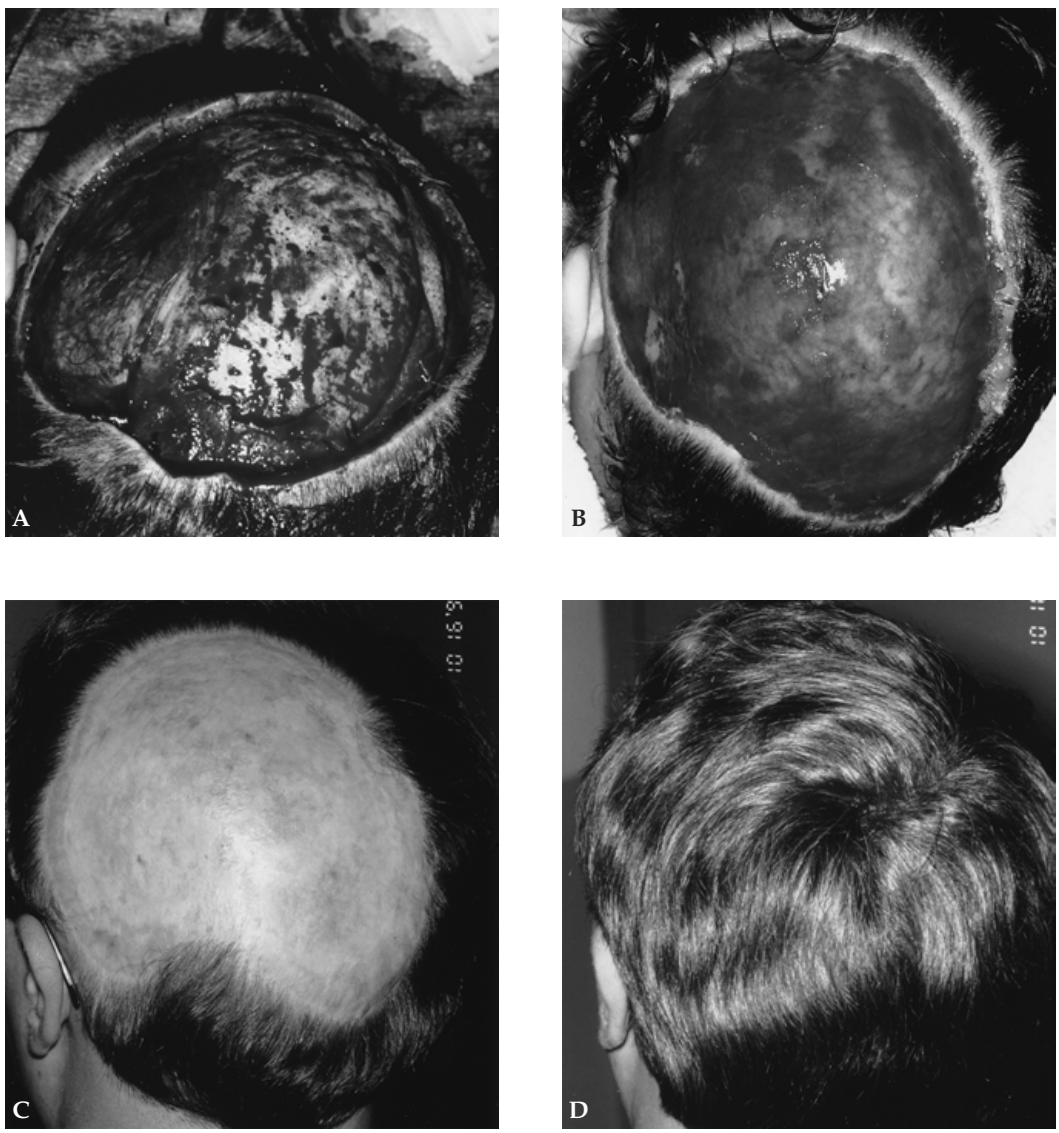

Figure 43–10 **(A)** A 27-year-old man who required full-thickness scalp excision and burring down of outer calvarial bone to remove dermatofibrosarcoma protuberans. **(B)** Scalp was allowed to granulate. **(C)** Split-thickness skin graft placed over well-granulated bed. **(D)** After healing, the patient wears a hairpiece to cover site.

Full-Thickness Skin Grafts

FTSGs consist of the entire epidermal and dermal layers of the skin. After transfer, they do not change in color or texture. As hair follicles are transferred with these grafts, hair growth is preserved. Because they are thicker than STSGs, they are more slowly revascularized. Intrinsically, they do not contract; however, their recipient bed does contract with healing. Facial areas for which FTSGs are very useful are at the nasal tip, eyelids, and auricle (Fig. 43–11 and 43–12).

Advantages in using FTSGs are as follows: (1) they give a more acceptable facial color and texture match than STSGs if taken from the preauricular, postauricular, upper eyelid, or supraclavicular donor sites, and (2) they are a single-stage procedure. Disadvantages of FTSGs are as follows: (1) they have a decreased "take rate" in comparison with STSGs; (2) deep defects may require adequate granulation tissue before grafting; (3) there is decreased durability to trauma in comparison with skin flaps; and (4) there is increased donor site morbidity.

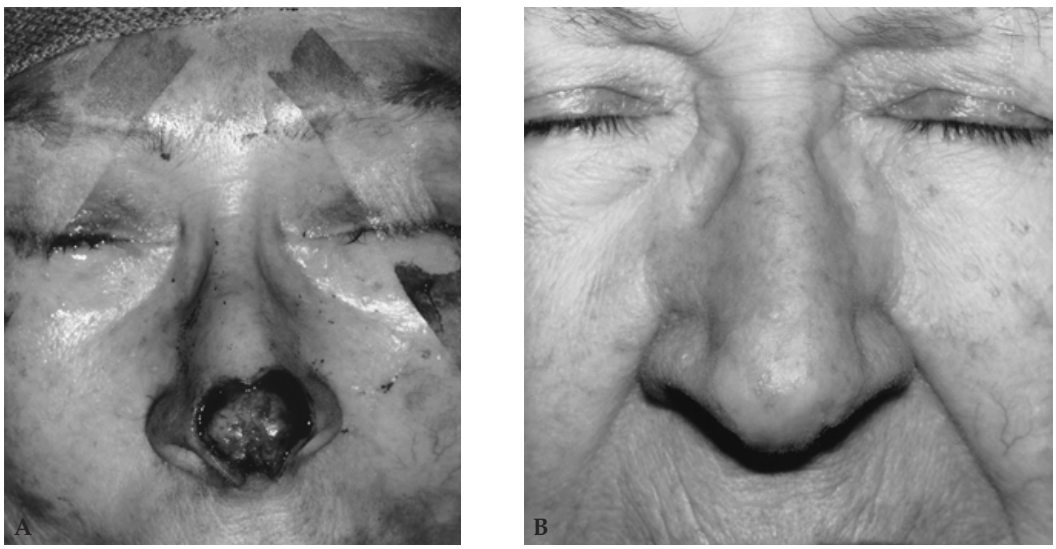

Figure 43–11 **(A)** Full thickness nasal tip skin defect following Mohs' micrographic excision of a basal cell carcinoma in 70-year-old women. A posterior auricular full-thickness skin graft was used to cover the defect. **(B)** Appearance 1 year later.

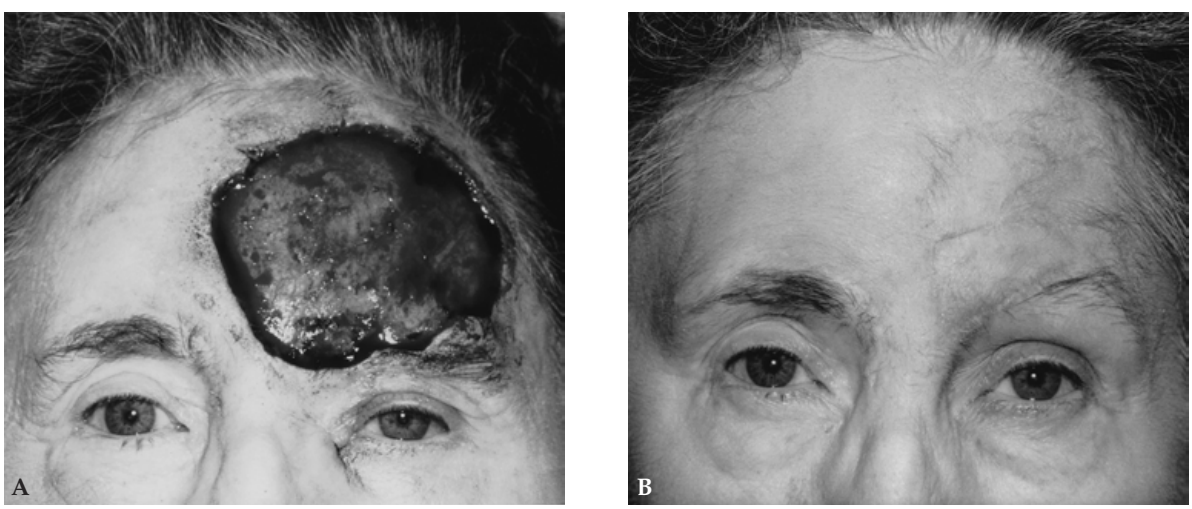

Figure 43–12 **(A)** Full-thickness forehead skin defect following Mohs' micrographic excision of a basal cell carcinoma in a 65-year-old women. A preauricular full-thickness skin graft was used to cover the defect. **(B)** Appearance 1 year later.

Recently, a new FDA-approved FTSG substitute is now available. It consists of living epidermal and dermal skin (Apila graft, Organogenesis) derived from cultured neonatal foreskin. Similar to an FTSG, this bilayer graft has living cellular and growth factor components. Its immune properties have been removed because the Langerhans cells have been extracted from the dermis. Presently, it is approved for use in venous ulcers and diabetic foot ulcers, but soon it may be used for head and neck defects.

Donor Sites

Skin on different regions of the body differs in color, texture, thickness, vascularity, and hair bearing nature. The closer in proximity the donor site is to the recipient site, the more likely the skin match. Thus, skin grafts taken above the clavicles tend to retain their natural blush state, in contrast to skin taken below the clavicle, which has a yellowish or brownish hue.[30] The most common donor sites used are the postauricular, preauricular, supraclavicular, and upper eyelid skin areas. Postauricular skin grafts 3 × 5 cm can be taken from the postauricular sulcus, encompassing the area from the helical rim to the hairline over the mastoid region. If necessary, this donor site can be closed primarily or with an STSG. At the supraclavicular and preauricular sites, the color match and texture are also good, with the skin being thicker. Upper eyelid skin can be used as a donor site when a small, thin FTSG is required for another eyelid site. Other donor sites are at the flexor crease of the antecubital or inguinal regions. When obtaining an FTSG, the subcutaneous fat should be removed because the adipose layer will act as a barrier to reduce revascularization of the dermis.

STORAGE OF SKIN GRAFTS

When it is anticipated that the skin graft may be needed in the future, it can be stored by two methods. STSGs can be placed back on the donor site and removed up to 14 days later. Another method is to wrap the skin graft in saline- or Ringer's lactate–soaked gauze and place it in a sterile jar in a refrigerator at 4°C. By this method, STSG can be refrigerated up to 21 days and still be used for grafting. It appears that using an STSG taken for the second time from its donor site gives a higher take rate than grafts stored in saline at 4°C.[31]

DERMIS GRAFTS

A dermis graft consists of an FTSG without the epidermis. By removing the epidermal surface, vascularization can occur on both surfaces of the graft. After a dermis graft is transplanted, an intense granulation reaction occurs within the graft mesoderm, which fibroses and contracts over several months.

Dermis grafts should be placed in areas where soft tissue contraction will not distort neighboring structures. They can be stacked in several layers before transplantation to give additional bulk for augmentation. Dermis grafts are useful in augmenting facial regions where bulk is required, but not for support.

COMPOSITE SKIN–CARTILAGE GRAFTS

Composite skin–cartilage grafts can give both covering and contour to a facial defect. To optimize perfusion of a composite skin–cartilage graft, all points of the graft should be within 5 mm of the edge.[32] Larger composite grafts up to 3.0 cm have been reported; however, beyond 1.0 cm diameter, the predictability of composite graft survival decreases.[33] Transferring more skin than cartilage can enhance neovascularization of larger composite grafts, thus converting the graft to more of a full-thickness type. Skin cartilage grafts are useful for closing defects of the nasal alar rim, columella, and eyelid when adequate vascularity of the surrounding tissue bed exists. Advantages of composite skin–cartilage grafts are that (1) it is a one-stage procedure, and (2) structural and epithelial coverage are transferred.

The disadvantages of composite grafts are that (1) once the size of the grafts is beyond 1.0 cm diameter, the predictability of composite skin–cartilage graft survival decreases, and (2) composite graft contraction occurs gradually, which can compromise the final cosmetic result.

In some instances, the revascularization of composite grafts can be improved by increasing the host bed surface area. This can be done by rotating an adjacent turnover flap to increase graft–host surface contact, rather than depending solely on edge-to-edge contact (Fig. 43–13).

Wound Healing of Skin–Cartilage Composite Grafts

The healing of composite skin–cartilage grafts is similar to that of skin grafts in that revascularization of grafted skin is essential for its long-term survival. During the revascularization process of composite skin–cartilage grafts, host vessels cannot penetrate cartilage. Hence, the host vessels spread along the underside of the cartilage until they reach the dermis of the graft. After 48 hours, vascularization begins at the host–dermis interphase of the composite graft, followed by vascularization toward the dermal center of the graft.[33]

WOUND CARE

To avoid cell damage, skin cleansers (Betadine and Hibiclens) should not be used repetitively. Wound cleaning can be performed using normal saline or commercial wound cleansers. Moisture-retentive dressings or ointments should be used until reepithelization of the wound is complete.

Local factors that impede wound healing, such as infection, hematoma, and seroma, will increase the likelihood of scarring. Another factor that increases scarring potential is excessive tension at the incisions. With careful preoperative planning and meticulous surgical technique, these risks can be minimized.

Figure 43–13 **(A)** Composite skin–cartilage graft for nasal ala defect. To increase composite graft–recipient surface contact for revascularization, an adjacent turnover flap was used, instead of solely depending on edge-to-edge contact. **(B)** Donor site of composite skin cartilage graft. **(C)** Placement of composite skin–cartilage graft at nasal alar rim and full-thickness skin graft over donor site.

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Chapter 44

Local and Regional Cutaneous Flaps

Stephen S. Park

Reconstruction of facial defects with local and regional cutaneous flaps is a challenging and rewarding part of facial plastic surgery. Over the years, the standard of care has risen significantly, and today's expectations are an inconspicuous aesthetic result with preservation of normal function. Many contemporary principles have allowed us to achieve these goals in a great number of patients.

Cutaneous lesions can be treated in a variety of ways, but Mohs' micrographic surgery represents the gold standard for complex malignancies of the face and neck. Frederick Mohs first described this technique in the 1940s while a medical student at the University of Wisconsin.[1] This original fixation technique occurred in situ and required a postoperative slough of tissue, forcing a majority of these defects to heal by second intention. The development of immediate, fresh tissue fixation allowed the definitive excision to be completed much more quickly and permitted immediate repair, thus catalyzing the interest in cutaneous reconstruction through local and regional flaps.

It is recognized that the primary risk for cutaneous malignancies is a series of high-intensity, short bursts of sun exposure at an early age, such as children with sunburns. Many adults today, however, grew up in an era when the importance of sun protection was less appreciated; consequently the incidence of cutaneous malignancies continues to rise. Ultraviolet-B (UV-B) rays are absorbed at the dermal–epidermal junction and are most responsible for malignant degeneration of epidermal cells. UV-C rays are the shortest wavelength and are absorbed by the ozone layer in their entirety. UV-A rays penetrate to the deeper dermal layer and are more associated with tanning and causing photoaging of skin.

ANATOMY AND PHYSIOLOGY

Vascular Supply

The cutaneous vascular network is a unique system with an abundant dermal and subdermal plexus that allows for dependable and versatile random donor flaps. This dermal plexus is regulated by arteriovenous shunts that are controlled by the adrenergic neural supply and function as one of the primary thermal regulators of our body. Skin may also have its arterial supply through an axial pattern based on a dominant artery in the subcutaneous layer. Muscular perforating arteries are also a dependable source to the cutaneous vascular bed. Local perfusion pressure is the driving force for random cutaneous flaps. Critical closing pressure is the pressure whereby capillary vessels collapse and all vascular flow ceases. This is thought to occur between 5 and 10 mm Hg.[2] The concepts of perfusion pressure and closing pressure have challenged the old dogma that random donor flaps require a *length to width ratio* of 3:1. Studies have now shown this to be a fallacy and that the essential variable for flap viability is the perfusion pressure and vascularity at the pedicle base.[3] This understanding has strongly supported the birth of pedicle flaps and microvascular free flaps.

Skin Lines

Langer lines were defined by the way a circular wound takes on an elliptical shape as rigor mortis develops.[4] Langer's assumption was that skin excisions oriented along the long axis of these wounds resulted in more favorable healing. Clinical experience has shown that this is not always accurate and they appear to conflict with other described skin lines. Today Langer's lines are of historical interest only.

Relaxed skin tension lines (RSTL) are derived from vectors within facial skin that reflect the intrinsic tension of skin at rest.[5] These properties of skin are defined by the microarchitecture, such as the alignment of elastic and collagen fibers, and, to a lesser degree, the influence of underlying bone and soft tissue bulk. RSTLs are the lines of intrinsic skin tension that appear when the skin is in repose and represent the directional pull on wounds. They have the greatest cumulative effect on wound tension and final healing. The RSTLs are generally parallel to external skin wrinkles but represent a distinct entity from them and occasionally conflict (Fig. 44–1).

Lines of minimal tension which are also known as natural skin creases or wrinkles are the lines that are externally visible and result from repeated bending of skin from muscular contraction until a permanent cutaneous crease has formed with adhesions between the dermis and deeper tissues. These natural skin creases run perpendicular to muscular fibers and can guide wound orientation for favorable healing. The glabella, nose, and lateral canthal areas have conflicting RSTLs and lines of minimal tension where repeated muscular pull creates permanent skin creases that override the intrinsic tension lines of the skin. In these regions, it is usually best to orient wounds and scars within skin creases rather than the RSTLs for best camouflage.

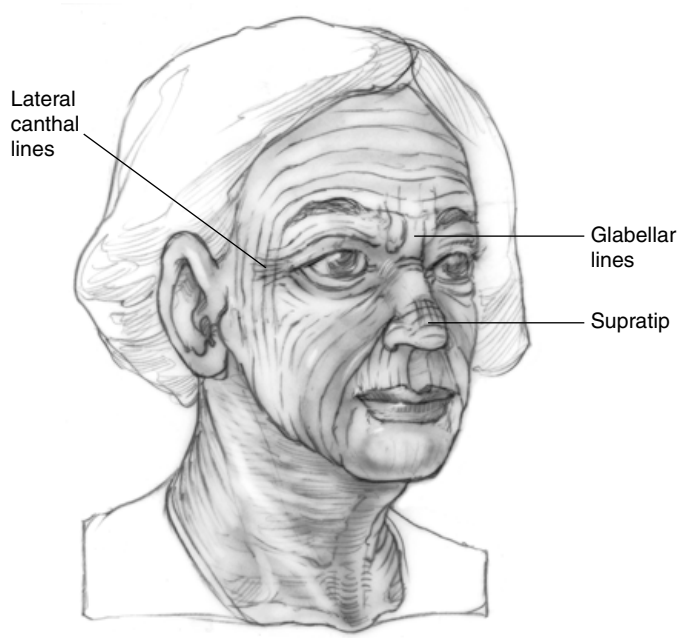


Figure 44–1 Relaxed skin tension lines (RSTLs) and natural skin creases of the face. Generally these coincide, but three areas of conflict are lateral canthus, nasal supra tip, and glabella.

Sleep lines represent the skin creases that result from the patient's habitual positioning while asleep, where the skin is unnaturally folded and remains independent of the intrinsic skin forces as well as muscular contraction.

Lines of maximum extensibility are important when recruiting tissue from adjacent areas. The tension on the flap is an essential consideration and can be minimized by studying the lines of maximum extensibility (LME). These lines typically run perpendicular to the RSTLs and parallel to muscular fibers. Extensibility must be distinguished from elasticity, the latter being the property of recoil as skin returns to its original shape.

TIMING

There is a general surgery dictum that soft tissue wounds that are not closed within 6 hours be left open to heal by second intention. The rationale for this is the concern with contamination and subsequent soft tissue infection. Although this is a significant concern with lower extremity wounds, it is not as applicable to the soft tissues of the face and neck. The robust vasculature of the face affords a very low incidence of soft tissue infections, and there is essentially no limit to the delay for facial wound closure. There are occasions where the repair of soft tissue wounds is best delayed for a couple weeks, such as when the accumulation of granulation tissue will improve the contour of the wound bed. Prior to closure of a delayed wound, it should be aggressively debrided with removal of the thin layer of fibrinous exudate that forms on the bed. Wound margins are "freshened" as peripheral epithelialization has often occurred. An important consideration with regard to delayed wound repair is soft tissue contracture, which may be favorable as the overall dimensions of the soft tissue deficit decrease. However, once this contracture distorts surrounding structures, such as eyelids, lips, or the alar rim, its surgical correction can be far more challenging than the original defect.

WOUND CARE

Closed incisions are cleansed with dilute hydrogen peroxide followed by a thick moisturizing ointment. The purpose of the peroxide is to remove any small blood clots and crusts within the skin incision itself. Left alone, these small scabs may contribute to a slightly wider scar as epithelialization occurs beneath it. Sufficient hemostasis has usually occurred after a few days, and peroxide is no longer needed. Continued moist wound coverage is essential and simple petrolatum gel is sufficient. All open wounds and skin grafts are managed with mild soap and water followed by ointment. Hydrogen peroxide is strictly avoided due to its cellular toxicity and the potentially delayed healing that may occur. Diligent sun protection is critical for at least 6 months following reconstructive surgery and is continually reiterated to the patients. All undermined skin as well as incisions are more sensitive to actinic injury and prone to early tanning and burning. Premature sun exposure may result in a permanent discoloration or a "tattooing" effect on the cutaneous scars.

FLAP NOMENCLATURE

Different disciplines participate in cutaneous flap surgery, and it remains important to use consistent nomenclature. Four systems are utilized, as follows:

1. *Blood supply*. Skin flaps may be characterized by their arterial blood supply as either *random donor*, *axial pattern*, or *pedicled*. The dermal and subdermal plexus alone nourishes random pattern flaps. Axial pattern flaps have more dominant superficial vessels that are oriented longitudinally along the flap axis. Pedicled flaps have large, named vessels that directly supply the skin paddle, often through muscular or fascial perforators (Fig. 44–2).

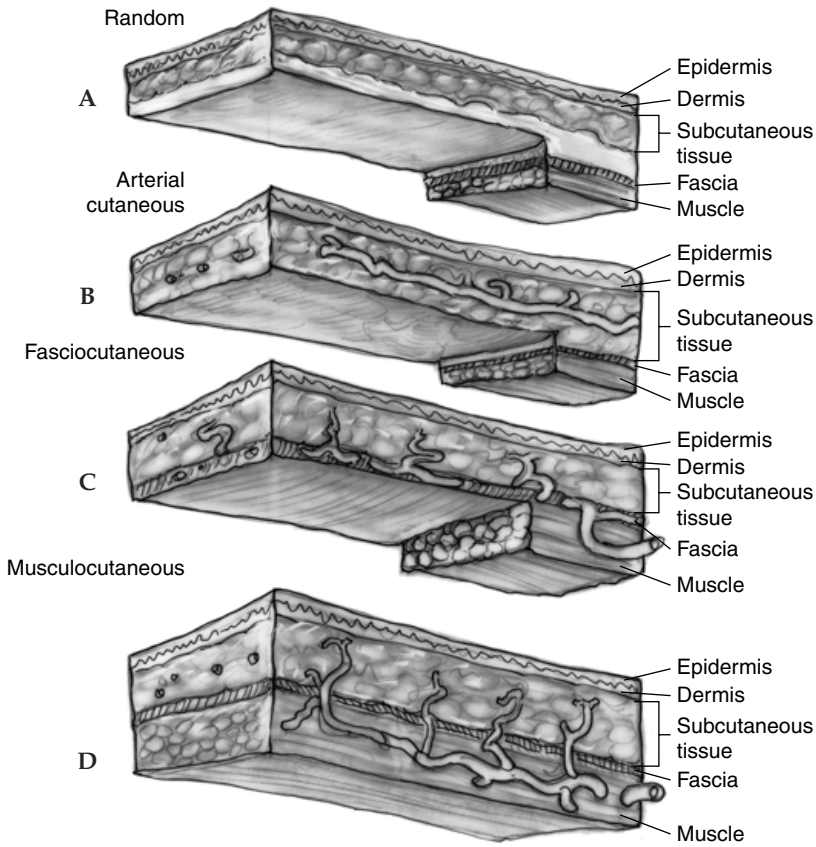


Figure 44–2 Vascular anatomy of cutaneous flaps: **(A)** random pattern flap based on subdermal plexus. **(B)** Axial pattern flap. **(C)** Fasciocutaneous flap with named vessel. **(D)** Musculocutaneous flap with named vessel.

2. *Location*. The region from which tissue is mobilized is another means of classification. Local flaps generally imply utilizing adjacent tissue. Regional flaps are from different areas of the same part of the body (e.g., forehead flaps for nasal reconstruction). Distal flaps are from different parts of the body, such as a pectoralis myocutaneous flap for the head and neck.
3. *Tissue content*. The embryologic layers of tissue contained within the flap are another means of classification. *Cutaneous flaps* are limited to the skin. As deeper layers are incorporated into the flap they are classified accordingly (e.g., myocutaneous, fasciocutaneous, and composite).
4. *Method of transfer*. Method of transfer is probably the most frequently utilized system of nomenclature but often inaccurately defined. Advancement flaps are mobilized in a unilinear fashion toward the defect. Rotational flaps pivot around a specific point and maintain that radius. Therefore, pure rotational flaps are rarely utilized. Most local flaps combine advancement and rotational elements. Transposition refers to a flap that is elevated and mobilized toward an adjacent defect and transposed over an incomplete bridge of skin. A rhombic flap is an example of a transposition flap in that the flap is elevated and transposed over a small triangle of undisturbed adjacent skin. Interposition flaps are similar to transposition flaps; however, the incomplete bridge of adjacent skin is also elevated and mobilized, usually in the opposite direction to fill the secondary defect. A Z-plasty is an example of an interposition flap. Interpositioned flaps differ from transposition flaps in that the skin flap is elevated and transferred over a complete bridge of intact skin. By definition, this creates a cutaneous pedicle and mandates a second stage for pedicle division. The forehead flap is an interpolated flap wherein the glabella represents the undisturbed bridge of skin. The island flap is a variation of an interpolated flap where the pedicle is deepithelialized and contains subcutaneous tissue alone. This pedicle can then be buried beneath the intact bridge of skin, thus obviating the second stage. Free microvascular flaps are based on a detached vascular pedicle and transferred to a different region for reanastomosis.

DEFECT ANALYSIS

During the initial evaluation of a cutaneous defect, the optimal method of reconstruction is not always immediately obvious and an algorithmic method of analysis can assist with flap selection and design. By reviewing four specific areas, one may lay out the most aesthetic cutaneous flap while avoiding gross facial asymmetry or distortion.

1. *Immobile structures*. What are the specific structures relevant to this facial defect that must not be distorted or come

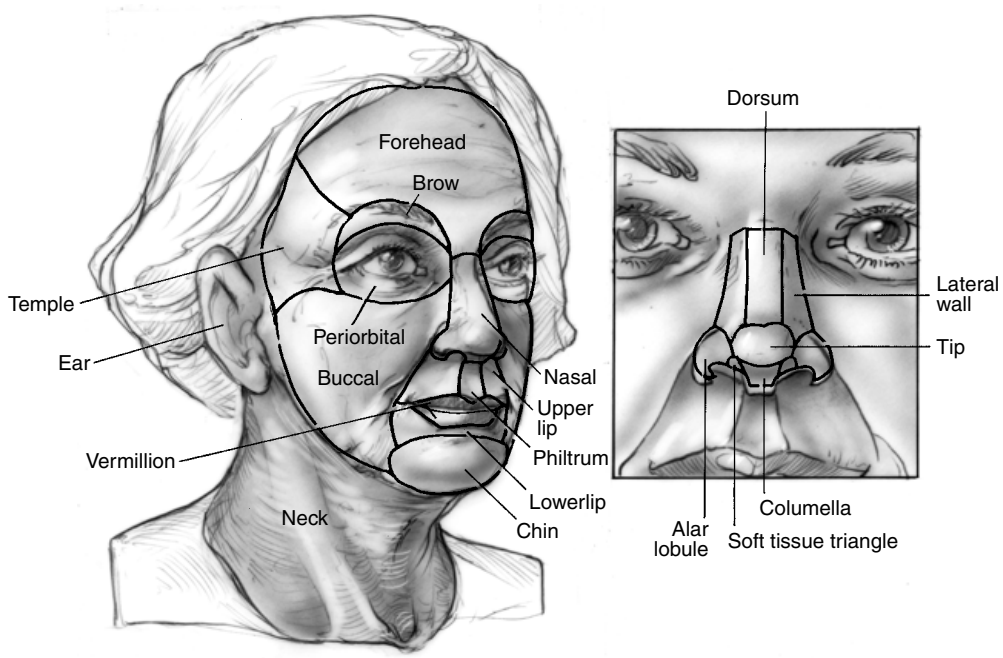


Figure 44–3 Facial aesthetic units. **(A)** The face is perceived as a series of block images and incisions/scars along unit borders tend to be less conspicuous. **(B)** The nose is further broken down to aesthetic subunits.

under any tension? These include such landmarks as the hairline, eyelid, melolabial fold, and so forth.

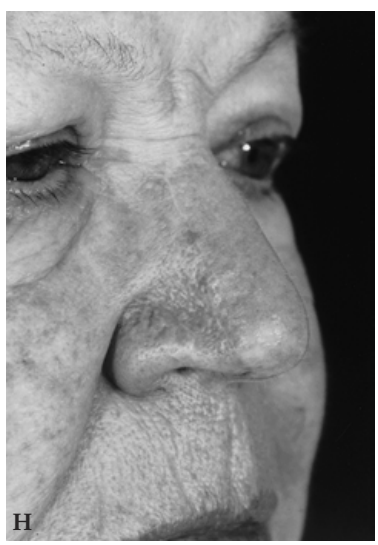
2. *Area of recruitment*. Which of the areas surrounding the defect is most readily accessible and has sufficient laxity to allow mobilization toward the defect?
3. *Relaxed skin tension lines and aesthetic units*. How are the RSTLs, skin creases, and LMEs oriented in that region to best accommodate additional skin incisions while minimizing wound tension? In addition, the borders of the aesthetic units represent imaginary lines that can accept skin incisions and their subsequent scars in an inconspicuous manner. The principle of the aesthetic unit is based on the fact that our eyes tend to see objects and faces as a series of block images that are spatially organized. For example, the face is characterized by several distinct aesthetic units, each seen by the casual observer as a single block image. The nose has been further divided into aesthetic subunits and has served as one of the major advances in contemporary nasal reconstruction[6] (Fig. 44–3). These aesthetic units of the face and nose are defined by subtle changes in topography, reflections of light, preexisting creases, and transition zones of skin texture. They do not necessarily correlate with the underlying bony and cartilaginous framework. Scars that lie at the junction of two adjacent aesthetic units tend to be inconspicuous because one expects delineation between these facial areas.
4. *Resultant scar*. One must always anticipate the final resultant scar of any local and regional flap. Oftentimes these flaps can be oriented in such a way as to comply with the preexisting variables discussed previously, e.g., relaxed skin tension lines and aesthetic unit borders.

This algorithm for defect analysis will often lead to the optimal reconstructive flap with the least functional problems and inadvertent distortion.

Representative Case 1 **(A)** An 82-year-old woman is referred for repair of a nasal Mohs defect. **(B–D)** The nasal aesthetic subunits are outlined and illustrate a majority of the tip unit to be missing along with 40% of the dorsal unit and 20% of the left lateral sidewall. A small superficial defect of the right ala is repaired independently with a full-thickness skin graft. **(E)** The aesthetic units are excised and resurfaced with a single flap. **(F–I)** The 18-month postoperative view demonstrates the camouflage that can be achieved by designing wound edges, flap borders, and subsequent scars consistent with principles of aesthetic subunits.

SECOND-INTENTION HEALING

Second-intention healing is often overlooked by facial plastic surgeons but is often employed by dermatologic surgeons and has several advantages. On occasion, second-intention healing may be the method of choice for obtaining the best aesthetic and functional outcome. Wounds that lend themselves to second-intention healing are superficial, concave, and not in close proximity to mobile structures that might be distorted during normal wound contracture. Patients who are exceptionally high surgical risks are also good candidates for this method of repair. A disadvantage of second-intention healing is the length of time required for complete healing; an average 1-cm defect may take close to 4 weeks for total reepithelialization. The inconveniences of continued wound care often exceed that of a surgical repair. If wound contracture occurs and causes significant distortion to adjacent structures, the secondary repair can represent a formidable challenge. Soft tissue contracture usually involves deeper tissues, and a multilayer reconstruction may be needed for correction.



Representative Case 1 **(A–I)** The nasal aesthetic subunits.

ADVANCEMENT FLAP

Wound edges from a Mohs defect must be "freshened" prior to definitive closure. The technique of Mohs' surgery leaves wound edges beveled toward the center of the wound to analyze the entire specimen margin. When closing cutaneous wounds, it is preferable for the edges to bevel away from the center to allow maximal skin eversion during subcuticular closure.

Primary closure is the simplest form of an advancement flap. An advancement flap refers to mobilizing tissue in a unilinear dimension without a rotational element. Circular defects closed primarily must be modified to an elliptical shape to avoid standing cutaneous deformities. The terminal angles of a defect should be roughly 30 degrees or less to avoid this "dog ear" deformity. This 30-degree angle serves as a reference to dictate how far one must extend the ellipse and how much normal tissue will be discarded. When this tissue cannot be readily sacrificed, the ellipse can be converted to a W-plasty with the apices of the "W" 30 degrees or less (Fig. 44–4). This preserves some surrounding tissue and also avoids extension of the resultant scar. A W-plasty can be very useful for cutaneous defects in close proximity to facial landmarks, such as a lip defect repaired primarily using an inferior W-plasty to avoid a scar that traverses the mental crease.

Pure advancement flaps have the feature of limiting wound tension to a single vector with minimal perpendicular tension (Fig. 44–5A). Advancement flaps are often utilized in the forehead and eyebrow areas to capitalize on the natural forehead furrows while causing no vertical distortion of the hairline superiorly or the brow margin inferiorly. The skin edges from the flap and nonflap sides are of different lengths, and their closure may create one or several standing

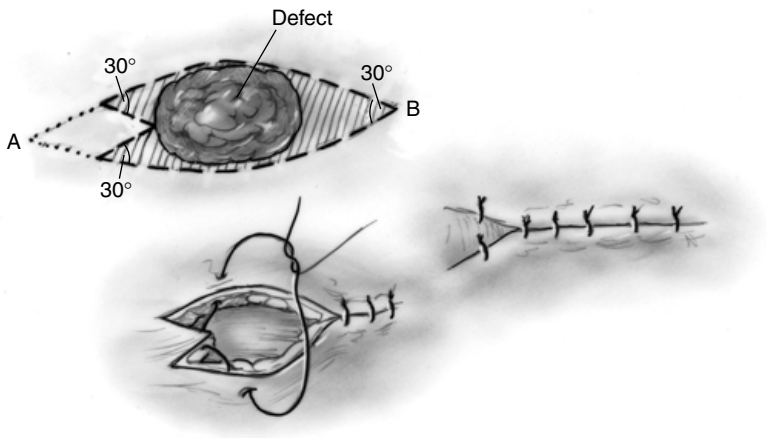
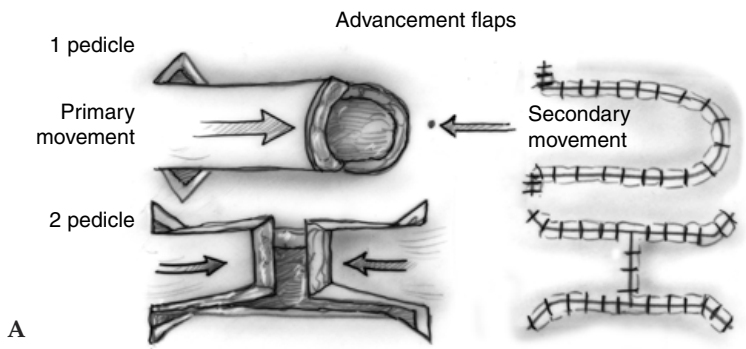


Figure 44–4 Primary closure with W-plasty. The terminal angles for any primary closure with advancement flaps must be 30 degrees or less to avoid the standing cutaneous deformity.



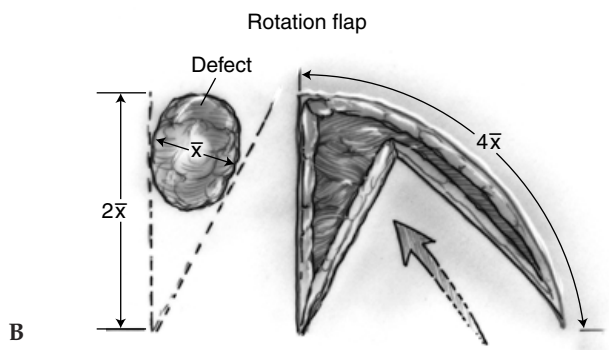


Figure 44–5 Unilateral and bilateral advancement flaps. **(A)** The primary tension vector is along a single axis with very little surrounding distortion. **(B)** Rotation flap around a given pivot point with an arc that is roughly four times the diameter of the defect.

cutaneous deformities that may require direct excision (Burrow's triangles). These excisions create scars perpendicular to the flap margin, which are generally undesirable and should be positioned as inconspicuously as possible. When smaller discrepancies exist, the flap borders may be closed primarily through serial halving sutures; that is, each sequential suture is placed midway along the incision such that the length discrepancy becomes evenly distributed along the length of the wound.

V-Y Flaps are also advancement flaps in that they are mobilized in a linear direction. They are based on a subcutaneous pedicle, which may limit the amount of advancement the flap can achieve. The secondary defect is closed primarily and the resultant scar resembles the letter "Y." Cheek defects along the alar facial groove are amenable to a V-Y flap repair, recruited from the melolabial fold. This minimizes distortion to the nose and upper lip while preserving the general orientation of the melolabial fold.

Representative Case 2 **(A)** A 74-year-old woman presents with a Mohs defect of the left cheek and lip that crosses the melolabial fold and is up to the alar facial groove. A preexisting scar is noted in the left cheek. **(B)** This is repaired with a V-Y advancement flap, with primary closure of the donor site leaving a scar within the melolabial fold. **(C)** The advancement flap is based on a subcutaneous pedicle and mobilized up to the alar facial groove. **(D)** The resultant scar is in the configuration of the letter "Y." **(E)** A 6-month postoperative view.

Representative Case 2 **(A–E)** The V-Y advancement flap.

SCALP FLAP

The scalp flap is a unique example of a pure rotation flap due to the extreme inextensibility of the galea in and around the flap. Many facial defects can be closed with a rotation flap designed with an arc four times the diameter of the defect (Fig. 44–5B). On the scalp, however, the arc must be roughly six times the wound diameter to allow primary defect coverage. Galeal incisions, galeatomies, can improve the extensibility of these tissues and are best performed parallel to the arterial flow and perpendicular to lines of tension. Multiple rotation flaps can be designed around the primary defect in a spiral fashion.[7] Scalp defects occasionally require preoperative tissue expansion to create adequate coverage.[8] The advantage of using a scalp flap for defects of the head is coverage with like tissue (i.e., adjacent hair-bearing tissue). A reasonable alternative is to allow second-intention healing or skin graft coverage followed by serial excisions every 2 months.

CHEEK FLAP (CERVICAL FACIAL FLAP)

The cheek flap is a common example of a combination rotation and advancement flap that is ideally suited for moderate to large cutaneous defects of the medial cheek area. It utilizes the usually abundant tissue laxity in the adjacent cheek and jowl areas. Although it requires a moderate amount of undermining and skin elevation, the strategic placement of incisions makes the resulting scar relatively inconspicuous and is a dependable and aesthetic flap for many cheek defects. The disadvantage of a cheek flap relates to the amount of skin mobilization needed for adequate coverage. In addition, some patients are left with cheek asymmetry wherein one side has notably fewer wrinkles and smaller jowls. When improperly done, the cheek flap may cause distortion to important landmarks, such as the lower eyelid and nasal ala.

The superior incision for a cheek flap typically extends along a subciliary crease and out the lateral canthal and temporal area. There is a tendency to allow the incision to drift inferiorly as one extends beyond the lateral canthus, and this should be deliberately avoided. It is more useful to extend this lateral extension in a superior direction prior to turning inferiorly toward a standard facelift or parotidectomy incision. This superior extension allows a more rotational element to the cheek flap with less advancement. The inferior extension can be similar to a parotidectomy incision with a horizontal limb in the upper neck. When necessary, this flap can be enlarged inferiorly to incorporate a deltopectoral flap. More skin recruitment can be achieved by extending the incision to the postauricular, non-hair-bearing area and transposing this over the ear in a bilobe fashion. The medial incision should be along the nasal facial groove and continued into the melolabial fold; it does not extend to the upper lip. There is usually some flap redundancy or standing cutaneous deformity around the melolabial fold that requires direct excision, which should be performed liberally. The plane of elevation is in the subcutaneous layer, superficial to the facial nerve. It is critical that the flap be suspended in a superior medial direction via direct anchoring to the periosteum of the zygoma, infraorbital rim, or nasal facial groove. There should be no tension on the lower eyelid, nasal ala, or upper lip during closure. The suspending sutures can be done with long-lasting resorbable material such as 4-0 polydioxanone (PDS, Ethicon, Somerville, NJ). Small cutaneous "dimples" may arise from the suspension sutures, but these are temporary and can be massaged out over time. The superomedial tip of the flap should maintain an acute angle and fit precisely in the borders of the cheek, eye, and nasal aesthetic units. There is a tendency to round this corner of the flap, which leaves a more conspicuous resultant scar that is more likely to pull the lower lid during contracture. The portion of the flap that is repositioned over the lower eyelid should be aggressively thinned to mimic the thickness of skin native to this area.

Representative Case 3 **(A)** A 77-year-old woman presents with a Mohs defect of the left medial cheek down to the subcutaneous fat. She has reasonable tone to the left lower eyelid. **(B)** The borders of the facial units extend along the subciliary crease, vertically along the nasal facial groove and into the melolabial fold. Although closure along the long axis of the defect would require less skin mobilization, the resultant scar would be more unfavorable because it would lie within the cheek unit. **(C)** The cheek flap is advanced medially, with the resultant scar along the borders of the facial aesthetic units. A small dimple can be seen in the medial aspect of the cheek flap that represents a suspension suture between the dermis and the periosteum along the pyriform aperature. The lower lid is not shortened, although this can be done when significant laxity exists. There is no inferior tension to the lid margin. **(D, E)** Nine-month postoperative views with scars less conspicuous due to their placement. The lower eyelid margin is maintained, although there is some asymmetry to the fullness of the lower eyelids and cheek.

"O-T" FLAP

This flap converts a circular defect to a T-shaped scar. It incorporates advancement and rotational vectors with the distinct feature of recruiting adjacent tissue from a specific area around the defect while leaving one border undisturbed. This design is well suited for defects juxtaposed to important aesthetic landmarks on which the closure must not exert tension or distortion. For example, a cutaneous defect along the hairline is easily repaired with the O-T flap because it avoids mobilization of hair-bearing skin onto the face. Other areas in which O-T flaps are frequently utilized include forehead, temple, and lips. These flaps have the disadvantage of leaving an unfavorable scar containing two perpendicular limbs, one usually opposing natural skin creases. In addition, the central limb from the circular defect must be extended to avoid the standing cutaneous deformity, requiring the excision of some normal tissue.

Representative Case 3 **(A–E)** Cheek advancement/rotation flap.

Representative Case 4 **(A)** A 62-year-old woman has a defect of the left temple. The regional immobile structures include the hairline, eyebrow, and lateral canthus. The greatest area of recruitment can come from the left cheek and, to a lesser extent, from the forehead. **(B)** An O-T advancement/rotation flap is designed leaving the hairline and brow undisturbed. Both flaps are mobilized in the subcutaneous plane, superficial to the facial nerve. **(C)** Flap closure is complete, with one horizontal limb running perpendicular to the RSTLs of the temple area. This is accepted as a trade-off for maintaining eyebrow and hairline position. Scar resembles the letter "T." **(D)** One-year postoperative view showing the oblique limb of the defect closure. Regional facial landmarks remain undisturbed.

O-Z FLAP

The O-Z flap is an advancement/rotation flap similar to the O-T flap, except that the adjacent flaps are based on opposing sides of the defect and the final incision resembles the letter "Z." The unique characteristic of this design is the resultant scar; rather than two perpendicular limbs, the O-Z flap

Representative Case 4 **(A–D)** The O-T advancement/rotation flap for the temple.

creates scars that run oblique to one another and can be more closely aligned with skin creases. This flap can be useful in the temple and cheek regions where scar alignment has a significant impact on the cosmetic outcome.

NOTE FLAP

The note flap is a simple transposition flap whereby a circular defect is repaired with an adjacent triangular flap and the donor site closed primarily.[9] The flap design resembles the musical eighth note and is transposed over a small incomplete bridge of adjacent skin. A Burrow's triangle is excised from the defect margin, along the base of the flap. The resultant scar has a circular and straight component. The incomplete bridge of adjacent skin can also be mobilized to fill the donor site as an interposition flap (Fig. 44–6).

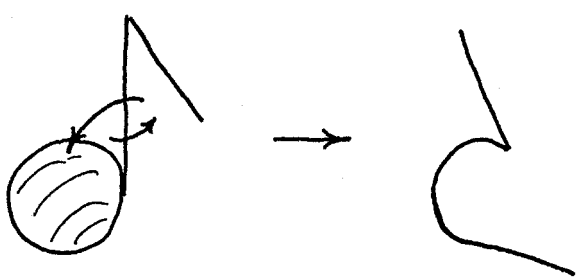


Figure 44–6 Note flap. The triangular flap can fill the circular defect as either a transposition or interposition flap. The circular defect can be converted to a triangle to maintain sharp angles.

RHOMBIC FLAP

The rhombic flap is a precise, geometric modification of the note flap and is a classic flap that remains the *workhorse* for many small cutaneous defects of the face. It is a transposition flap in that the mobilized tissue is elevated over an incomplete and undisturbed bridge of skin. The rhombic flap recruits and mobilizes tissue from a specific area and results in a predictable scar with well-defined vectors of tension.

The *Limberg* rhombic flap is the traditional design whereby the defect has 60- and 120-degree angles and the limbs are of equal length.[10] The flap begins by extending an incision along the short axis of the defect, equal in length to one side of the rhombic defect. The second incision is 60 degrees from the first and equal in length. A disproportionate amount of tension (58%) can be found at a single point of the flap corresponding to the closure of the secondary defect. More importantly, the vector of this tension is predictable and runs roughly parallel to the adjacent limb of the original defect[11] (Figs. 44–7 and 44–8A, B). The resultant scars run in multiple directions and it is not possible to align them all parallel to RSTLs. This vector of maximum tension, therefore, dictates flap orientation such that it runs parallel to the existing lines of maximum extensibility (LME). One of the disadvantages of the classic Limberg flap is the significant tension at the closure point as well as the amount of discarded tissue needed to convert circular defects to a geometrical rhombus. Dufourmentel modified the Limberg flap to accommodate defects that are more square and to minimize discarded normal tissues[12] (Fig. 44–8C, D). The transposed flap is proportionally wider than the Limberg one and still creates a vector of tension that dictates the orientation for flap design.

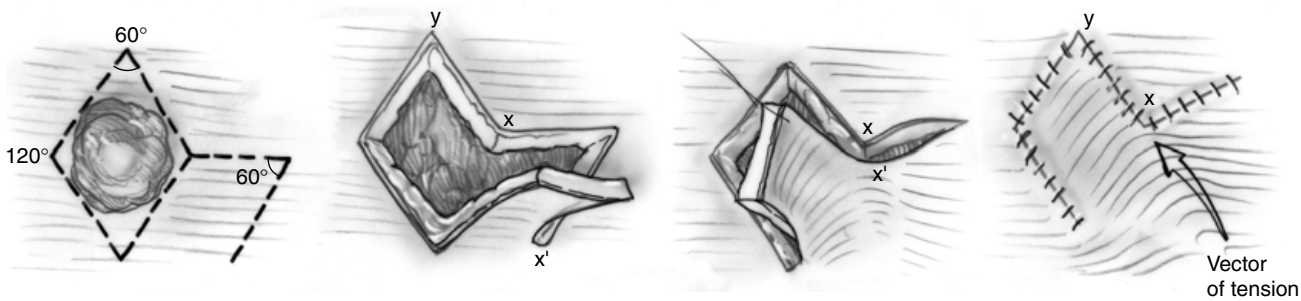


Figure 44–7 Rhombic flap. Limberg flap design and transposition. Note the primary vector of tension being parallel to an adjacent limb of the primary cutaneous defect.

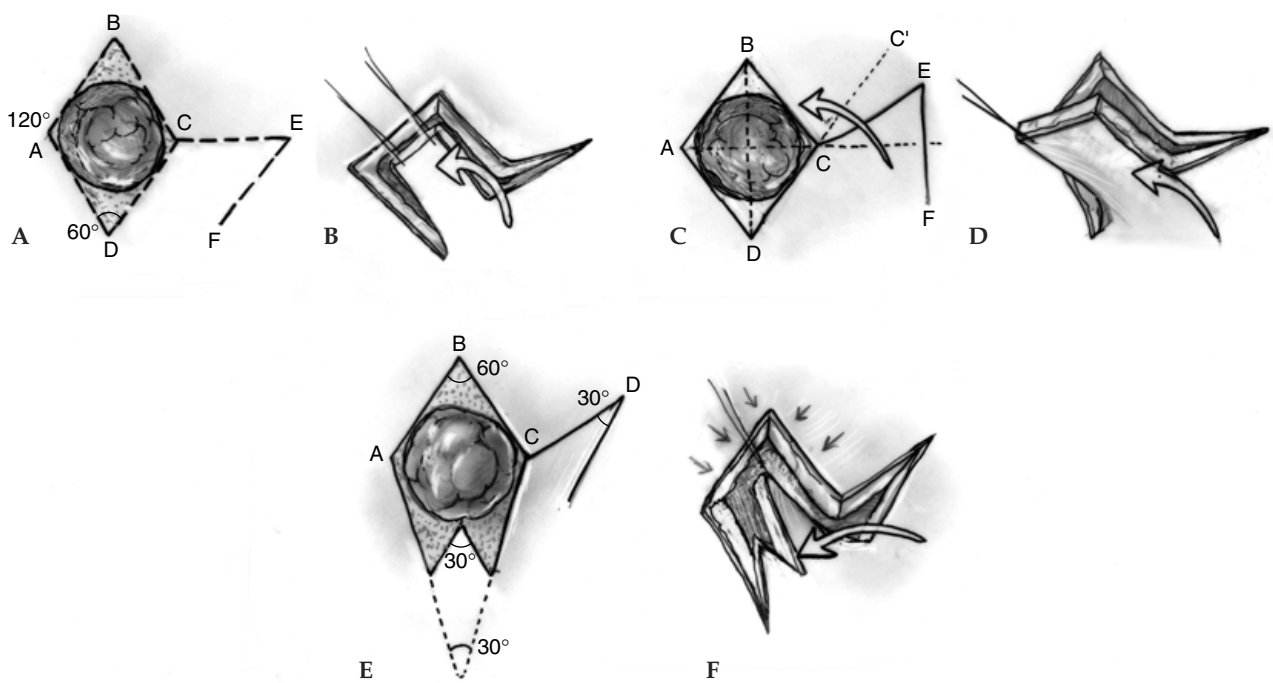


Figure 44–8 **(A, B)** Classic Limberg flap. **(C, D)** Dufourmentel modification for closure of square defects. **(E, F)** Webster 30-degree modification with inferior W-plasty.

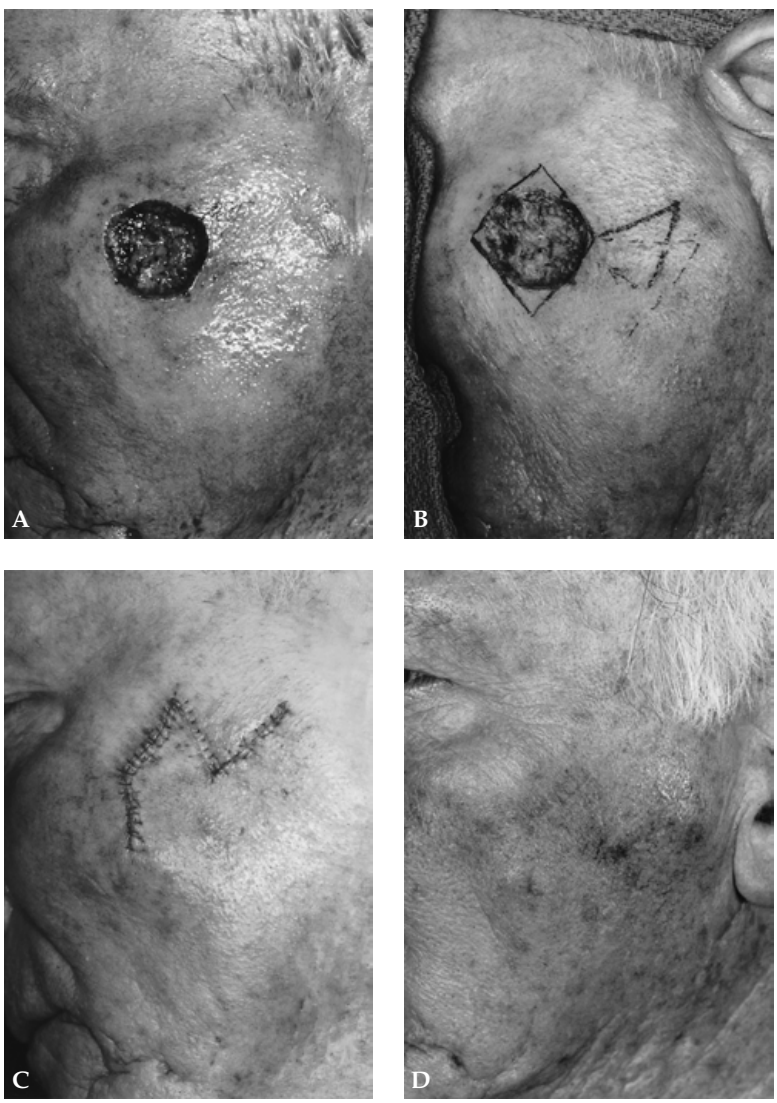
The Webster 30-degree rhombic transposes a narrower flap with more acute angles, facilitating donor site closure without "dog ears" and creating a more even distribution of tension around the defect.[13] This distribution of tension may translate to small amounts of distortion to neighboring structures, which must be anticipated. A W-plasty is often incorporated into the defect to preserve more tissue but at the expense of an additional limb of scar (Fig. 44–8E, F).

Most defects that are repaired with a rhombic-type transposition flap utilize a combination of these modifications. Very rarely is the cutaneous defect converted to an exact rhombus; more often, the transposed flap is slightly narrower and oriented more along the long axis of the defect, both of which facilitate donor site closure and create an even distribution of tension around the defect. Multiple rhombic flaps can be designed around larger cutaneous defects of rectangular or circular shapes.

Representative Case 5 **(A)** A circular defect of the left cheek area measures 23 mm in diameter and extends to the subcutaneous tissues. **(B)** A modified rhombic flap is designed with components from both the Dufourmentel and Webster modifications. Less normal tissue is discarded from the apices of the defect. The flap is recruited from the lower cheek area and oriented such that the vector of maximum tension during flap mobilization runs parallel to the LME. **(C)** The flap is closed with a predictable resultant scar that crosses many natural skin creases and RSTLs; however, it is under the least possible tension and causes no distortion to the lower eyelid. **(D)** A 12-month postoperative view demonstrates acceptable healing due to closure under minimal tension.

BILOBE FLAP

The bilobe flap is a transposition flap with two circular skin paddles based on a common cutaneous base, transposed over an incomplete bridge of skin. It is primarily a rotational flap around a pivot point, but it incorporates small degrees of advancement. These bilobe flaps have the distinct advantage of moving the areas of recruitment, and therefore tension,



Representative Case 5 **(A–D)** Rhombic flap for a cheek defect.

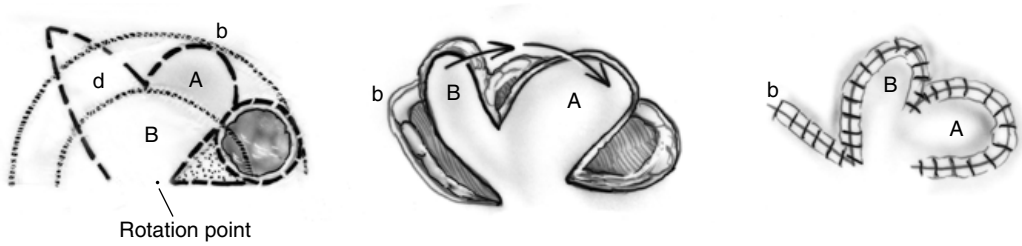


Figure 44–9 Bilobe flap. The axis of the second flap is roughly 100 degrees from the axis along the primary defect, thus decreasing the arc of rotation and standing cutaneous deformity.

further from the primary defect. This second lobe allows the transfer of tension from donor site closure further from the primary defect, which is especially useful for small defects of the lower nose and temple areas. Earlier designs oriented the skin paddles 90 degrees to each other. The secondary flap, therefore, had its axis 180 degrees away from the original defect and created a large arc of rotation with more standing cutaneous deformities. The bilobe design has been modified to rotate around a smaller arc, usually 90 to 100 degrees, thus reducing the amount of dog ear[14] (Fig. 44–9).

The disadvantages of bilobe flaps are that they leave circular scars that will not blend easily with existing creases or RSTLs. Moreover, bilobes frequently develop some "pin cushioning" of the skin paddle for several reasons: (1) The flap is typically based on a narrow pedicle and prone to congestion, especially when superiorly based. (2) A wide bed of scar develops beneath the flap and impedes lymphatic drainage. (3) Most importantly, the cutaneous scars are curvilinear; they contract and tend to bunch the flap up as the incision shortens. This pin cushioning typically resolves over the course of a year and is facilitated by steroid injections.

The design for a bilobe flap begins with identifying the area of recruitment and a pivot point. This pivot point is roughly a radius of the defect away from the wound margin. The first lobe of the flap can be the exact size of the primary defect and the second lobe slightly smaller, with a triangular apex to allow primary closure. The axis of the second flap is about 100 degrees from the primary defect, with the plane of elevation for the nose immediately above the perichondrium/periosteum. Elsewhere, the flap is elevated in the standard subcutaneous layer. Wide undermining best distributes tension. Whereas the primary and secondary defects result in curvilinear scars, the tertiary defect is linear. One can take advantage of this and orient the flap such that this linear scar comes to lie at the border of aesthetic subunits or at least parallel to skin creases (Fig. 44–10A, B). This primarily rotational flap tends to exert some tension along the border of the primary defect, and this should be kept in mind for defects along the nasal tip and ala. Paradoxically, the tension to the border of the defect is often in an inferior direction due to the rotation of the flap.

FOREHEAD FLAP

The forehead flap is a workhorse flap for large nasal defects and can be traced back to antiquity.[15] Historically, a number of forehead flaps have been described as being based on a variety of vessels, including the anterior branch of the

Figure 44–10 Bilobe. Bilobe closure for nasal tip defect oriented such that the resultant scar from the secondary lobe is along the aesthetic subunit border. The Burrows triangle off the primary defect is positioned along the supra-alar crease. This flap receives its random pattern blood supply off the angular artery.

superficial temporal artery, supraorbital artery, and others on both supratrochlear vessels.[16–18] The contemporary forehead flap is primarily based on a single supratrochlear vessel with a relatively narrow pedicle (1.0 to 1.5 cm) and utilizes a skin paddle from the midforehead area.[19] This flap is transposed as an interpolated flap over the intact glabellar skin and mandates a second-stage procedure for pedicle division.

The forehead flap is the flap of choice for larger cutaneous nasal defects because it is characterized by many of the virtues of a regional cutaneous flap. (1) There is abundant tissue allowing resurfacing of the entire nasal unit with a single flap. (2) It follows the principle of replacing tissue with like tissue in that there is an excellent match of skin color and texture to the native nose. (3) There is acceptable donor sight morbidity. (4) The flap has proven to be extremely robust and dependable, even in individuals with small-vessel disease. The primary disadvantage is the need for additional stages and the fact that the pedicle is cumbersome and requires continued wound care for a longer postoperative period.

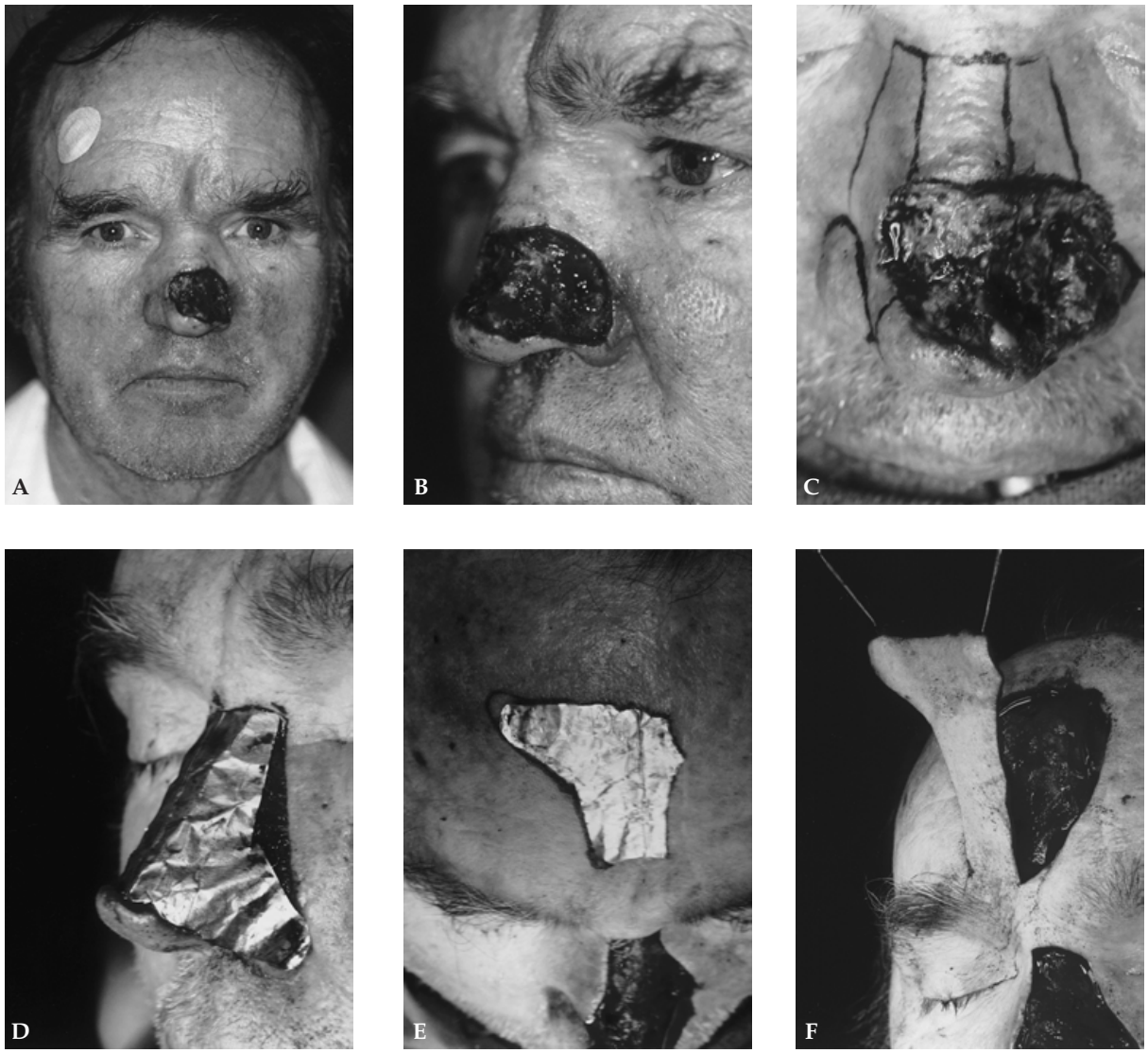
The technique for elevating and transferring a forehead flap has been described.[20,21] A template of the nasal defect is useful for defining the outline of the skin paddle on the forehead. This accounts for the three-dimensional contours of the nose that may be lost if one simply uses a ruler to measure defect dimensions. Forehead flaps can be designed as either a paramedian or a midline flap. The distinction between these flaps refers to the precise location of the skin paddle, not the pedicle base. The paramedian is centered on the supratrochlear artery, whereas the midline is located in the precise anatomic center of the forehead. However, both flaps utilize a narrow pedicle (<1.5 cm) centered on a unilateral supratrochlear artery and can easily extend below the level of the brows. There is a rich anastomosis in this region between the supratrochlear and angular arteries, allowing for a robust perfusion pressure at the base of the pedicle.[22] The advantage of the paramedian flap is that it is centered on the supratrochlear artery, incorporating more of the main trunk and its dermal branches within the pedicle and skin paddle. Improved clinical viability with this design has not been shown over the midline flap. The advantage of a *midline* flap is that the resultant scar is located in the exact center of the forehead and tends to be less conspicuous than a paramedian one. In spite of the fact that both flaps leave a vertical forehead scar running perpendicular to RSTLs, they tend to heal quite well. However, the midline scar is consistent with aesthetic units in that the casual observer tends to see the face as two halves. The midline design also gives greater length to the flap than the paramedian one, an important consideration in individuals with a low anterior hairline.

The skin paddle is elevated in either the subgaleal or the subcuticular plane, but in either case, additional debulking in selective areas is needed prior to inset. It is imperative to maintain crisp corners at the edge of the flap to inset precisely with the borders of the aesthetic subunits of the nose. The pedicle portion of the flap is always elevated in the subgaleal plane, incorporating the frontalis muscle with the pedicle. On occasion, one can elevate subperiosteally around the base of the pedicle to achieve greater length and rigidity around the supratrochlear vessel. The width of the pedicle need not be greater than 1.5 cm and is more often closer to 1.0 cm, allowing for easier rotation and less kinking of the pedicle. During dissection at the base of the pedicle, the corrugator muscle must be divided; this is done carefully under direct vision to preserve all major feeding vessels. The pedicle can easily extend beneath the level of the eyebrow, providing additional length as needed. Immediately prior to flap inset, the skin paddle can be selectively thinned again to match the native skin thickness that is variable for different areas of the nose. The pedicle is typically divided 3 weeks later and aggressively thinned in a cephalad to caudad direction, particularly because the native skin in that area is thin. The base of the pedicle is usually amputated with a small inset into the glabellar area to reestablish brow symmetry.

Representative Case 6 **(A, B)** A 73-year-old man presents with a cutaneous nasal defect following Mohs' excision of a recurrent basal cell carcinoma. **(C)** The aesthetic units of the nose are defined and modified slightly. **(D)** A template is formed of the modified nasal defect. **(E)** The template is transferred to the midline forehead. **(F)** The midline forehead flap is elevated, based on the unilateral supratrochlear area. The pedicle is no wider than 1.5 cm to facilitate rotation. The arterial supply in this area is through rich collaterals between the supratrochlear and angular arteries. **(G)** The skin paddle of the forehead flap is aggressively thinned to resemble the native nasal skin. A characteristic cobble-stone appearance is seen on the undersurface of the flap. The frontalis muscle and galea are not included in the skin paddle. **(H)** The periosteum at the base of the pedicle can be included to further facilitate the rotation and pedicle stability. **(I)** The forehead flap is transferred and a small bolster suture is left in the left supraalar crease to accentuate that area. **(J)** Three weeks postoperatively, the patient is ready for pedicle division. **(K, L)** Twelve months postoperative view demonstrating acceptable donor site scar and full viability of all corners of the midline forehead flap.

High-risk individuals, such as those with known small-vessel disease, can have the entire flap elevated and transferred in the subgaleal plane. This requires an intermediate stage at 3 weeks at which the flap is elevated and debulked from the lateral aspect while remaining perfused in a bipedicle fashion through the pedicle and columella.[21] Three weeks following this intermediate stage, the pedicle is divided in the standard fashion. The advantage of this method is that it further ensures flap viability while neovascularization occurs. This comes at the expense of an additional stage and requires the patient to endure the pedicle for 6 weeks rather than 3.

The other extreme allows a forehead flap to be transferred as a single-stage flap and is reserved for those individuals free of small-vessel disease. The pedicle of the flap is deepithelialized and transferred under intact glabellar skin, thus converting the interpolated forehead flap to an island flap and obviating the need for a second-stage pedicle division. The procerus muscle is usually resected to minimize bulk in that region. For elderly individuals with any systemic vascular disease and smokers, the procedure is



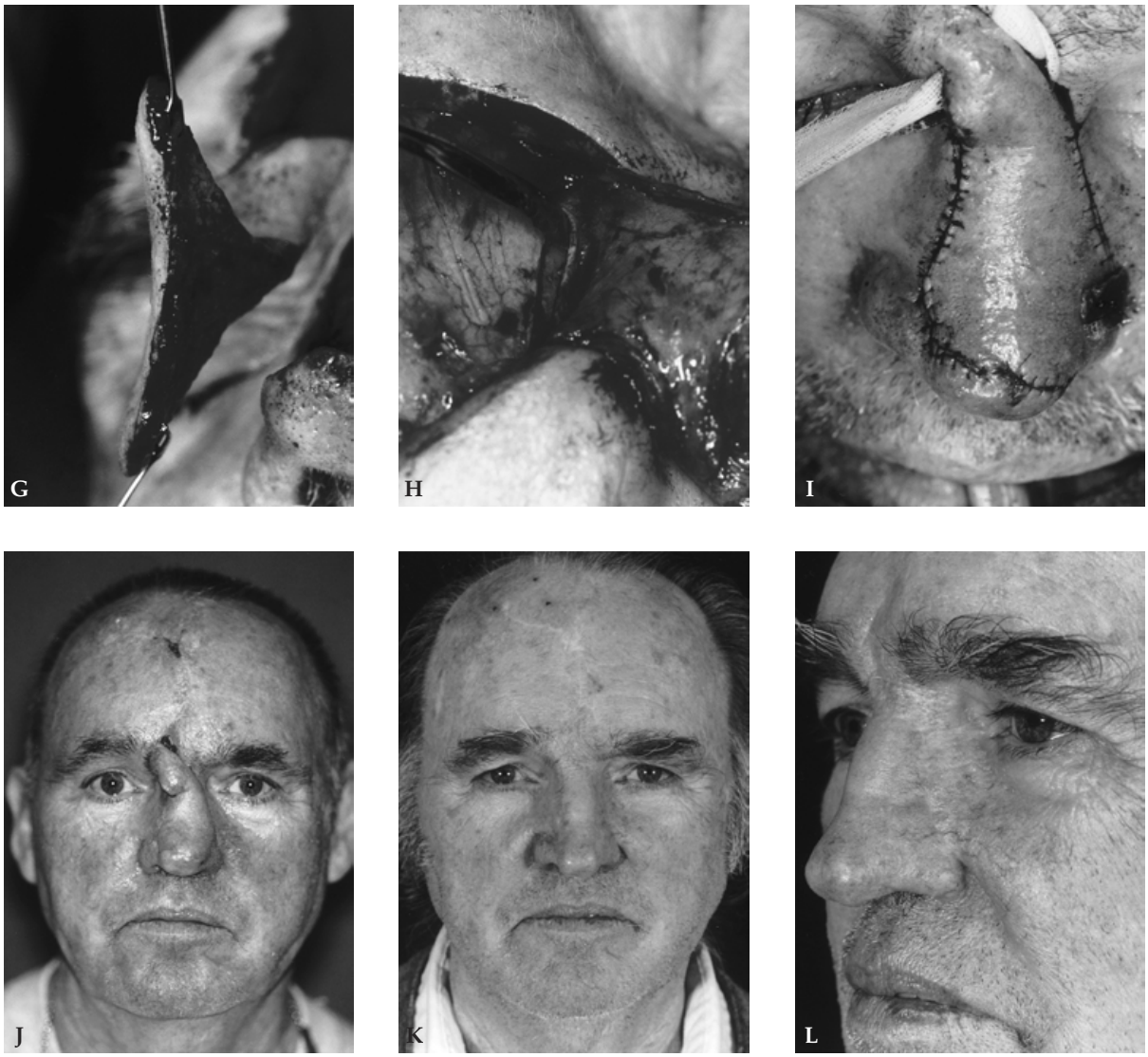
Representative Case 6 **(A–F)** Midline forehead flap for a nasal defect. *(continues on next page)*

contraindicated. The advantage of this "single-stage forehead flap" is that it completes the reconstruction in one operation, although it does leave some fullness to the glabellar area that tends to recede with time. On occasion, patients will desire a debulking procedure for that region, which can be done at any time.

Representative Case 7 **(A)** A 52-year-old woman presents with a nasal and cheek defect following Mohs' surgery. **(B)** The cheek portion is repaired with a cheek advancement/rotation flap, up to the nasal facial groove. The nasal aesthetic units are outlined. **(C)** The defect is modified to resemble the borders of the nasal aesthetic subunits. **(D)** A template of the modified nasal defect is transferred to the precise midline. **(E)** The forehead flap is based on a subcutaneous pedicle. **(F)** The forehead flap is transferred under the intact glabellar skin as a single-stage procedure. The procerus muscle has been resected to better accommodate the subcutaneous pedicle. **(G)** The forehead flap is approximated to the local cheek flap. **(H)** Twelve months postoperatively, the forehead flap is viable but some discoloration is evident, reflective of the patient's forehead skin.

MELOLABIAL FLAP

The melolabial flap is a useful flap for reconstructing defects of the lower third of the nose, especially the alar lobule or columella.[23] It can be transposed as either an interpolated flap requiring subsequent pedicle division or a single-stage transposition flap. The flap is primarily based on the angular artery off the facial artery. When based inferiorly, the pedicle may capture the artery itself, but when based superiorly, as is more frequently done, the pedicle contains only perforators from this



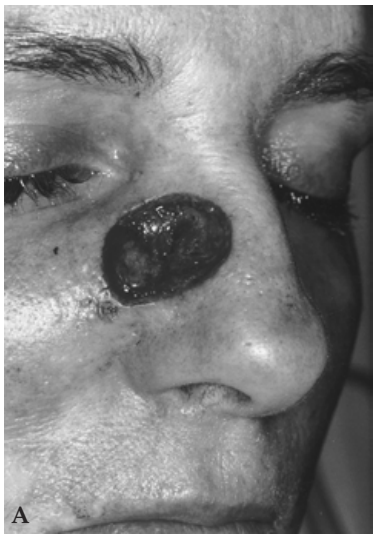
Representative Case 6 (G–L) *(continued)*

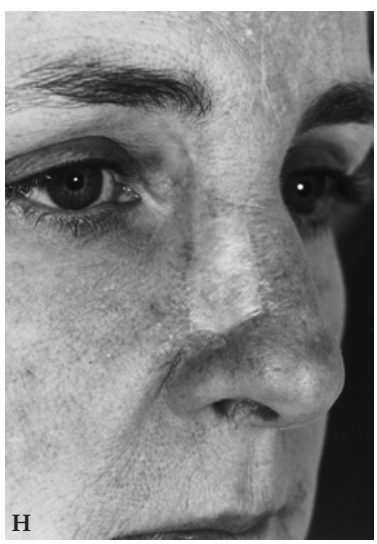
main artery and is converted to an axial pattern arterial flap. The skin paddle is thinned aggressively to minimize bulk to the nose.

For nasal reconstruction, a melolabial flap has the advantage over a forehead flap that the area of recruitment is in closer proximity to the primary defect. This results in less translocation of tissue and a shorter pedicle that does not traverse between the eyes, which is often a significant complaint. The disadvantage of the melolabial flap is limited donor tissue availability for resurfacing. In addition, there may be more problems with the donor site than the forehead flap; noticeable facial assymmetry can occur along the melolabial folds.

When designing the melolabial flap, it is useful to use a precise template of the primary defect to ensure sufficient width of the flap. A "pivot point" is identified to ensure sufficient length to the flap; often the skin paddle is harvested more inferiorly than first impression. The pedicle base can be designed with a wide skin paddle to capture subdermal vascularity, but this not only creates problems with the donor site scar but also impedes mobilization of the flap. The melolabial flap is better designed with a wide subcutaneous pedicle centered on the angular artery and an elliptical, shallow skin incision. This serves to improve the rotational movement of the flap and extends its reach. Furthermore, it lends itself to primary closure of the secondary donor site during pedicle division.

During pedicle division, the defect can be closed primarily with a resultant scar situated along the nasal facial junction and melolabial fold. This requires undermining and advancement of the cheek, which may lead to some facial asymmetry. Alternatively, the entire skin pedicle can be returned to the cheek. The latter method will maintain symmetry to the melolabial folds but will result in two vertical scars, the lateral one being located within the cheek aesthetic unit and running obliquely across natural RSTLs.





Representative Case 7 **(A–H)** Single-stage forehead flap.

Representative Case 8 **(A)** A 68-year-old man presents with a left nasal defect that includes small portions of left lower lateral cartilage but has not violated the intranasal mucosa. **(B)** The defect's shape is modified to mimic the natural aesthetic alar unit. Although it is superior to the contralateral supraalar crease, this modification tends to be more accepting to the casual observer. Conchal cartilage is placed as a batten graft along the caudal border of the left ala. Note the nonanatomic position of this support graft, which reinforces the lobule and prevents collapse. **(C)** A left melolabial flap is designed, based on perforators from the angular artery. The skin portion of the pedicle tapers to a point to allow easy rotation and inset. The subcutaneous pedicle, however, remains at least 1.5 cm wide. **(D)** After 3 weeks, the pedicle is ready for division and closure. **(E, F)** A 6-month postoperative view demonstrating the reconstructed alar lobule and the donor site scar within the melolabial fold.

Single-stage melolabial flaps are transposition flaps with primary closure of the donor sight. These flaps are useful for small, lateral nasal defects but have the disadvantage of creating nasal asymmetry. When mobilizing cheek skin across the aesthetic border onto the nose, the nasal facial junction is often blunted and leaves fullness to the side of the nose.

COMPLICATIONS: PREVENTION AND MANAGEMENT

A detailed history can identify those individuals with various risk factors involving small vessels. They include any systemic collagen vascular disorder, hypertension, diabetes, previous irradiation, preexisting scars, and tobacco use. It is important to keep in mind that replacement of smoking with nicotine patches is not a beneficial alternative. It is

Representative Case 8 **(A–F)** Melolabial flap for alar reconstruction.

possible to minimize postoperative complications through early recognition, careful flap design, and enhancement of soft tissue viability.

Flap Delay

Flap delay has been consistently shown to enhance flap length and viability by as much as 100%.[24] The method of delaying the flap involves incising the borders of the flap with or without partial subcutaneous elevation but leaving it in situ for 2 weeks. Following this, the flap is fully elevated and transposed. The mechanism of action for this process remains unclear but several hypotheses exist:

1. Metabolic adaption. One of the early assumptions was that a biochemical adaptation occurring at the cellular level allows this tissue to better tolerate relative ischemia.[25] This has been disproved because it is now known that delaying the base of the flap or pedicle is more important than delaying the tip or skin paddle itself. In fact, delayed tissue appears to tolerate degrees of ischemia more poorly than nondelayed tissue.[26]
2. Adrenergic spasm. On cutting nerve endings, there is a sudden release of norepinephrine and subsequent vasoconstriction, thus exacerbating flap ischemia and diminishing flap viability. The delayed procedure could sympathectomize the flap by depleting the surrounding nerve endings of norepinephrine and preventing the adrenergic spasm to occur during definitive flap elevation and transposition.[27] If this were the only mechanism of action, however, only a single day of delay would be necessary because norepinephrine is rapidly depleted from neural endings following transection and is cleared from local tissues. A 1-day delay has been shown to be ineffective for flap enhancement.[28]
3. Arteriovenus shunt. The neural sympathectomy should close arteriovenous (AV) shunts along the flap borders and increase perfusion pressure and nutrient supply via capillary levels. However, tests with radiolabeled microspheres have shown that AV shunts are not closed during the delayed process.[29]
4. Vascular collateral. The density of capillary flow within the flap appears enhanced during the delayed period, and the border of capillary perfusion is similarly extended.[30] Some angiographic studies, however, do not support this concept, although the sensitivity of these tests may not be sufficient.[31] While animal studies have reproduced the beneficial effects of a delayed process, its mechanism is probably multifactorial and its understanding limited by biotechnical studies available today.

Hyperbaric Oxygen

Hyperbaric oxygen has a proven beneficial effect on the vascularity of marginal tissues.[32] Whereas normal tissues are not significantly affected, relatively ischemic tissues have a greatly amplified ischemic gradient, which serves as an angiogenic stimulus for new-vessel ingrowth. This occurs in all areas where marginal oxygenation exists, such as diabetic foot wounds, irradiated mandibles prior to dental extraction, and cutaneous flap enhancement. The primary role for prophylactic hyperbaric oxygen therapy in cutaneous flap surgery is with the irradiated tissue bed, characterized by vascular sclerosis, hypoxia, and hypocellularity. A course of hyperbaric oxygen treatments pre- and postoperatively can enhance flap dependability. This involves a significant patient commitment and should be used only selectively on individuals with known preexisting hypoxic tissues (e.g., prior irradiation to the head and neck).

Congestion

Early recognition of the compromised flap is essential to maximize salvage. Most vascular problems with facial flaps involve congestion and, less frequently, arterial ischemia. It is possible for different areas of a single flap to be suffering from both venous congestion and arterial ischemia. Typical signs of a congested flap are warmth, edema, and a purplish blue color that blanches with pressure but promptly refills (Fig. 44–11). A pinprick demonstrates dark venous blood. Arterial ischemia, on the other hand, is characterized by a cool, pale, and flat skin paddle and does not blanch with gentle pressure. A pinprick will often not bleed.

When venous congestion is significant, it can lead to arterial compromise and flap necrosis. This can be managed in several ways. Sutures can be temporarily released to allow the flap edges to decompress. Tight bandages or closure around the flap pedicle may also be released. Medicinal leeches (*Hirudo medicinalis*) are effective in decompressing venous blood in a congested flap through a transcutaneous route. Leeches should only be used in flaps that are congested with venous blood and are not beneficial when arterial

Figure 44–11 Congested flap. A reimplantation of an amputated nose demonstrating signs of congestion. This flap did not survive and required a midline forehead flap for definitive repair.

ischemia exists. Fortunately, they generally do not adhere to flaps that are not already engorged. Saliva from a leech contains an anticoagulant and a vasodilator that facilitate continued oozing from the bite site for 6 hours after they detach, decompressing the flap of roughly 50 mL of blood. Usually, several leeches are utilized simultaneously and therapy continues for several days until revascularization is under way. Most medical centers maintain an inventory of leeches, but they may also be purchased from private companies and delivered via overnight service.

Hyperbaric oxygen is beneficial to congested flaps by creating a local arterial vasoconstriction through the dramatic rise in tissue oxygen content, thus reducing the volume of inflow. In spite of this vasoconstriction and reduction in vascular perfusion, tissue oxygen levels in the flap continue to rise due to improved diffusion and net oxygen delivery.

Ischemia

Arterial ischemia to a cutaneous flap is less common than congestion and more challenging to rectify. The most significant and direct means of enhancing viability is through administration of hyperbaric oxygen. This can maintain flap viability while continued neovascularization occurs and a more definitive arterial supply is established. Heparin and dipyridamole have been shown to increase the survival of an ischemic flap, presumably by preventing clot formation in small vessels that were injured during ischemia.[33,34] After tissue necrosis has been established, it is better to debride the dry eschar and maintain a clean, moist wound bed, which will allow for more rapid healing and epithelialization.

CONCLUSION

Local and regional cutaneous flaps continue to be an important tool for the facial plastic surgeon. Despite the many years that such techniques have been employed, the art and science of local flaps continue to evolve and improve. Our understanding of wound healing, local tension vectors, aesthetic units, and flap enhancement techniques has allowed us to repair most cutaneous facial defects with a dependable, acceptable, and functional outcome.

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Chapter 45

Tissue Expansion in Reconstruction of the Head and Neck

John F. Hoffmann

Extensive facial defects resulting from trauma, tumor resections, or congenital lesions challenge the reconstructive surgeon. Traditional local and regional skin flaps should always be considered first as they provide the optimal aesthetic result when feasible. Skin grafts may be an acceptable option in selected situations, but in general they are cosmetically inferior. In recent years, microvascular free tissue transfer techniques have allowed large volumes of vascularized tissue to be brought into large defects of the head and neck. However, these flaps from distant sites rarely offer a cosmetically desirable soft tissue match for facial skin. When adequate tissue is unavailable adjacent to large cutaneous defects of the face and neck, adjunctive techniques, such as tissue expansion, may be necessary. Tissue expansion may allow the surgeon to develop a local or regional flap of sensate tissue, which matches the defect nicely. However, tissue expansion should be chosen carefully as complications are not unusual and the patient may be forced to endure some hardships during the process of expansion. This chapter will review the physiology, techniques, indications, and complications of tissue expansion as it relates to facial reconstructive surgery.

HISTORY

Tissue expansion is a natural physiologic process that is well exhibited by abdominal tissues in pregnancy and obesity. People have employed forms of tissue expansion for facial decoration, mutilation, and enhancement for centuries. During the twentieth century, tissue expansion entered the realm of reconstructive surgery. It was not until the 1970s that suitable experimental and clinical experience with tissue expansion was reported. Although Neumann[1] reported the use of expansion with a subcutaneous balloon in 1957, it wasn't until Austed[2] and Radovan[3] separately published their work in the late 1970s and early 1980s that tissue expansion became widely accepted. These authors laid the ground work for the basic science understanding and clinical applications of contemporary tissue expansion. Since then, numerous reports of clinical[4–6] and experimental[7–11] experience with tissue expansion have shown the safety and efficacy of the technique. Tissue expansion may be indicated in situations where a surgeon is unable to close a wound primarily and the aesthetic needs of the wound require large amounts of tissues that have good color, thickness, and texture match.

TISSUE RESPONSES TO EXPANSION

Human tissues respond dynamically to the effects of sustained pressure and expansion. The histologic and biochemical changes that occur during expansion have been studied in both animal models and humans. Different tissues respond variably to the forces of expansion, and the rate and duration of expansion have a large effect on the tissue response. As expected, tissues do not tolerate rapid or extreme expansion as well as controlled, gradual expansion.

A distinction should be made between the similarly named—but physiologically distinct—techniques of conventional, progressive tissue expansion and rapid intraoperative expansion (ITE). Sustained, progressive tissue expansion results in significant histologic and physiologic changes in the skin and subcutaneous tissues. In contrast, ITE likely represents mechanical changes in the skin or simply enhanced undermining and recruitment of surrounding tissues.[12–14] These differences will be discussed in this chapter.

LONG-TERM TISSUE EXPANSION

Extensive biologic and morphologic changes occur in tissues subjected to prolonged tissue expansion. Even though the surface area is ever increasing during expansion, the overlying epidermis does not thin and has even been found to slightly thicken.[7,8,15] Studies have shown that the mitotic activity of the expanded skin is increased,[16] and this enhanced mitotic rate serves to maintain and even enhance the epidermal height while the normal stratified appearance is preserved. The changes in the epidermis appear to be temporary, and microscopically the skin returns to normal within a year or two after the expansion. Clinically, the most common visible skin changes are dryness and hyperpigmentation.

The dermis, however, does not respond as favorably to chronic expansion as the epidermis. The dermis has been observed to thin dramatically (30 to 50%), especially with accelerated expansion.[8,17] Increased metabolic activity has been observed in many of the cell populations within the dermis. Fibroblast activity is typically increased and collagen synthesis is enhanced. Furthermore, the physical arrangement of the collagen fibers is altered and elastic fibers are fragmented. Increased pigmentation may occur during expansion due to temporarily enhanced melanin production. Hair follicles become less dense due to the increased surface

area, but the actual number of follicles remains the same. In addition, the thickness of the basal layer has been seen to increase, and more myofibroblasts are found than in unexpanded skin. These changes within the dermis and associated appendages may account for the clinical changes of stiffness, striae, erythroderma, alopecia, and decreased sensation.[18]

The expansion process also affects the associated structures of the subcutaneous tissues. Adipose tissue is very intolerant of expansion and thins dramatically, losing up to 50% of its initial thickness. The fat cells become flattened, lose their fat content, and may be replaced with fibrous tissue. However, some of this fatty loss may be regained after expansion. Vascular changes during expansion can be dramatic. Chronic tissue expansion is a strong stimulus for vascular proliferation.[19] This is one of the great benefits of expansion, as the process typically leads to an enhanced blood supply to the flap being expanded. This can be particularly helpful in instances when the vascularity of the tissue is compromised. In these cases, expansion may provide not only more surface area but also an enhanced blood supply and more resistance to infection in expanded tissue.[20] During expansion there is a proliferation of capillaries and, ultimately, venules and arterioles, and lengthening of vascular structures occurs.[21] Clinical experience has shown that expanded flaps do have an enhanced survival rate much like delayed flaps.[22] A dense fibrous capsule invariably forms around the expander balloon, which not only contains high concentrations of fibroblasts but is also highly vascular (Fig. 45–1). The capsule is lined with macrophages surrounded by fibroblasts, which actively produce collagen. The capsule may contribute some to the enhanced vascularity of expanded flaps, but it also contributes to the contracture and shrinkage of the flap after the expander has been removed and the flap set in. This subsequent contracture may cause the flap to become thick and unsuitable for certain reconstructions that require thin, pliable flaps (e.g., forehead flaps for nasal reconstruction)[23] (Fig. 45–2). If needed, the capsule can be excised presumably without compromising the vascularity of the flap overall,[24] although capsule excision should be done with caution.

Muscular tissue does not tolerate expansion as well as vascular tissue. Muscle thinning, necrosis, atrophy, and clinical weakness have all been observed.[25] In the head and neck this would be most problematic with the frontalis or other muscle of facial expression. Neural tissue is more accepting of expansion as gradual lengthening of nerves can be accomplished without necrosis of nerves. Experimental studies have shown that peripheral nerves can be lengthened up to 32% with long-term expansion but with some diminished function.[26] The facial nerve has been studied during rapid expansion by Martini et al,[27] who found that the facial nerve of a cat could be significantly lengthened with intraoperative expansion. However, 40% of the expanded nerves failed to regenerate, likely either due to mechanical axonal disruption or from compromised vascularity during the rapid intraoperative expansion. A significant concern with tissue expansion of the head and neck is that the expander may weaken facial muscles or branches of the facial nerve. Therefore, it is probably prudent to place expanders in the face and neck superficial to the superficial musculo-aponeurotic system and platysma to minimize such risk.

RAPID INTRAOPERATIVE EXPANSION

Rapid intraoperative expansion is a technique championed by Sasaki, which arose from his experiences with conventional tissue expansion.[28] Basically, this technique involves a rapid, cyclical stretching of the skin performed during the

Figure 45–1 Flaps raised after long-term expansion of the forehead. Note thickness of the flaps and the capsule on their undersurface.

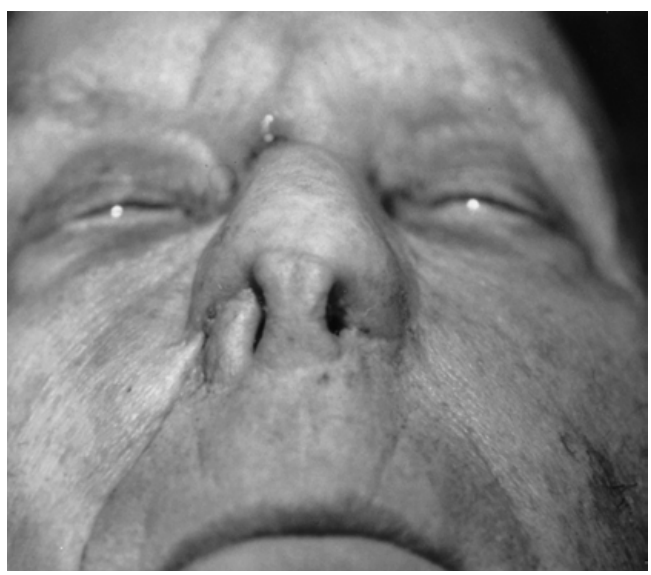

Figure 45–2 Thickened and contracted paramedian forehead flap that was expanded prior to elevation and transfer to the nose. Excision of the capsule may have avoided this.

operative session in which one elevates and mobilizes tissue flaps. Initially it was found that one could overinflate a chronically expanded balloon immediately prior to its removal, thereby gaining some apparent additional flap length. This concept was then applied on its own without preceding chronic expansion. Sasaki reported his experience with almost 300 cases in which it was felt that 1 to 3 cm of additional flap length could be gained with this technique. The rapid nature of this technique obviously does not allow the physiologic or metabolic changes seen in long-term expansion. Instead, the increase in skin length is thought to arise from mechanical "creep" and maximization of the skin's natural extensibility. Mechanical creep involves interstitial fluid and ground substance displacement, fragmentation of elastin, collagen fiber realignment, and adjacent tissue displacement into the expanded field.[17] Rapid intraoperative expansion is a controversial technique, and debate has centered on whether there are true expansion effects or simply enhanced undermining, tissue recruitment, and redraping.[12,29–32] Additional clinical and experimental experience will hopefully allow us to better understand the process of and applications for rapid intraoperative expansion. In addition, a technique of continuous expansion performed over a few days has recently shown promise in animal models.[14] This concept is especially attractive for cases in which cutaneous defects are present and a prompt reconstruction is needed. Clinical experience with this technique is still lacking, however.

INDICATIONS FOR TISSUE EXPANSION

Tissue expansion is theoretically possible anywhere in the head and neck. However, clinical experience has shown that some areas are better suited to the techniques. Tissue expansion works best when there is a solid bony support under the expander balloon. As such, the scalp[33] and forehead[34] (Fig. 45–3) are ideal locations for expansion. Staged repair of scalp defects (Fig. 45–4) and hair replacement[35] are excellent

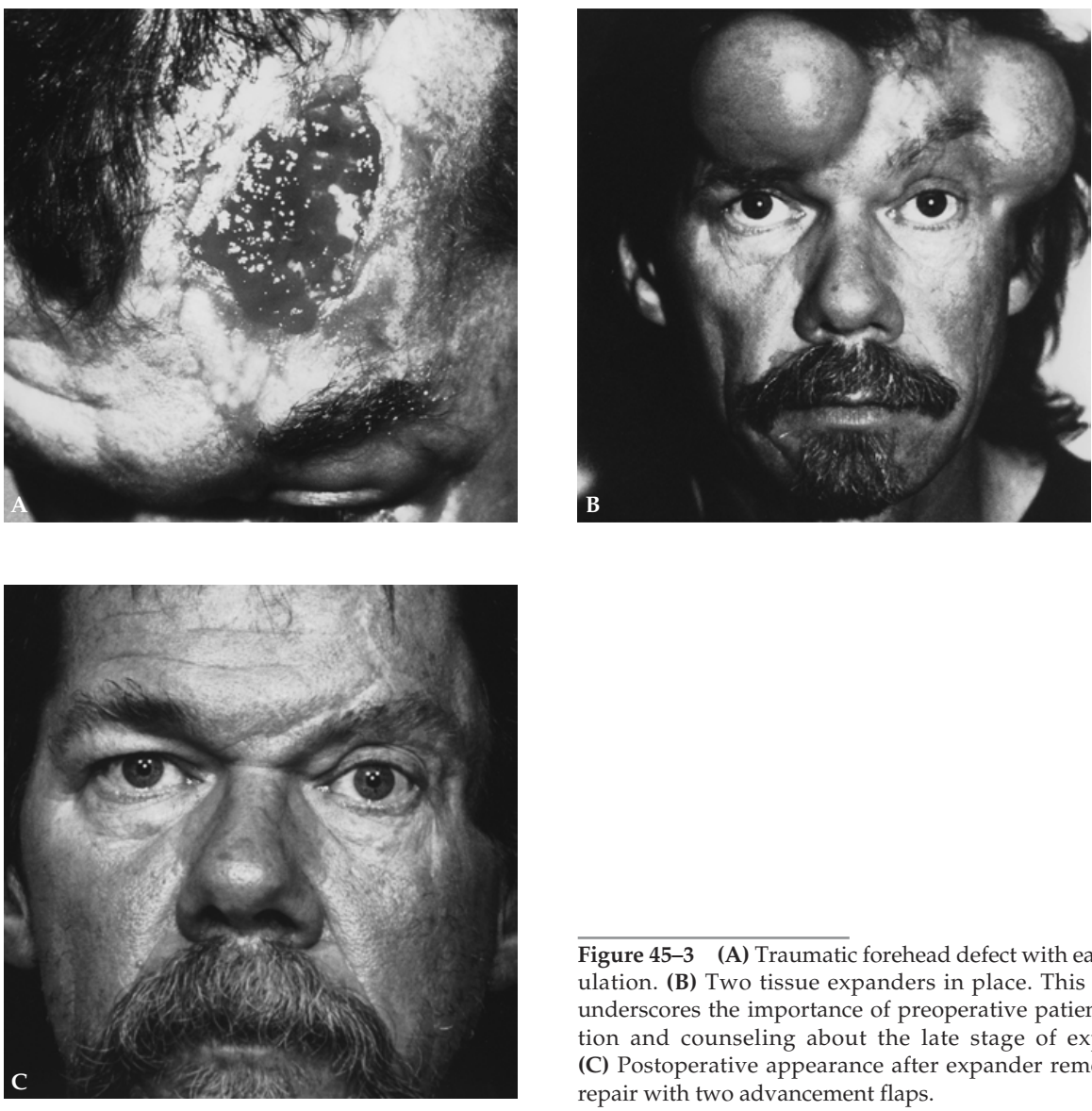

Figure 45–3 **(A)** Traumatic forehead defect with early granulation. **(B)** Two tissue expanders in place. This example underscores the importance of preoperative patient education and counseling about the late stage of expansion. **(C)** Postoperative appearance after expander removal and repair with two advancement flaps.

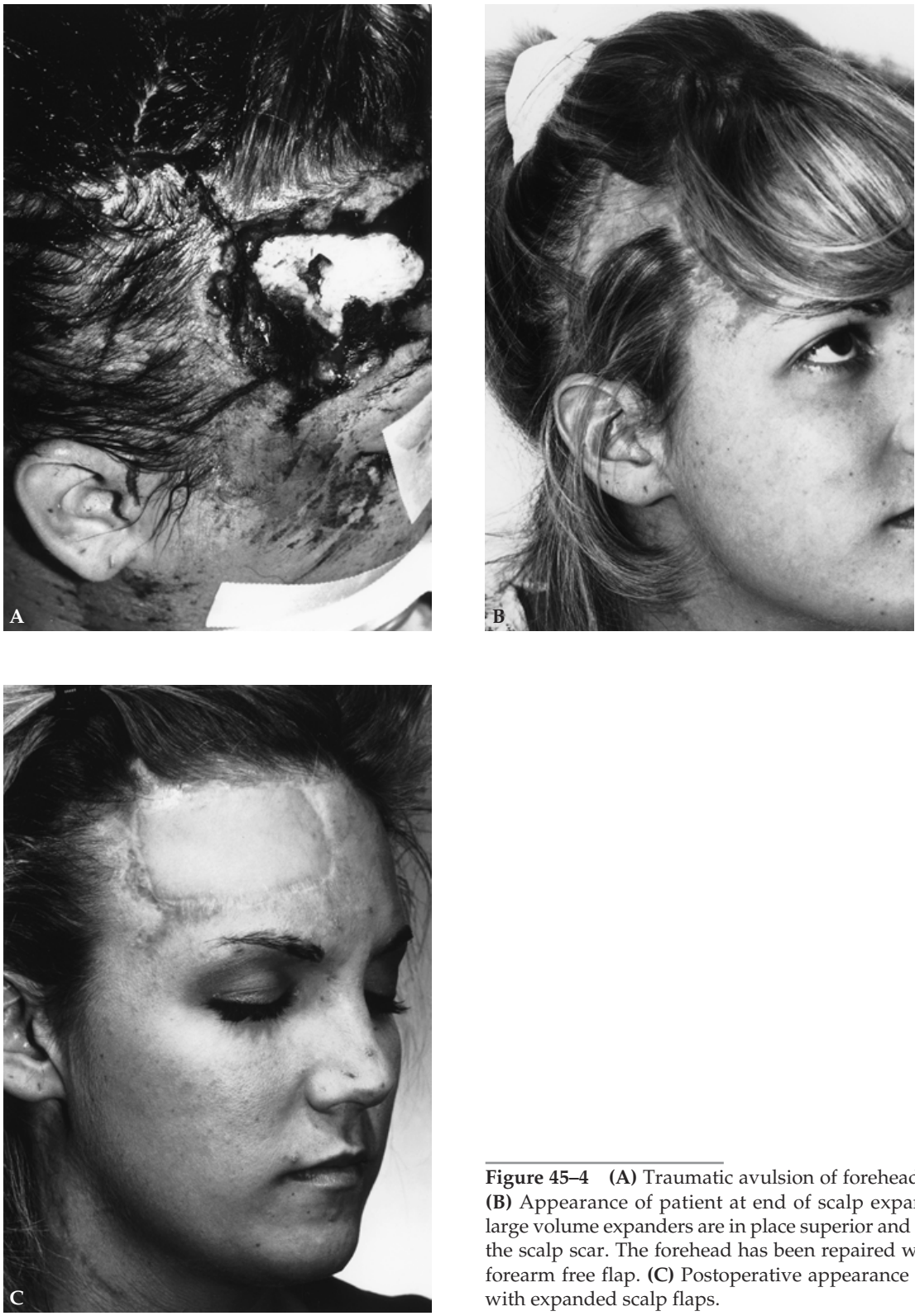

Figure 45–4 **(A)** Traumatic avulsion of forehead and scalp. **(B)** Appearance of patient at end of scalp expansion. Two large volume expanders are in place superior and posterior to the scalp scar. The forehead has been repaired with a radial forearm free flap. **(C)** Postoperative appearance after repair with expanded scalp flaps.

choices for expansion. Similarly, many surgeons have used expanders for auricular reconstruction.[36,37] However, as mentioned before, the subsequent potential for flap contracture and thick scarring may limit the application of expansion of flaps used in reconstruction of the ear and the nose. Expansion within the cheek has been used for skin cancer defects (Fig. 45–5) and congenital lesions such as hairy nevi.[38,39] Expansion of the cheek skin may be poorly tolerated because of the already thin overlying skin and the potential for damage to the facial nerve and musculature. In these locations,

Figure 45–5 **(A)** Tissue expander in place in right cheek. **(B)** Defect of upper lip and cheek following tumor removal. **(C)** Expanded flap in place.

expansion must be carried out slowly and carefully. Likewise, tissue expansion in the neck may be difficult due to the thin skin and underlying neurovascular structures. Tissue expansion may be particularly helpful in previously irradiated or operated areas because of the enhancement of the vascularity, which is observed. Caution should be exercised in these patients as well, as their tissues will be more fragile and potentially more prone to breakdown. Some authors have also reported on their experience with expansion of myocutaneous or free flaps prior to the elevation and transfer to the head and neck.[40–42] Such expansion may not only lessen donor site morbidity but may also provide more tissue for transfer with the flap. Whenever possible, the reconstructive surgeon should try to anticipate the size of a defect that may result from extirpation of a cutaneous malignancy before the resection or Mohs' surgery is done. In this way, one can perform a necessary expansion before the cutaneous defect is produced. A large area of expanded adjacent tissue will then be available to immediately reconstruct the defect produced by the tumor excision.

OPERATIVE TECHNIQUE

Conventional Tissue Expansion

A wide variety of tissue expanders are available for clinical use (Fig. 45–6). These expanders may be of many shapes and sizes. Some have integral inflation ports, but most often a remote inflation/injection port is desired for the head and neck. The remote port allows the surgeon to place the port away from critical structures or in areas that are less sensitive and painful during the inflation period. This can be especially important in children who would not tolerate injections in or around the face. Frequently, the injection port is placed in the scalp or in the neck away from the patient's field of vision. Templates of the various expanders are available from the manufacturers (Fig. 45–7). These can be very useful in selecting the appropriate expander and help with the counseling of the patient preoperatively. It should be mentioned that tissue expansion can be especially trying for patients and their families. Multiple surgeries are required to first place

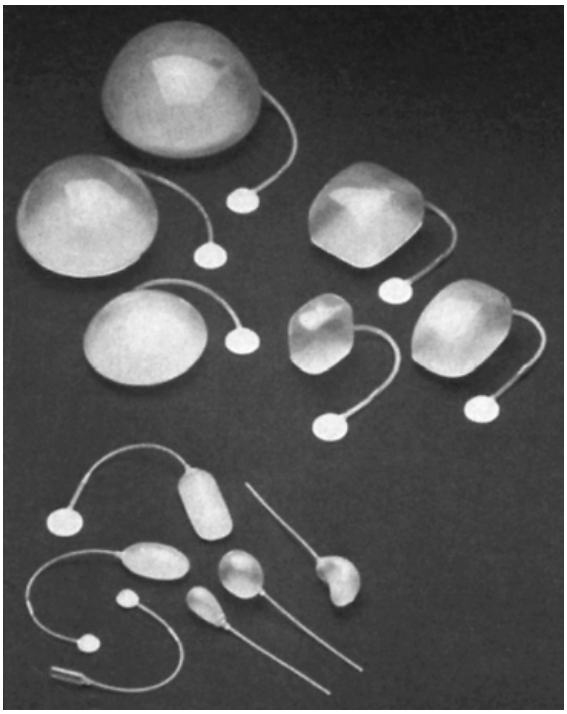

Figure 45–6 Examples of available silastic expanders with remote injection ports. (From Swenson RW. Tissue expansion. In: Papel ID, Nacklas NE (eds). *Facial plastic and reconstructive surgery*. St. Louis: Mosby, 1992:60. With permission.)

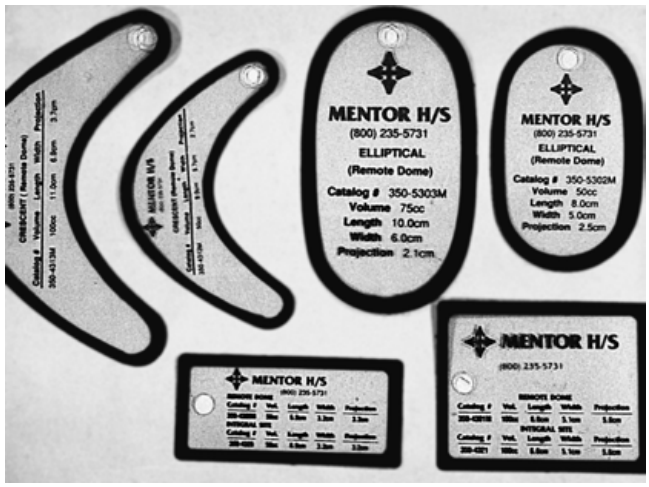

Figure 45–7 Examples of various tissue expander templates for preoperative planning.

the expander and then to subsequently raise and transfer the flaps. Numerous visits to the surgeon's office are required to inflate and monitor the expansion process. In some instances, patients or their families will have to perform the painful process of expander inflation themselves. In addition, the final phases of expansion can lead to very deforming bulges over the expanders, which may make it difficult for patients to work and interact with friends and family (Fig. 45–3). Patients should be thoroughly informed about the expansion process, limitations, advantages, and potential complications.

Selection of the proper size and shape of the expander remains somewhat of an art, but there are guidelines to follow. The most commonly used shapes in the head and neck are the rectangle, crescent, and oval. Often, the type and shape of flap that is planned dictate the shape of the expander. For example, an advancement flap planned for the forehead may be best expanded with a rectangular expander, whereas a scalp rotation flap may be best expanded with a crescent-shaped balloon. The expander should also be chosen so that during expansion critical adjacent structures (e.g., ear, eyelid) will not be adversely affected.

Selection of the proper expander encompasses the size of the defect and the availability and location of donor flap skin. Choosing the proper size of expander can be troublesome, but one should remember that less skin will typically be available for reconstruction after expansion than one calculates or expects preoperatively. Many cumbersome, and usually impractical, formulas have been proposed to calculate the size of expander needed for a given defect. A general guideline for the selection of an expander base size is $2\frac{1}{2}$ to 3 times the area to be reconstructed.[43] Sasaki[44] in his excellent text on tissue expansion proposed the following general guidelines for expander selection and inflation: Fill the expander to a width 2.0 to 2.5 times the width of the defect for flat areas and 2.5 to 3.0 times the width over curved areas (Table 45–1). For some defects this would mean that the expander required would be larger than the available surrounding tissues. In this case, it would be necessary to place two or more expanders around the defect and have expanding multiple flaps advanced into the defect (Figs. 45–3 and 45–4).

When an appropriate expander size and shape has been selected, the first stage of expander implantation is performed. The surgeon should carefully outline the flaps needed and the locations of the expander and injection port. The incision selected should reflect where incisions will be required for the final flap. One should also carefully identify relevant neural and vascular structures that may

TABLE 45–1 Guidelines for Expander Selection and Inflation

Site	Expanded flap width (cm)	Expected flap advancement (cm)
Scalp	12–16	Up to 8
Forehead	8–14	Up to 7
Midface	10–14	Up to 7
Ear	4–8	Up to 4
Neck	12–16	Up to 8

Modified from Sasaki GH. Tissue expanders and general guidelines for tissue expansion technique. In: *Tissue expansion in reconstructive and aesthetic surgery*. St. Louis: CV Mosby, 1998. With permission.

be needed for the flap so that they will not be damaged by placement of the expander or with the final flap. The incision should be as unobtrusive as possible and as far from the expander as is feasible to minimize the risk of wound dehiscence and expander exposure. The depth of placement of the expander varies depending on the area to be expanded. In the scalp, the most common location is between the galea and the pericranium. Too superficial placement in the scalp could lead to alopecia. In the forehead, the expander is also placed deep to the frontalis and atop the periosteum. In the cheek and neck, the expander is usually placed in a subcutaneous plane to avoid injury to the facial nerve, although a sub-SMAS (subplatysmal) placement is possible. Facelift or neck crease incisions can be used for access as indicated.

Wide undermining of the pocket into which the expander is placed is necessary. The pocket for the balloon must be large enough to allow the expander to lie flat with no folding or buckling. An appropriate location for the injection port should also be selected and a pocket made for it. Most commercially available tissue expanders come with a preattached port at a given length from the balloon. However, most of these can be adapted by the surgeon to lengthen or shorten the tubing that connects the balloon and the port as required. Many surgeons employ permanent sutures even in the deep layers of tissue to minimize the risk of early wound dehiscence during the early phases of inflation. Slight inflation of the balloon is usually done at the time of insertion to obliterate any dead space and to aid hemostasis around the expander pocket. There should not be any tension on the wound, however. Typically, 2 weeks is allowed to pass before the sequential inflation is begun.

The inflation of the balloon via the injection port is done using sterile techniques. Sterile saline is typically injected once or twice a week. The volume injected varies depending on the expander size and where in the course of the expansion you are. Some areas of the face are more painful to expand than others and as such, the expansion should proceed more slowly. In addition, those areas where the skin is thin (e.g., cheek, neck) should also be expanded more slowly to minimize the risk of epithelial breakdown and expander exposure. A small butterfly needle (23-gauge) is convenient for injection. Most injection ports have a raised, palpable ring on the top and a reinforced undersurface, which is resistant to penetration and minimizes the chance of injection of saline into the surrounding tissue. If such an inadvertent injection does occur, one should simply allow the saline to be absorbed and then continue with the usual injection process. In general, inflation continues until the overlying skin is firm or until the patient is uncomfortable. If pallor or blanching occurs in the overlying skin, then some saline should be withdrawn. In most cases, 4 to 8 weeks is required to reach full inflation. However, it is essential to follow these patients closely and tailor the inflation schedule to the expanding tissue's ability to keep up with the process. The surgeon should also give the patient some control over a frequently painful and emotional process. Oftentimes patients will benefit from the administration of a mild pain medication shortly prior to their scheduled expansion session. When an adequate area of tissue is available, then one can proceed with the definitive flap elevation.

During flap elevation, some technical points may be important. Immediately prior to the removal of the expander it may be helpful to briefly overinflate the balloon. This can provide some rapid expansion to the flap, aid the elevation of the flap, and help to disrupt some of the capsule around the expander. Some authors also advocate the excision of some or all of the capsule at the time of flap elevation. An advantage of capsule removal is that the bulk of the flap will be reduced and subsequent flap contracture may also be reduced. This may be especially critical during auricular or nasal reconstruction where any contracture seriously affects the final result. Because of these concerns, Burget and Menick[45] never utilize expansion in paramedian forehead flaps used in nasal reconstruction. Instead, they advocate raising a thin unexpanded flap even for total nasal reconstructions and allow the forehead defect to heal by secondary intention.

Rapid Intraoperative Expansion

In rapid intraoperative expansion, the expansion is performed at the same time as the flap design, elevation, and transfer. One can utilize either a large Foley catheter or a commercially designed intraoperative expander. Sasaki[46] has provided guidelines for how much lengthening can be expected with intraoperative expansion (Table 45–2). After the flap has been designed, cyclic expansion is performed (Fig. 45–8). The balloon is filled until tissue pallor and firmness are reached. The inflation is maintained for 3 minutes; then the saline is withdrawn and the tissue allowed to rest for several minutes. The cycle is then repeated twice, whereupon the flap is transferred and the donor site closed. Surgeons who wish to employ intraoperative expansion must have realistic expectations of how much additional tissue will be made available with this technique. Some authors believe that there is a lot of immediate stretch-back of the expanded tissue, which may limit the usefulness of the technique.[12] Sometimes this technique may be helpful in the closure of donor sites instead of the flap itself (Fig. 45–9).

TABLE 45–2 Lengthening Provided by Intraoperative Expansion

Site	Average tissue gain per expander (cm)
Scalp	1.0–1.5
Forehead	1.0–2.5
Upper half of nose	1.0–1.5
Nasal tip	0.5–0.75
Midface	1.0–2.5
Neck	1.0–2.5

Modified from Saski GH. Intraoperative tissue expansion as immediate reconstructive technique. In: *Tissue expansion in reconstructive and aesthetic surgery.* St. Louis: CV Mosby, 1998. With permission.

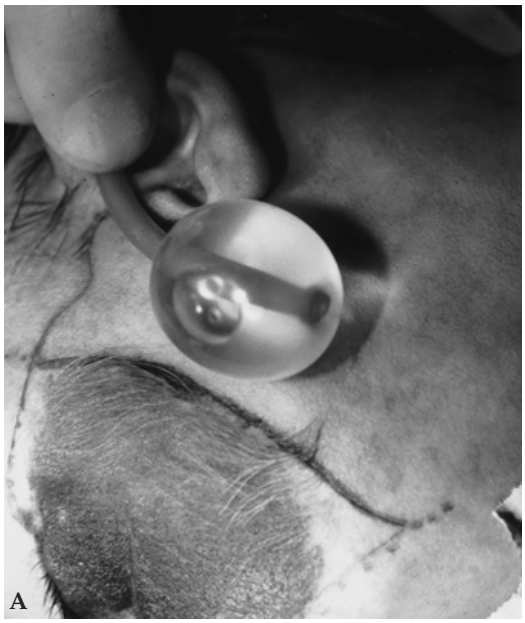

Figure 45–8 Rapid intraoperative expansion. **(A)** Foley catheter used for expansion of bilobed cheek flaps for a large congenital hairy nevus. **(B)** Two catheters in place under each lobe of the flap. **(C)** Flaps in place after excision of the nevus.

COMPLICATIONS

Chronic tissue expansion may subject facial tissues to significant mechanical and biologic strains. As such, these techniques should be used with caution and close observation. One may expect a complication in approximately 10% of patients; however, most of the time the expansion and reconstruction can continue even in the face of a problem. The most common complication is exposure or extrusion (Fig. 45–10). Typically this occurs through an incision line. If it occurs early in the course of expansion, then the procedure may need to be aborted. If it occurs later on near the end of expansion (as is most common), then the inflation may be completed or perhaps truncated. Exposure is most common in thin-skin areas, such as over the mastoid and in the midface or neck. Slow, cautious inflation may reduce this risk. Prior irradiation or scarring will increase the risk of exposure as well.

Infection around expanders in the head and neck is unusual. Infection is more common around the ear and scalp. Again, if infection occurs early on, then removal may be indicated. Later on, the expansion may continue with appropriate antibiotic therapy. Strict adherence to sterile technique during inflations may help to reduce the likelihood of infections around the expander. Ischemia and necrosis of flaps in the head and neck during expansion are rare. In most instances, the likely cause is too rapid or overzealous inflation. Risk factors for this disastrous complication include a history of smoking, diabetes, and prior

Figure 45–9 **(A)** Intraoperative expansion utilized to aid closure of the forehead after elevation of a large paramedian forehead flap for total nasal reconstruction. **(B)** Forehead closed primarily and flap in place.

irradiation. However, with judicious techniques expansion should actually enhance the flap's viability and vascularity. Expander failure and deflation are very rare and usually due to improper inflation or surgical technique. One must carefully palpate and localize the center of injection port each time one injects. Otherwise the tubing or main balloon could be punctured or lacerated, thus allowing the saline to escape. If this were to occur, then the expander will have to be replaced. Neuropraxias during expansion are unusual, and the nerve most at risk in the face is the mandibular branch of the facial nerve. It is best to place expanders in the neck superficial to the platysma to minimize this problem. As in facelift surgery, one should carefully avoid injury to the greater auricular nerve during expander placement and subsequent flap elevation.

Figure 45–10 Exposed expander in a previously operated and irradiated scalp.

SUMMARY

Tissue expansion has become a widely accepted adjunctive technique in head and neck reconstruction. Expansion should be considered any time one cannot close a defect primarily and more tissue than is readily available from conventional facial flaps is needed. With careful planning, surgical technique, and inflation, chronic tissue expansion is a safe and reliable technique. Tissue expansion can allow the extension of conventional local, regional, or free flaps, which can provide an ideal replacement for missing or deranged facial tissues.

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Chapter 46

Musculocutaneous Flaps

Donald J. Annino, Jr. and Russell S. Shu

Since the 1970s, pedicled musculocutaneous flaps have been used successfully as a source for well-vascularized tissue to reconstruct large head and neck soft tissue defects. They have withstood the test of time and remain dependable and an important part of the armamentarium of head and neck reconstructive surgeons.

The use of such flaps is not new. In fact, the first report was in 1896 with the use of a pedicled latissimus dorsi flap for breast reconstruction.[1] The first use of musculocutaneous pedicled flaps in the head and neck was not until 1955.[2] The reason for the delay in the use of pedicled flaps was the prevailing surgical principle of never using a flap when a skin graft was possible. This concept was slow to change despite multiple reports of various pedicled musculocutaneous flaps within the ensuing two decades. Instead, reconstruction evolved first to the use of fasciocutaneous flaps, such as deltopectoral, nape of neck, and forehead, before pedicled musculocutaneous flaps became widely accepted. The turning point was in 1979, when Ayrian published a report on the use of the pectoralis musculocutaneous flap for reconstruction in the head and neck.[3] With more widespread use and reporting of the musculocutaneous pedicled flaps came the realization they offer improved reliability, one-stage reconstruction, and more bulk than fasciocutaneous flaps. They quickly became the workhorse flaps for head and neck reconstruction and remain an important and integral tool in that field.

PECTORALIS MAJOR MUSCULOCUTANEOUS FLAP

The pectoralis major musculocutaneous flap was first described in 1968 in the context of the resurfacing of an anterior chest wall defect.[4] Since the 1940s it had been used as a muscle flap alone.[5] Its first use in the head and neck was not until 1979.[3] Since then it has become one of the workhorse flaps for head and neck reconstruction. It has been used to reconstruct defects of the oral cavity, the oropharynx, the face, and the neck.

The pectoralis major musculocutaneous flap has the advantages of being easy to raise, reliable, and requiring only a single stage. It offers the added advantage of providing carotid coverage and protection in patients who have simultaneously undergone an ipsilateral neck dissection. Its primary limitation is excess bulk. This is a result of the adipose tissue between the skin and the muscle. It can be overcome with the use of a skin graft to resurface the muscle.

The pectoralis major is a fan-shaped muscle. It is flat and arises from the medial half of the anterior surface of the clavicle, the sternum, the costochondral cartilages of the first six ribs, and the aponeurosis of the external oblique muscle. The muscle inserts into the biceps groove of the humerus. Importantly, the fascia, which surrounds the muscle, separates it from the pectoralis minor.

The blood supply is from the thoracicoacromial artery and reaches the muscle by passing through the clavicopectoral fascia. The lateral thoracic artery also supplies the flap but frequently must be sacrificed for increased arc of rotation. The thoracicoacromial artery arises from the axillary artery. The pectoral branch is the largest of its branches and is the main supply to the pectoralis major muscle (Fig. 46–1).

Surgical Technique

The position of the pectoral branch of the thoracicoacromial artery is marked on the patient by drawing a line from the acromian to the xiphoid process. The pectoral artery runs

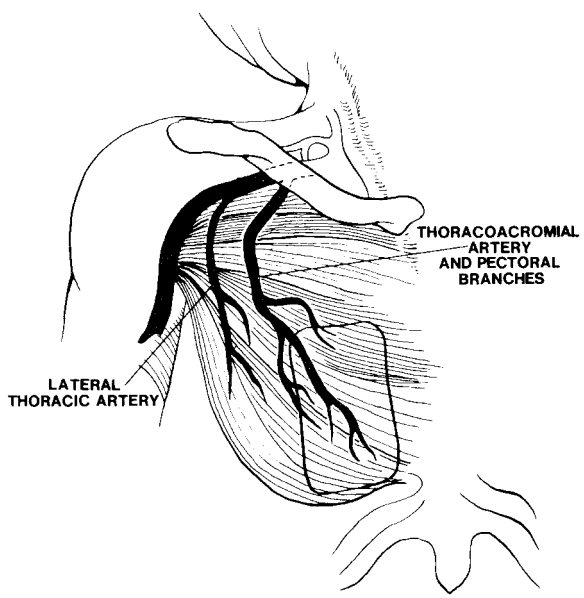

Figure 46–1 Vascular anatomy of pectoralis major musculocutaneous flap.

along this line after arising from the thoracicoacromial artery. The thoracicoacromial artery leaves the axillary artery at a right angle from below the medial third of the clavicle. The skin paddle is designed to lie between the nipple and the sternum. The size is determined by the defect. Ideally, the skin paddle will not violate the territory of a deltopectoral flap. Therefore, the parasternal perforators of the second and third intercostal spaces are left intact. An incision is made from the upper lateral edge of the paddle to the axilla. The design is different in a female patient, with the skin paddle placed to give minimal distortion to the breast and the incision to the axilla placed in the inframammary crease.[6] In both men and women, it is always preferable not to include the nipple in the skin paddle if possible.

After completing the incision to the axilla, the lateral border of the pectoralis major muscle is identified by wide undermining of the medial and lateral skin flaps. The incision around the skin paddle is completed once it has been determined that the paddle is primarily located over the muscle with as small a random component as possible. When performing the incision around the skin paddle and elevating the flap, care must be taken to limit any shearing forces on the skin paddle. Some recommend the use of tacking sutures to keep the skin paddle securely attached to the muscle; however, this is not necessary when care is taken.

When the skin paddle has been incised, the pectoralis major muscle is freed from the chest wall and dissected superiorly. As the dissection proceeds, the medial aspect of the muscle must be freed from the sternum and the parasternal perforators ligated. As the dissection advances superiorly, the vascular pedicle is identified on the undersurface of the muscle. The pedicle is on the medial aspect of the muscle. The plane between the pectoralis minor and major is dissected bluntly. The lateral thoracic pedicle is encountered and usually needs to be sacrificed for complete mobilization and an optimum arc of flap rotation. The arc of rotation is also improved by narrowing the segment of muscle overlying the vascular pedicle. This is always done with direct visualization of the pedicle.

A subcutaneous tunnel is created connecting the neck dissection to the dissection on the chest. The flap is passed over the clavicle and turned 180 degrees. A minimum of three fingers should fit comfortably through the tunnel to ensure that the flap will have enough room to pass without constriction of the pedicle. It is important to ensure that the pedicle does not become twisted or kinked as it passes through the tunnel.

The donor site is closed primarily, with wide undermining of the skin. A perforating towel clamp can be helpful to keep tension off the incision during the closure and released after enough deep sutures are in place. A suction drain is always used in the donor site postoperatively.

TRAPEZIUS MUSCULOCUTANEOUS FLAP

Three flaps are possible with the trapezius musculocutaneous unit. They are the lateral island, the superior- and the anterior-based flaps. The first report of a trapezius flap came in 1842 when Mutter described use of a mastoid-occiput-based shoulder cutaneous flap to fill a defect of the anterior neck created by release of scar contracture.[7] Zovickian in 1957 used delay procedures to extend the length of the flap farther onto the shoulder to repair pharyngocutaneous fistulas.[8] In 1979, McGraw et al described an undelayed Mutter-Zovickian flap by including underlying trapezius muscle to improve circulation.[9] This became known as the superior or upper trapezius musculocutaneous flap. The lateral island trapezius musculocutaneous flap was described by Demergasso and Piazza in 1977.[10] The lower trapezius island musculocutaneous flap was not described until 1980 by Baek et al.[11]

The ideal areas for reconstruction with these flaps are the lower two thirds of the face, neck, and temporal fossa. The trapezius muscle has the advantages of being thin, located outside the usual field for head and neck irradiation, and having a long arc of rotation and a long pedicle to help it reach most areas in the head and neck.

Its disadvantages are that it must be harvested in the lateral decubitus position, that there is frequent need of skin grafting to resurface the donor site, and that the spinal accessory nerve must be sacrificed. The limitations of shoulder mobility following a neck dissection are exacerbated with the harvest of this flap.

The trapezius is a flat triangular muscle arising from the occiput, the superior nuchal line, the nuchal ligament, and the spinous processes of C7 to T12. The muscle inserts on the lateral third of the clavicle, the scapular spine, and the acromion. It helps to elevate and rotate the shoulder.

The blood supply to the trapezius is from four sources. The paraspinous perforators supply the muscle along its entire course. The superior portion of the muscle receives its blood supply from the occipital artery. The transverse cervical (TCA) and dorsal scapular (DSA) arteries supply the inferior part of the muscle.

Urken et al describe the trapezius muscle as having one dominant pedicle (the transverse cervical artery and vein) and two minor vascular pedicles (the occipital and posterior intercostal vessels).[12]

The TCA originates from the thyrocervical trunk but also can originate directly from the subclavian artery.[13] This variation is not important when raising a lower trapezius island flap because the pedicle is not mobilized up to its origin. However, when the TCA arises from the subclavian artery it may run deep to or through the brachial plexus, thus limiting the use of the lateral island flap. The TCA travels in a superolateral direction superficial to the anterior scalene muscle, phrenic nerve, and brachial plexus, but deep to the omohyoid muscle. It enters the midpoint of the trapezius muscle, near the entrance of the spinal accessory nerve. At this point, the TCA divides into a deep and superficial branch. The deep branch passes along the undersurface of the minor rhomboid muscle, emerges from between the minor and major rhomboids, and enters the lower portion of the trapezius. This deep branch is also known as the dorsal scapular artery and can sometimes originate directly from the subclavian artery. As it runs along the undersurface of the trapezius, the superficial branch of the TCA divides into an ascending and descending branch.[14] The ascending branch supplies the superior portion of the muscle, whereas the descending branch supplies the lower portion of the muscle. It divides into a supererficial and deep branch. The superficial branch passes over the levator scapulae and itself branches into

descending and ascending branches. The descending branch continues on the undersurface of the muscle. The ascending branch supplies the upper portion of the trapezius muscle. The deep branch of the TCA passes deep to the levator scapulae and is known as the dorsal scapular artery. It continues along the medial border of the scapula and enters into the trapezius after exiting between the rhomboid major and minor. It supplies the inferior portion of the trapezius.

The concept of cutaneous angiosomes should be understood when designing the lower island flap.[12] The trapezius muscle can be divided into three vertical angiosomes. The superior angiosome is supplied by the TCA, whereas the middle angiosome is supplied by the DSA. Finally, the lower angiosome (overlying the latissimus dorsi) is supplied by the intercostals. According to the concept of angiosomes, the tissue of an adjacent angiosome can be captured and transferred. Thus, one can reliably include the lower trapezius angiosome if the DSA (middle angiosome) is preserved. It most commonly arises from the thyrocervical trunk. However, in 20% of cases it arises from the subclavian artery.

The nerve supply to the trapezius is from the spinal accessory cranial nerve.

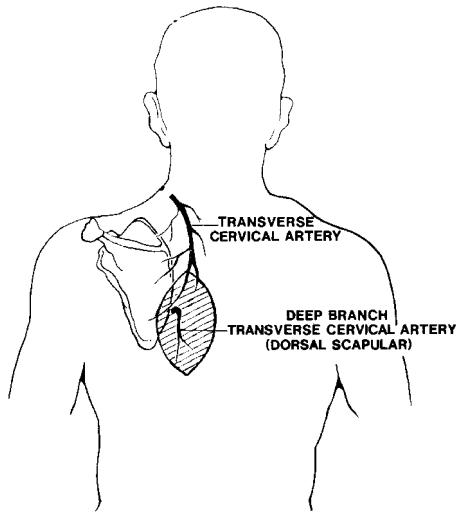

Figure 46–2 Vascular anatomy of lower trapezius island musculocutaneous flap.

LOWER TRAPEZIUS ISLAND MUSCULOCUTANEOUS FLAP

The lower trapezius island musculocutaneous flap is the most versatile of the flaps involving the trapezius system. It has the greatest arc of rotation. It is possible to reach the midline of the neck, the lateral skull base, and the cheek. It is possible to minimize morbidity from this flap by preserving the superior portion of the trapezius and utilizing only the portion of the muscle inferior to the skin paddle. The blood supply for this flap is the transverse cervical and dorsal scapular arteries and veins. However, the flap can be harvested on the transverse cervical artery and vein alone, as long as the inferior end of the flap does not extend beyond the rhomboids. Elevation of the flap with sacrifice of the dorsal scapular pedicle improves the arc of rotation. Inclusion of both TCA and DSA allows the inferior end of the flap to extend 10 to 15 cm beyond the inferior end of the scapula. Therefore, with this flap it is critical that the transverse cervical artery and vein not have been sacrificed during a neck dissection (Fig. 46–2).

Surgical Technique

The flap is elevated with the patient in the lateral decubitus position. Adduction and internal rotation of the arm will help to increase the working area between the medial surface of the scapula and the spine. The skin paddle is marked on the skin between the medial border of the scapula and the midline of the back. To ensure a dependable skin paddle, based on the transverse cervical pedicle, it should not extend 5 cm beyond the inferior border of the scapula. Superiorly from the skin paddle a line is incised going to the posterior triangle of the neck. After the skin incisions are made, the trapezius is exposed along its entire length, but leaving the skin paddle attached to it. Beginning laterally, the dissection is performed between the trapezius and the rhomboids. Medially the trapezius is separated from the vertebrae, sacrificing the paraspinous perforators. The dorsal scapular artery and vein are identified as they enter the trapezius from between the rhomboids. If the dorsal scapular vessels are to be saved the dissection must include the rhomboid minor muscle. Care should be taken not to divide both rhomboids as this will result in a mobile scapula. The dorsal scapular vessels must remain intact if the skin paddle has extended beyond the scapula tip. Otherwise the dorsal scapular vessels are ligated and the rhomboid muscle remains down and intact. The dissection then continues superiorly with preservation of the anterior segment of the trapezius, if the eleventh nerve is intact, by passing of the flap beneath it.

Closure is performed primarily, by wide undermining. A suction drain is used to decrease the chance of a seroma, which can be common with this flap.

SUPERIOR TRAPEZIUS FLAP

The superiorly based trapezius flap is harvested in the lateral decubitus position. It is based on the paraspinous perforators and the occipital artery (Fig. 46–3). Therefore, the blood supply is not compromised by a previous neck dissection. The flap provides excellent coverage for defects in the neck that do not extend across the midline. Its orientation with a superior base helps to prevent gravity from separating the flap from the recipient site as it heals. It is the most reliable of the three trapezius flaps.[13,14]

Surgical Technique

The flap is outlined over the superior portion of the trapezius. It is determined that the superior incision will be along the anterior edge of the muscle. The inferior incision is planned based on the width of tissue required and the necessity of including at least two paraspinous perforators. The inferior incision should be parallel to the superior one. The lateral extent of the incision can be up to 10 cm over the deltoid muscle as long as the fascia from the deltoid is included with the flap. The limitation to the

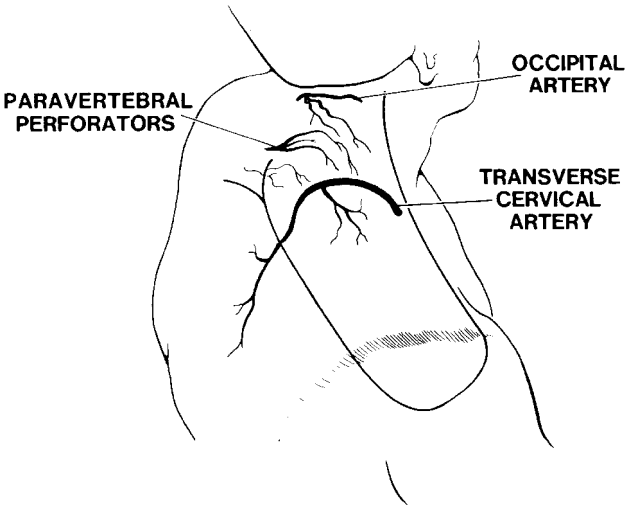

Figure 46–3 Vascular anatomy of superiorly based trapezius musculocutaneous flap.

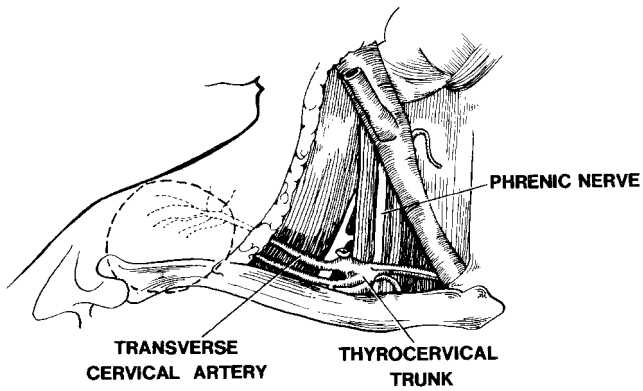

Figure 46–4 Vascular anatomy of lateral trapezius island musculocutaneous flap.

arc of this flap is always the inferior incision at the midline. Panje introduced the modification of extending the incision beyond the midline and turning it superiorly.[14] This improves the arc and reach of the flap. The plane of dissection is deep to the trapezius muscle and therefore above the supraspinatus, levator scapulae, rhomboid major, and deltoid. The transverse cervical pedicle is encountered and usually needs to be ligated to allow adequate mobilization of the flap. Ideally, if possible the pedicle should be saved, but this is not routinely done. A skin graft is used to close the donor defect. The flap usually incorporates the skin paddle along the entire length of the muscle, but it can be designed as an island musculocutaneous flap.

LATERAL TRAPEZIUS ISLAND MYOCUTANEOUS FLAP

The lateral trapezius island myocutaneous flap is reported to be the least reliable of the trapezius flaps.[13,15] It is based on the transverse cervical artery and vein (Fig. 46–4). Therefore, careful thought must be given prior to elevating this flap after a neck dissection. One must either be sure the vessels are intact or explore the neck prior to elevating the flap. The flap is used to reconstruct external defects of the neck or mucosal loss in the oral cavity and pharynx.

Surgical Technique

This flap is designed as a skin flap overlying the superior lateral aspect of the trapezius muscle. The first step, as was mentioned above, is to find the transverse cervical artery and vein in the posterior neck to ensure that use of the flap is feasible. The skin paddle is centered as well as possible over the transverse cervical pedicle. The anterior border of the trapezius is identified and the skin edges are incised. The incisions are then continued through the subcutaneous tissue and muscle. Frequently, the DSA has to be ligated with the distal portion of the TCA to completely mobilize the flap. In elevating the flap it is possible to extend the skin paddle distally to include random-pattern skin. In elevating this flap, one must be aware that the TCA may be intertwined with the roots of the brachial plexus. This is particularly a risk when the TCA arises directly from the subclavian artery.

STERNOCLEIDOMASTOID MUSCULOCUTANEOUS FLAP

The sternocleidomastoid musculocutaneous flap was first reported in 1955.[2] At that time, it was thought the blood supply was from the posterior auricular artery. The platysma was also incorporated to improve the blood supply to the skin. It was not until 1980 that the arterial supply was properly understood.[16] A branch from the occipital artery supplies the superior segment of the muscle. A branch of the superior thyroid artery supplies the middle third of the muscle. A branch of the thyrocervical trunk supplies the inferior third of the muscle. This clarification of the blood supply allowed design of the flap to be based superiorly or inferiorly depending on the area of reconstruction. Ideally, both flaps should include two vessels (i.e., the superior thyroid artery contribution is always included). However, the blood supply is therefore of a random pattern and not as reliable as that from flaps with an axial-pattern blood supply. The flap is suited for resurfacing of the oral cavity or for providing lining or coverage for pharyngeal reconstruction.[17–19] It is important when using this flap not to forget oncologic principles. It is not wise to use this flap when neck disease would normally require resection of the muscle.

The sternocleidomastoid muscle arises from two sources: the sternum and the medial head of the clavicle. The two heads fuse to insert in the mastoid process. The muscle is innervated by the spinal accessory nerve.

Surgical Technique

When harvesting this flap the skin paddle is outlined over the sternocleidomastoid muscle. Inferiorly, the skin can extend over the clavicle. The incision is carried down through

the skin, the subcutaneous tissue, and the platysma. A vertical incision is made to the mastoid process. In elevating the superiorly based flap the branches from the thyrocervical trunk are sacrificed. Ideally, the blood supply from the superior thyroid artery is preserved. However, this may limit the arc of the superiorly based flap.

The harvesting of the inferiorly based flap is similar, except that the skin paddle is over the mastoid tip. In this case, the blood supply from the occipital artery is ligated.

With both the inferiorly and superiorly based flaps, local skin undermining and advancement can usually close the donor defect. A suction drain is placed at the time of closure.

PLATYSMA MUSCULOCUTANEOUS FLAP

In 1887, Robert Gersuny, an Austrian surgeon, described his reconstruction of a full-thickness cheek defect with a cervical skin/platysma flap.[20] The flap was rotated inward to provide a new lining for the buccal mucosa. This was probably the first description of the platysma musculocutaneous flap. In 1978, Futrell et al reported the first large series involving use of the platysma flap for head and neck reconstruction.[21]

This flap has been most commonly reported to be of use in reconstruction of intraoral defects, such as those of buccal mucosa and floor of mouth.[21–26] In addition, oropharyngeal and hypopharyngeal defects have been reconstructed with this flap.[23] Outer skin of the midface and lip region are other reported sites of reconstruction.[25]

The accessibility of this flap in the surgical field, lack of bulk, pliable nature, one-stage reconstruction capability, and primary closure with minimal donor site deformity have made this flap a very attractive option for head and neck reconstruction.[26]

The platysma muscle lies in the superficial fascia of the neck. The muscle originates from the upper portion of the thorax. It extends across the clavicle, over the border of the mandible, superficial to the facial vessels to insert in the skin at the lateral angle of the mouth. The cervical branch of the facial nerve innervates it. The platysma's major vascular pedicle is the submental branch of the facial artery.[22] It also is supplied inferiorly by the superficial branch of the TCA, medially from the thyroid vessels, and laterally from the occipital and posterior auricular vessels.

Initial reports were concerned with the reliability of the flap when the facial artery is ligated during neck dissection. However, McGuirt et al questioned this, with 19 of 20 patients in their series having the facial artery ligated and divided (bilaterally in two) with loss of only the flap with bilateral facial artery ligation.[23] Through cadaveric studies, they found that numerous anastomoses exist between the anterior facial artery system and both ipsilateral internal and external carotid systems. In addition, contralateral external carotid contributions exist via the labial arch. These ipsilateral and contralateral contributions allow retrograde filling of a proximally ligated facial artery. Thus, the submental artery should be preserved distal to the submandibular gland. Venous drainage of the flap is in a vertical orientation. Tension and kinking should be limited with adequate length and back-cuts to ensure good venous outflow.

There has been concern over preoperative irradiation resulting in vascular changes that would compromise flap viability.[27] However, this flap has been successfully used in previously irradiated patients.[28] Concern over use of the flap in patients with prior radical neck dissection should be based on the previous neck incisions. A transverse neck incision may divide the pedicle and compromise viability. If flap loss does occur, there are reports of successfully using the nonviable flap as a biologic dressing, with debridements but no need for secondary reconstruction.[24]

Surgical Technique

First the defect to be reconstructed is measured. The outline of the platysma flap is initially made as an ellipse with the inferior margin low in the neck. Typically, the dimensions of the skin ellipse are 5×10 cm to 7×14 cm.[21] If a standard apron flap is raised for a neck dissection, the inferior margin of that flap will be the inferior margin of the platysma flap. The inferior skin incision will pass through the platysma, whereas the superior skin incision will pass only through skin. A skin-only flap is then raised superior to the skin paddle up to the mandible, leaving the platysma down. At this point, the distal skin island with its supporting platysma is elevated superiorly in a subplatysmal plane in a fashion typical for standard exposure for neck dissection. After the tumor ablation and neck dissection, the platysma musculocutaneous flap is rotated superiorly and 180 degrees into the defect and sutured in position. The donor site is closed primarily with some undermining of the upper chest wall skin.

LATISSIMUS DORSI MUSCULOCUTANEOUS FLAP

The latissimus dorsi was the first musculocutaneous flap described.[1] However, it was not described in the context of head and neck reconstruction until 1978.[29] It offers the advantages of substantial bulk, a site distant from the usual head and neck irradiation fields, and provides protection to the carotid artery following a neck dissection. In fact, it provides the largest volume of regional soft tissue for reconstruction in the head and neck. It also is fairly hairless, and the donor site can be more aesthetically acceptable to some patients than the pectoralis major. This is particularly true for women.

It also has the following disadvantages: bulkiness of the flap, necessity to position the patient in the lateral decubitus position, and increased shoulder weakness and loss of range of motion, particularly in conjunction with sacrifice of the accessory nerve. Special care must be taken to position the ipsilateral arm so that brachial plexus injury does not accompany dissection of the flap.[30]

The latissimus dorsi muscle is a flat muscle that arises from the thoracic, lumbar, and sacral vertebrae, the thoracolumbar fascia, the external oblique fascia, and the iliac crest. It inserts on the intertubercular groove of the humerus.

It has an axial blood supply from the thoracodorsal artery. This is the end artery of the subscapular artery, which arises from the axillary artery (Fig. 46–5).

The thoracodorsal nerve innervates the latissimus dorsi muscle.

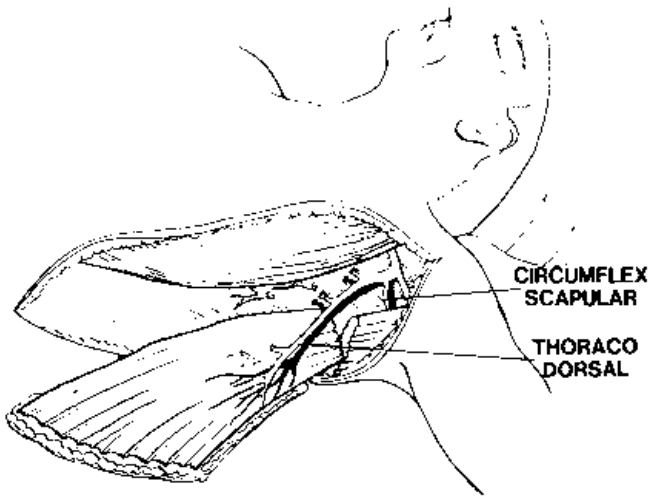

Figure 46–5 Vascular anatomy of latissimus dorsi musculocutaneous flap.

Surgical Technique

The patient is placed in the lateral decubitus position. The skin paddle is drawn over the muscle based on the size of the defect. The incision is made from the superior margin of the skin paddle to the axilla and around the skin paddle. After the incision is made the skin flaps are elevated to expose the muscle. First, the muscle is released inferiorly and anteriorly. The vascular pedicle is identified just inside the anterior border of the muscle as the dissection proceeds superiorly. With the superior dissection the muscle is separated from the serratus anterior, and the branch from the thoracodorsal to the serratus anterior is identified and ligated. When the dissection reaches the circumflex scapular vessels the flap will reach most areas in the head and neck. If extra length is needed, the circumflex vessels can be sacrificed as well. The muscle is separated from the humerus, with care taken to protect the pedicle from injury. The posterior border of the latissimus dorsi is then freed from the vertebrae. The flap is passed into the neck through a subcutaneous tunnel created to extend from the axilla to the neck. To prevent constriction of the pedicle the arm can be elevated for the first few days. The wound can usually be closed primarily if the width of the skin paddle is 10 cm or less. Defects larger than this require a skin graft to assist with closure. A suction drain is routinely used for the donor wound.

THE TEMPORALIS MUSCLE FLAP

The first description of the use of the temporalis muscle flap was in 1898 in connection with the reconstruction of an orbit.[31] It was first used for rehabilitation of facial nerve paralysis in the 1930s.[32] The temporalis is a broad, thin muscle. It arises from the pericranium and passes obliquely forward and inferiorly to the coronoid process of the mandible. The blood supply is from the anterior and deep temporal arteries off the internal maxillary artery.

The temporalis muscle flap is used for dynamic facial rehabilitation and facial augmentation. It is particularly useful for reconstruction of the orbit and cheek. However, a short arc of rotation and the impossibility of incorporating the overlying skin in the muscle limits the use of this flap. Fortunately, it is easily covered with a skin graft. An additional disadvantage is the resulting depression in the temporal region following rotation of this flap. This can be improved with augmentation of the area with various alloplastic materials as well as the use of folded temporoparietal fascia.

Surgical Technique

The incision is "Y"-shaped, extending down from the superior temporal line to the helix of the ipsilateral ear. It is best not to make the incision straight but rather to make it sinusoid in an attempt to camouflage the scar postoperatively. The incision can continue inferiorly preauricularly, usually not lower than the level of the tragus. The depth of the incision should be through the temporoparital fascia and to the level of the deep temporal fascia. Reflecting the scalp flaps exposes the deep muscular fascia. Care must be taken anteriorly because this is where the frontal branch of the facial nerve is situated. Undermining beyond the hairline puts the nerve at great risk. The nerve runs in the superficial temporal fascia, also known as the temporoparietal fascia.

The muscle is elevated starting at the superior temporal line. Once the junction of the deep fascia and the periosteum is divided, the muscle is dissected bluntly from the skull with a periosteal elevator. The dissection proceeds inferiorly toward the zygomatic arch and the point of muscle insertion on the coronoid process. Care must be taken as the dissection approaches the zygomatic arch because this is where on the medial surface the vessels enter the muscle. Frequently, it is helpful either to section the zygomatic arch or, if the flap is to obliterate the orbit, to create a lateral orbitotomy to improve the arc of rotation and reach of the flap. When elevating this flap it is possible to tailor its size as needed; either the entire muscle or a strip can be used.

A word of caution is in order if this flap is to be used in conjunction with a temporoparietal fascial flap in patients who have received radiation in the area. In these patients, the skin flaps will not survive following mobilization of the temporoparietal fascia with the superficial temporal artery and vein.

CONCLUSION

The goals of surgical treatment and reconstruction of head and neck cancer are survival, preservation, and restoration of function and normalization of appearance. The ideal is a single-stage resection and reconstruction. Musculocutaneous flaps offer the advantages of dependability, bulk, and single-stage reconstruction. Each regional musculocutaneous flap has its own characteristics, which make it suitable for specific defects. These include the total area of the defect, the thickness of the flap, its pliability, length of the vascular pedicle, ease of harvest, and donor site morbidity.

Musculocutaneous flaps have many advantages but also limitations. The most common reason for failure is technical error during the preparation and insetting of the flap. Complications can range from total or partial loss, suture line

dehiscence, fistulae, wound infection, and hematoma and seroma formation. These complications can occur either at the donor site, the recipient site, or both. Limiting any trauma during elevation, transposition, and insetting of the flap is extremely helpful in preventing complications. In addition, utmost care must be taken to ensure that the pedicle is not constricted or kinked. Whenever possible, the flap should be designed to avoid excess bulk and tension.

Microvascular free flaps have helped to increase the spectrum of reconstructive options but have not rendered myocutaneous pedicled flaps obsolete. Pedicled flaps remain reliable and technically easier to use than microvascular free flaps.

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Chapter 47

Microvascular Flaps

Brian B. Burkey and John R. Coleman, Jr.

In the latter half of the twentieth century, head and neck surgeons witnessed a tremendous evolution in the reconstruction of postsurgical, traumatic, and congenital defects. The era of microvascular reconstruction became evident in the early 1970s. Refinements in technique, donor sites, and surgical skills have led to the widespread use of free-tissue transfer. Most patient series reported in the last 3 years detail a success rate of 95% or greater, and most major medical centers have either head and neck surgeons, plastic surgeons, or both who are well versed in multiple flap options to reconstruct head and neck defects.

The purpose of this chapter is to provide the reader with an overview of microvascular free-tissue transfer. We will discuss surgical technique, flap monitoring, and management of flap failure. We will then examine 10 donor sites that are commonly used, discussing the anatomy, surgical technique, and advantages and disadvantages of each flap. The chapter will conclude with a review of functional sites in the head and neck and the different flaps that might be used in each location.

PERIOPERATIVE MANAGEMENT

Surgical Technique

To achieve a successful transfer of free tissue, the microvascular surgeon must use meticulous technique to ensure appropriate harvest of the flap, handling and preparation of the vessels, anastomosis of the vessels, and insetting of the flap with attention to vessel, geometry.

Flap Harvest

Successful transfer of free tissue begins with the flap harvest. A detailed knowledge of the anatomy and elevation planes allows an efficient and safe harvest. The surgeon must respect the location of the vascular pedicle and protect the pedicle during the harvest. It is imperative to avoid separating the pedicle from the tissue to be transferred. All branches and perforators not included with the flap should be separated from the pedicle at the greatest distance possible. Surgical clips, bipolar electrocautery, and surgical ties are all acceptable options depending on the vessel size. Unipolar cautery should always be avoided in close proximity to the pedicle. After the pedicle has been dissected a sufficient distance to create adequate pedicle length, the flap vessels can be divided and the flap taken to a back table for vessel preparation.

Vessel Preparation

The back table allows the microvascular surgeon the opportunity to prepare the flap and its vessels for transfer. At this point, the flap is flushed with heparinized saline to remove blood and thrombogenic precursors. The appropriate microvascular instruments to ensure gentle handling of the flap should be used. Typically, an operating microscope is used for illumination and magnification (4 to 16 times). Some surgeons use high-power loupe magnification and have demonstrated equal success rates.[1] Jeweler's forceps, straight and curved microscissors, a vessel dilator, and a curved-needle holder are essential to the next stages of the transfer (Fig. 47–1). The interior of the vessels should never be handled directly.[2] The loose layers of the adventitia are removed from the ends of the vessels for an appropriate distance to allow for the anastomosis. This dissection is most easily accomplished with the surgeon and the assistant grasping the vessel at 180-degree opposite points to create traction and open space for the dissection. The artery and vein(s) should also be separated from one another so that good vessel geometry and spacing can be obtained during anastomosis.

Anastomosis

After an analogous cleaning of the adventitia is accomplished on the recipient vessels in the neck, the anastomosis of the vessels can be performed. Typically, arterial anastomoses are end-to-end and venous anastomoses are accomplished either end-to-end or end-to-side. It is important to choose appropriate recipient vessels when multiple vessels are available. Vessels for anastomosis should be of similar caliber, and inflow and outflow vessels should exhibit brisk bleeding. Unfortunately, this is a luxury that the microvascular surgeon does not always have. If a lumen size mismatch beyond 2:1 exists, the surgeon can fish-mouth the smaller vessel and take unequal bites to achieve adequate approximation.[3] The end-to-side anastomosis can also be used for large-vessel mismatch (Fig. 47–2). Most microvascular surgeons prefer to use an end-to-side anastomosis for the donor vein(s) to the internal jugular vein; Ueda et al demonstrated no statistical difference in vessel thrombosis when comparing the end-to-side anastomosis to the jugular vein with end-to-end venous anastomoses.[4]

The traditional technique for the anastomosis involves the use of interrupted stitches with 9-0 or smaller nylon; however, an equivalent rate of vessel patency has been reported with continuous-suture technique.[5] The continuous-suture technique

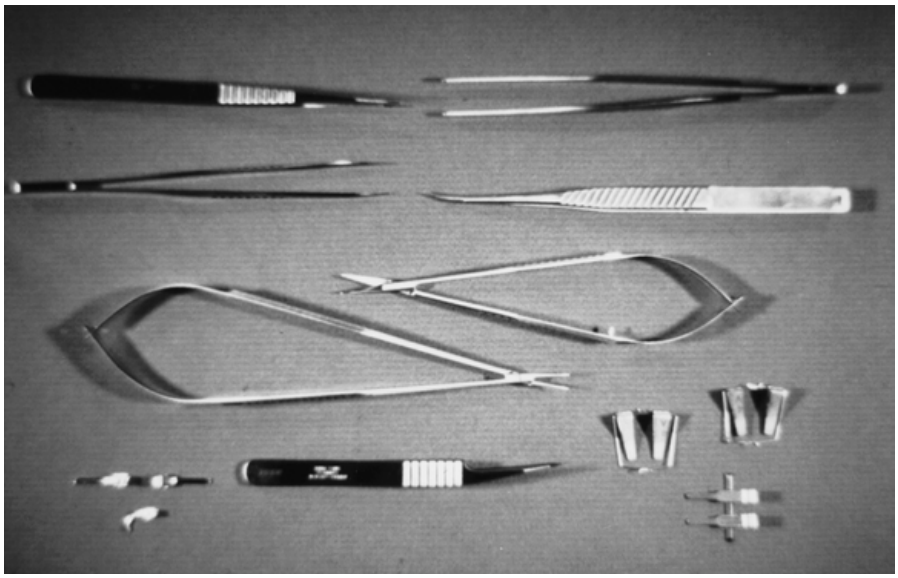

Figure 47–1 The basic microvascular equipment tray, including straight and curved scissors, jeweler's forceps, vessel dilator, vessel clamps, and vessel approximators.

Figure 47–2 Anastomoses for a lateral arm flap showing an arterial end-to-end anastomosis and a venous end-to-side anastomosis (to the internal jugular vein).

allows for a faster anastomosis and is particularly helpful with vessel size mismatch. The disadvantage of the continuous technique is the potential narrowing at the anastomosis of the vessel lumen. Framed clamps are commonly used for end-to-end anastomoses, whereas end-to-side anastomoses are generally done free-hand. Other authors have examined the use of anastomotic devices in head and neck free-tissue transfer.[6,7] They have found the devices to be safe and effective, with a similar thrombosis rate. Shindo noted that the only failures that occurred in her series were with the arterial anastomosis; therefore, her group recommends the ring anastomotic device for venous anastomoses only. The advantages of the device were decreased operative time and the ability to perform the anastomosis even when exposure was not ideal.[6]

No matter the technique chosen for vessel anastomosis, the microvascular surgeon *must* ensure that the intimal layers of the vessels are well approximated and that the sutures are placed in such a fashion as to prevent damage to the endothelium and thrombosis formation. Another common mistake is "back-walling" of the vessel. This occurs when the back wall of the vessels is incorporated in a stitch that reapproximates the front wall. This mistake is prevented by always having direct visualization of the needle as it passes through the tissue and inspecting the anastomosis carefully after the first half of the vessel is completed.

Vessel Geometry

Vessel geometry refers to the orientation of the anastomotic vessels. Although this appears to be a simple concept, success or failure of the flap often hinges on the orientation of the pedicle.[8] It is essential that the pedicle be anastomosed in a tension-free environment, allowing sufficient length to create gentle curves rather than tight turns that can potentially kink. It is preferable for the anastomosis to sit down in the neck rather than ride up immediately under the skin. With bone flaps, the surgeon must decide whether to take the pedicle over or under the bone segment as undue pressure can be placed on the pedicle by a tight tunnel under the bone or by external compression over the bone. At each step in the reconstruction, the surgeon should check the orientation of the vessels and the external forces that can be placed on them; often, this attention to detail and a simple tacking suture where needed can help ensure a successful transfer.

Flap Monitoring

After the vessels have been anastomosed, flap monitoring for perfusion begins. Immediately in the operating room, most surgeons rely on direct examination of the flap. Bleeding from the cut edges of the flap, capillary refill on the skin paddle if one is available, flap warmth, and ultrasonic Doppler

signals directly over the vessels all indicate a successful anastomosis and a well-perfused flap. When the flap has been inset and the case completed, the choice of flap monitoring is surgeon-dependent, and often varies with the type and location of flap. An ideal technique for postoperative monitoring of all flaps has not yet been described.[9] An ideal technique would be safe, inexpensive, effective with 100% sensitivity and specificity, reproducible, noninvasive, easily interpreted by nursing staff and physicians alike, and provide continuous monitoring with instantaneous notification of changes in the vessel dynamics.[10]

The number of techniques that have been discussed in the literature is significant and continues to grow as new devices and ideas are created. Techniques typically rely on assessment of a monitoring segment,[11] vascular perfusion (e.g., Doppler ultrasonography, laser Doppler flowmetry),[12] tissue perfusion (e.g., oxygen tension,[13,14] photoplethysmography),[15] or tissue metabolism (e.g., hydrogen clearance).[16] Each technique has positives and negatives. Despite all of the technology available, the vast majority of microvascular reconstructive surgeons employ clinical assessment as their monitoring method of choice.

At our institution we rely on clinical assessment (capillary refill, bleeding, temperature) of all flaps with cutaneous paddles or monitoring segments and Doppler ultrasonographic signals over the monitoring segment. For the first 72 hours the flap is checked every hour by nursing staff. They assess the color, warmth, capillary refill, and Doppler signal of the flap as possible based on location. If a change occurs, the surgeon repeats the previous assessment and also performs a needlestick exam. If an unsatisfactory change has occurred, the patient is scheduled for urgent exploration. If a hematoma is suspected as the cause of flap failure, the wound is opened at the bedside and the patient taken to the operating room as soon as possible. After 72 hours, flap monitoring is reduced to every 4 hours for 2 days and then every 8 hours until discharge.

On the assessment examination described previously, a normal examination would find the flap to have a pink color, be warm to the touch, have capillary refill of to 3 seconds, and have strong arterial and venous Doppler signals. A pinprick would produce bright red blood within several seconds of removal of the 20-gauge needle. Arterial insufficiency is characterized by a skin paddle with a pale or bluish hue, a flap that is cool to the touch, capillary refill that is prolonged to greater than 5 seconds if it can be detected, and a pinprick that reveals dark blood, which takes a long time to reach the surface if ever. The hallmarks of venous insufficiency are a congested blue flap, brisk capillary refill that returns almost as soon as the finger or instrument is removed, and dark blood that appears right after the needle has been removed. In both cases, urgent surgical exploration is required.

Flap Failure

The success of free-tissue transfer has reached the level that most large series report a success rate of 95 to 98%. Failure due to salvageable vessel thrombosis has been found to occur early in the postoperative course. In the M. D. Anderson data, thrombosis of the vein (54%) was more common overall than thrombosis of the artery (20%).[17] The vast majority (90%) of the arterial anastomoses that failed did so within the first 24 hours, whereas most venous failures presented later. All salvageable thromboses occurred within the first 3 days following surgery. Multiple factors have been examined to determine if they affect flap survival.[18–20] Although studies differ on which factor is most important, one can say that detailed attention to the flap choice (attempting to avoid vein grafts), flap harvest, vessel geometry, vessel anastomosis, and postoperative monitoring can lead to high success rates.

Identification of a problem and swift, effective correction of the problem can lead to flap salvage when flap failure is imminent. The goal of the microvascular surgeon is to limit the ischemia time that the tissue experiences. After a certain time, the flap becomes unsalvageable due to the "no-reflow phenomenon."[21] This phenomenon represents the point at which the microvascularity of the flap suffers such damage from the ischemia that the vessels can only exist in a thrombosed state. The endothelium of the microvascular circulation has been damaged and depleted of its energy reservoir, and despite reperfusion of the larger vessels, the injury cannot be overcome and thrombosis reversed. The exact amount time before the no-reflow phenomenon becomes evident is unknown. The microvascular surgeon must rely, then, on early identification of problem and rapid correction to prevent flap failure. Salvage rates after early detection range from 69 to 100% in the literature.[18,21]

To lessen the likelihood of vessel thrombosis, many surgeons use an anticoagulant regimen perioperatively. Although the benefit of this has never been proven in microvascular reconstruction, it has been shown to be of value in reimplantation and traumatic amputations.[22,23] Agents commonly employed include aspirin, dextran, heparin, and prednisone. These medications work primarily to prevent platelet deposition and clot formation. Currently, we use aspirin beginning on postoperative day 1 and continuing for 3 weeks in all free-tissue transfer patients. We also frequently use dextran-40 for up to 48 hours. The decision to use dextran is based on flap and patient characteristics. We use dextran when the flap has smaller vessels, the anastomoses are difficult, or the flow though the donor vessels is not as brisk as desired. We avoid dextran or limit the length of its use in patients with poor heart function and functional anemia. The volume expansion effect of dextran can lead to pulmonary edema and falling hematocrit.

MICROVASCULAR FLAPS USED IN HEAD AND NECK RECONSTRUCTION

Fascial and Fasciocutaneous Flaps

Radial Forearm Free Flap

The radial forearm free flap was first described in 1978 by Goufan, Baoqui, and Yuzhi.[24] Its popularity since its introduction has soared, and it is now considered the workhorse flap in head and neck reconstruction. The applications for the radial forearm free flap are diverse and commonly include reconstructions of the oral cavity/oropharynx, hypopharynx, total pharyngoesophagus, external skin and scalp, and skull base.[25]

Anatomy

The radial forearm free flap can be harvested as a fascial flap or as a fasciocutaneous flap and with or without bone and sensate innervation. The typical design includes a variable-sized skin paddle centered over the pedicle; reports have shown that nearly the entire skin of the forearm can be used for the transfer if needed.[26] The pedicle consists of the radial artery and two venae comitantes. The pedicle travels in the intermuscular fascial septum separating the flexor carpi radialis and the brachioradialis muscles. Multiple perforators are given off from the pedicle to the skin, the muscles, and the lateral cortex of the distal radius. Although rarely harvested due to the need for long-term immobilization and the risk of pathologic fracture, the distal cortex of the radial bone can be incorporated with the flap to create composite tissue for transfer.[27,28] Superficial venous drainage of the flap can be and usually is included during the harvest by recruiting branches of the cephalic vein. Studies have demonstrated that the two deep venae comitantes will often join to form one deep system in the proximal forearm, and in less than 50% of cases the deep and superficial systems will unite to form a common vein.[29] However, clinical work has demonstrated that flap survivability is not dependent on both systems and can be effectively maintained with either the deep or superficial system.[30]

Three sensory nerves are encountered during elevation of the radial forearm flap. The medial and lateral antebrachial nerves can be incorporated into the flap harvest and anastomosed to a local sensory nerve to obtain a sensate flap. The superficial branches of the radial nerve are also encountered during the distal harvest of the flap from the radial side. If possible, these branches should be preserved, as dividing them can lead to anesthesia of the skin over the thumb and dorsal surfaces of the first two fingers.

The final anatomic point to be made is in relation to the palmaris longus muscle. As novel, complex reconstructions are being devised (e.g., total lip[31] and hemilarynx[32]), the palmaris longus muscle is being used to support the reconstructions. The muscle originates from the deep fascia near the medial epicondyle, and the tendon inserts into the palmar aponeurosis. There is little morbidity associated with the removal of this muscle–tendon complex for reconstruction.

Surgical Technique

The preoperative assessment of the radial forearm free flap relies on ensuring adequate blood flow to the hand after sacrifice of the radial artery. This is accomplished by most surgeons using Allen's test. It is becoming increasingly popular at our institution to also obtain a Doppler-aided Allen's test to further verify flow.

The patient is supine with the operative arm on two arm boards. The radial forearm free flap can be harvested with tourniquet control. This provides for a bloodless dissection. Care should be taken to exsanguinate the forearm with an Esmarch bandage before the tourniquet is inflated. Moreover, it is important to maintain meticulous hemostasis as the dissection proceeds.

The dissection begins from either the ulnar or the radial side of the flap; elevation of the fascia or fasciocutaneous flap is deep to the fascia but superficial to the paratenon over the muscular tendons (Fig. 47–3). The paratenon will supply vascularity to the skin graft used in closure of the donor site. Elevation proceeds from each side until the pedicle is reached in the intermuscular septum between the brachioradialis and the flexor carpi radialis. Attention to the superficial venous drainage system and the superficial branches of the radial nerve is important in the radial dissection, whereas preservation of the paratenon and median nerve is important in the ulnar dissection (Fig. 47–4). Once the pedicle has been approached from both sides, it can be elevated from its deep muscular and bony attachments and dissected proximally toward the antecubital fossa until a sufficient pedicle length has been obtained. Typically, the pedicle is traced back to the junction of the radial, ulnar, and brachial arteries. Before the distal pedicle is ligated, we like to perform an intraoperative Allen's test by dropping the tourniquet with a microvascular clamp on the distal pedicle and checking hand perfusion. Closure of the donor site is accomplished with a split-thickness skin graft from the anterior thigh; a dorsal splint is placed for 6 days to immobilize the forearm and enhance graft take (Fig. 47–5).

Figure 47–3 Proposed incisions for a radial forearm free flap, with dots to indicate the course of the radial artery and a curvilinear incision from the flap to the antecubital fossa.

Figure 47–4 The radial forearm flap raised to show the paratenon. Arrows show the pedicle (superior) and the lateral antebrachial cutaneous nerve (inferior).

Figure 47–5 The flap site closed with a skin graft at the donor site. Note the suction drain. A pressure dressing and dorsal splint will be placed next.

Advantages and Disadvantages

The radial forearm free flap is widely used because it provides thin, pliable tissue that can be adapted to meet the needs of multiple reconstructions (Fig. 47–6). The skin has little hair; the pedicle has adequate vessel size and superior length and is reliably found in the intermuscular septum. The flap can be made sensate and can include both bone and tendon to enhance reconstructions.

The disadvantages of the flap are related to donor site morbidity. The ultimate complication of this flap is ischemia of the hand. Fortunately, it is exceptionally rare that Allen's test fails to identify this problem.[33] The appearance of the harvest site after skin graft closure is a significant drawback to this flap. Local flaps and tissue expanders have been used, but their overall benefit has not been great.[34,35] Exposure of the forearm tendons and decreased hand function has been reported.[36] Overall, though, the wrist range of motion, grip strength, and sensation over radial, ulnar, and median distributions has been shown to be similar in patients who have undergone radial forearm flaps and those who have not. Finally, as previously noted, the risk of pathologic fracture after harvest of radial bone is significant and has been reported in up to 43% of cases.[37]

Lateral Arm Free Flap

The lateral arm free flap was introduced by Song et al in 1982.[38] It can be harvested as a fascial or fasciocutaneous flap. A humeral bone segment, two cutaneous nerves, and a portion of the triceps muscle can be included in the harvest to enhance the reconstruction. This is a versatile flap that has been used for multiple reconstruction defects. Its unique feature is the variability of skin thicknesses included with the flap, allowing thicker skin to be used for tongue base reconstruction and thinner skin to be used for lateral pharyngeal wall reconstruction.[39]

Anatomy

The lateral arm flap is based on the posterior radial collateral artery, which is a terminal branch of the deep brachial artery. The posterior radial collateral artery is found in the lateral intermuscular septum between the brachioradialis and the triceps. The lateral intermuscular septum can be approximated by a line drawn from the deltoid insertion to the lateral epicondyle. The skin paddle for the flap is centered over the lateral intermuscular septum in the distal third of the arm; although most authors recommend a cutaneous paddle limited to a width one third the circumference of the arm (approximately 6 cm), substantially larger paddles can be safely harvested[40] (Fig. 47–7). In fact, the vascular territory has been shown to extend to the upper forearm, allowing the dual-thickness flap previously described to be harvested.[41] Limiting the width of the flap to 6 cm or less typically allows for primary closure of the defect. Perforators from the artery give blood supply to the triceps and to the periosteum overlying the humerus. This allows for composite transfer to be performed, with the triceps giving additional bulk to the transfer and the humerus providing a bone source (approximately 1 × 10 cm of bone).[42,43]

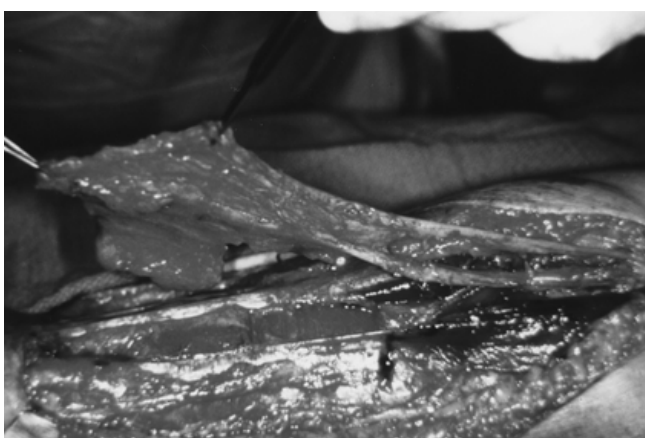

Figure 47–6 A radial forearm flap raised on its pedicle, after the tourniquet has been released. Note the thinness and the vascularity of the flap, as well as the long vascular pedicle.

Figure 47–7 Proposed incisions for a lateral arm free flap. The incision from the flap superiorly to the deltoid insertion is shown and includes a back cut to facilitate exposure of the pedicle.

Figure 47–8 Neural dissection during lateral arm flap elevation. The radial nerve is easily identified. The clamp is under the posterior cutaneous nerve of the arm, which branches from the radial nerve and provides sensory innervation to the flap.

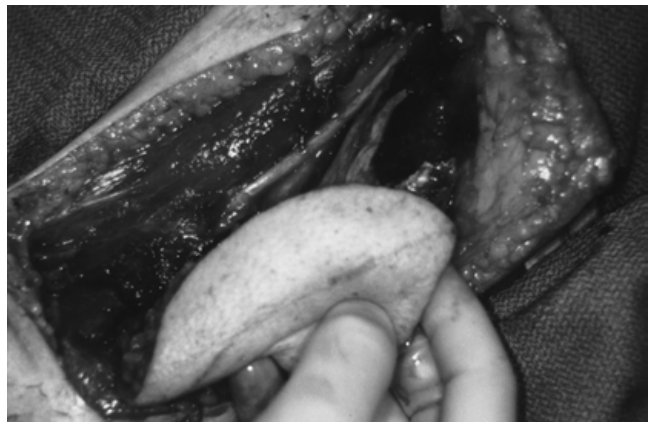

Figure 47–9 The lateral arm flap elevated, showing its thinness. The vascular pedicle lies in the spiral groove.

Like the radial forearm free flap, the lateral arm flap has dual venous drainage. The deep drainage consists of paired venae comitantes that typically join in the proximal arm to form one common deep system. The superficial system consists of branches of the cephalic vein. Although either venous system can be used for free transfer, the deep system alone is most commonly used for transfer.[44]

There are three nerves that should be identified in the lateral arm harvest. The largest nerve seen is the radial nerve. It travels with the profunda brachii in the spiral groove of the humerus and then pierces the lateral intermuscular septum to run the length of the arm. It typically has two branches, which can be identified and used in reconstructions. The posterior cutaneous nerve of the arm supplies cutaneous sensation to the area over the skin paddle, and the posterior cutaneous nerve of the forearm accompanies the pedicle, providing sensation to the forearm (Fig. 47–8). Because of the close proximity of the posterior cutaneous nerve of the forearm to the vascular pedicle, this nerve can be harvested as a vascularized nerve graft.

Surgical Technique

The lateral arm flap can be harvested simultaneously with the head and neck extirpation. Although the flap can be harvested with a tourniquet, this is rarely necessary. The elevation can begin from either the anterior or the posterior limb of the incision. Below the epicondyle the plane of dissection is superficial to the antebrachial fascia. Above the epicondyle the dissection from the anterior incision proceeds in a subfascial plane over the brachioradialis and brachialis muscle until the intermuscular septum has been identified. Fibers of the brachioradialis originate from the septum and must be separated from the septum to facilitate identification of the radial nerve, the posterior cutaneous nerves, and the vascular pedicle. The approach from the posterior incision is in a subfascial plane over the triceps muscle to the intermuscular septum. The vascular pedicle is identified adjacent to the humerus and traced with the radial nerve into the spiral groove. To maximize the pedicle size and length, the pedicle is followed in the spiral groove to its junction with the brachial artery and vein (Fig. 47–9). Not infrequently, the two venae comitantes will join to form a single venous system before joining the brachial vein. To make visualization of this portion of the dissection possible, the lateral head of the triceps is released from its attachment to the humerus. The radial nerve is mobilized away from the pedicle. The posterior nerves are transected, and the flap harvest is completed.

The donor site is typically closed with skin mobilization and primary closure. If primary closure is not possible, then skin grafting can be performed. It is advisable to close the brachioradialis to the triceps to cover the radial nerve in cases of skin grafting.

Advantages and Disadvantages

The lateral arm free flap represents a thin, supple, fasciocutaneous flap that can be innervated. The two principle advantages of this flap are that variable thicknesses of skin are available and the vascular pedicle is a nonessential, terminal branch of the brachial artery and therefore plays no role in hand or arm viability. The thickness of the skin paddle over the arm is typically between the thickness of the radial forearm (thinner) and that of the scapular or parascapular skin paddles (thicker).

The disadvantages of this flap are described in the large series (123 flaps) by Graham et al.[45] The principal disadvantages include donor site appearance (27%), lateral arm numbness (59%), hair growth at the recipient site (78%), and elbow pain (19%).

Lateral Thigh Free Flap

The lateral thigh free flap is a fasciocutaneous flap that was first described by Baek in 1983.[46] The flap has been popularized in head and neck reconstruction by Hayden. Similar to the radial forearm and lateral arm, there are numerous applications for the lateral thigh free flap. The thickness of the flap, which relates to patient body habitus, plays a critical role in the use of this flap. Thin flaps are used in situations

analogous to those calling for use of the radial forearm flap and can even be tubed to reconstruct long pharyngoesophageal defects; thicker flaps can be used for total glossectomy reconstruction.

Anatomy

The lateral thigh flap is a fasciocutaneous flap harvested from the lateral aspect of the thigh. It is based on a cutaneous perforator of the profunda femoris. The profunda femoris, or deep femoral artery, originates from the femoral artery inferior to the inguinal ligament. Typically, as the artery courses through the posterior compartment, it gives rise to two to six perforators. Most commonly, there are four perforators, and the third perforator provides the major blood supply to this flap. Intravascular connection between the perforators is almost always seen. There can be significant contributions to the skin from either the second or fourth perforator. In cases in which the second perforator provides the dominant blood supply to the flap, it is imperative to preserve the supply of the nutrient artery of the femur, which is a branch of the second perforator. The cutaneous branches of the perforators travel through the intermuscular septum between the vastus lateralis and biceps femoris to reach the skin. The intermuscular septum can be approximated by drawing a line from the greater trochanter to the lateral epicondyle. In thin individuals, the location of the septum can be palpated. Miller demonstrated that the third perforator exits 14.5 ± 3.5 cm superior to the lateral epicondyle, and this typically corresponds to half-way between the greater trochanter and the lateral epicondyle.[47] The venous drainage of this flap is via paired venae comitantes, which travel with the artery. They form a common system prior to joining the profunda femoris vein.

The skin paddle is based around the midpoint of the intermuscular septum, with the long axis parallel to the septum. Skin flaps up to 27 × 14 cm have been described.[48] The thickness of the flap will vary with the body habitus of the individual.

This flap can be neurotized using the lateral femoral cutaneous nerve. To harvest the sensate flap, a counterincision over the sartorius muscle will allow identification of the main trunk prior to its arborization over the lateral thigh.

Surgical Technique

The flap can be harvested simultaneously with the head and neck resection. The knee is flexed and rotated internally to expose the lateral thigh for dissection. The anterior incision is made and the dissection toward the intermuscular septum is superficial to the fascia of the vastus lateralis. When the perforator is identified, it is traced over, under, or through the short head of the biceps femoris. Significant branches to the muscle will be identified, and a portion of the muscle could be included with the flap if composite tissue is needed. With retraction the vascular pedicle can be traced to the adductor fascia. Following the pedicle through the small, semilunar hiatus and releasing the adductor attachments from the linea aspera allows access to the posterior compartment and the profunda femoris. The profunda can then be dissected proximally to the origin of the second perforator and sectioned just below this perforator. This maneuver will maximize the pedicle length and vessel diameter. The posterior elevation can be completed once the vessels have been isolated. The dissection is superficial to the investing fascia of the biceps femoris. The posterior skin attachment prevents sheering forces on the vessels during the dissection and provides nutrients to the skin paddle during the harvest.[49]

Primary closure of the lateral thigh defect is over suction drains. If primary closure is not possible, then a split-thickness skin graft can be used. Deschler recommends a relaxing incision over the anterior thigh when a skin graft is necessary as the take rate of the skin graft over the anterior thigh is higher than that over the intermuscular septum.[48]

Advantages and Disadvantages

The principle advantage of the lateral thigh flap is the amount of tissue that can be obtained from a single donor site. Depending on the thickness, this flap can be used for a variety of defects by virtue of its surface area, bulk, and pliability. When primary closure of the defect is possible, donor site morbidity is quite low, with a linear scar occurring on the lateral leg.

The disadvantages of this flap are primarily related to the harvest. There is anatomic variability, and the dissection can be quite challenging. There is a risk to the blood supply to the femur if the second perforator is the dominant vessel to the flap.

Superficial Temporal Parietal Fascia Flap

The superficial temporal parietal fascia flap (STPFF) is another thin, pliable flap used in head and neck reconstruction. Although the fascia flap is usually transferred as a pedicled flap, it can be transferred as free tissue with adequate vessel size to allow anastomoses to be performed. This flap is exceptionally versatile; it can be transferred with hair-bearing tissue from the scalp, split-thickness calvarial bone grafts, or cartilage from the root of the helix.[50] It also provides a vascularized bed to enhance the take of split-thickness skin grafts. Typical uses of the STPFF in head and neck reconstruction include oral cavity, skull base, and auricular reconstructions.

Anatomy

To understand this flap, one must comprehend the layers of the scalp. The superficial temporal parietal fascia (STPF) is located immediately beneath the skin and subcutaneous tissue. It is a superior extension of the superficial musculoaponeurotic system of the face. It continues superiorly as the galea aponeurosis and is continuous anteriorly and posteriorly with the epicranium musculature. Beneath the STPF is a loose layer of areolar tissue and then the deep temporal fascia (DTF). The DTF splits into a deep and superficial layer with relation to the zygomatic arch. The blood supply to the STPF is the superficial temporal artery and vein (Fig. 47–10). The artery is the terminal branch of the external carotid and takes a tortuous path through the parotid gland before arborizing over the lateral scalp. The artery has three main branches. The first branch is the middle temporal artery, found at approximately the level of the zygomatic arch. This branch provides the blood supply to the DTF. Dissection of the pedicle proximal to the middle temporal artery then can produce a flap with two fascial paddles. The other two branches are the frontal and parietal branches. Safe dissection can proceed for 3 to 4 cm along the frontal branch of the

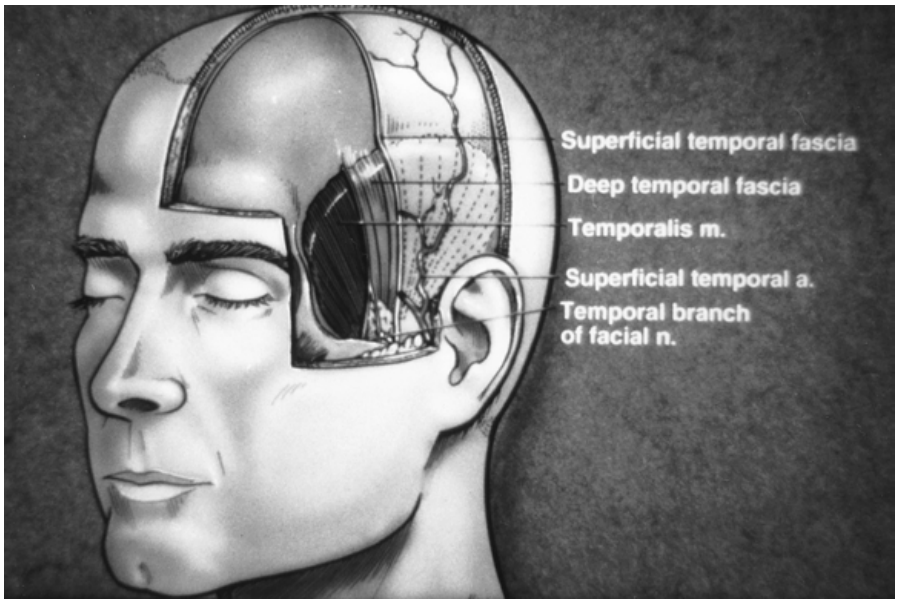

Figure 47–10 Layers of the scalp and infratemporal fossa. Understanding these relationships is vital to the successful elevation of the superficial temporoparietal fascia flap.

artery before there is significant risk to the temporal branch of the facial nerve, which courses approximately 1 to 1.5 cm from the lateral orbital rim. The parietal branch forms the major blood supply of this flap. The artery runs in the substances of the fascia, whereas the vein lies superficial to the fascia. A successful dissection can yield a flap that has a surface area of 14 × 17 cm and a thickness of 2 to 4 mm.[43]

Surgical Technique

The STPFF is harvested with the patient in the supine position. For a fascial flap, the incision extends from the superior aspect of a parotid incision into the scalp. The skin is elevated in a plane just beneath the hair follicles and subcutaneous tissue. Avoidance of electrocautery will help prevent damage to the hair follicles. After the skin is elevated, the pedicle is identified proximally and protected. The flap is now incised to the desired size and elevated off of the deep temporal fascia. The pedicle can then be skeletonized from the surrounding tissue and mobilized for use as either a pedicled flap or a free flap (Fig. 47–11). Primary closure of the defect is nearly always possible. Closed-suction drains and a pressure dressing help to prevent seroma formation.

Advantages and Disadvantages

The STPFF is a thin, pliable, yet durable flap that can be harvested with composite tissue and used as a solution to a variety of reconstructive dilemmas. The primary disadvantage to use of the flap is the risk of spotty to permanent alopecia over the harvest site.[51] The secondary risk is to the temporal branch of the facial nerve. Finally, the superficial course of the vein to the flap can lead to its damage during harvest.

Myocutaneous and Enteric Flaps

Rectus Myocutaneous Free Flap

The rectus myocutaneous free flap transferred on the deep inferior epigastric vessels was first described by Pennington and Pelly in 1980.[52] The rectus free flap can be used as a myogenous, myofascial, myosubcutaneous, or myocutaneous flap in head and neck reconstruction.[53] The versatility of the flap combined with the ease of two-team harvest has popularized this flap. The rectus flap has been used for skull base reconstructions, oral cavity reconstructions, and cutaneous/soft tissue reconstructions.

Anatomy

The rectus free flap has two dominant vascular pedicles, and free transfer and rotation flap transfer have been described

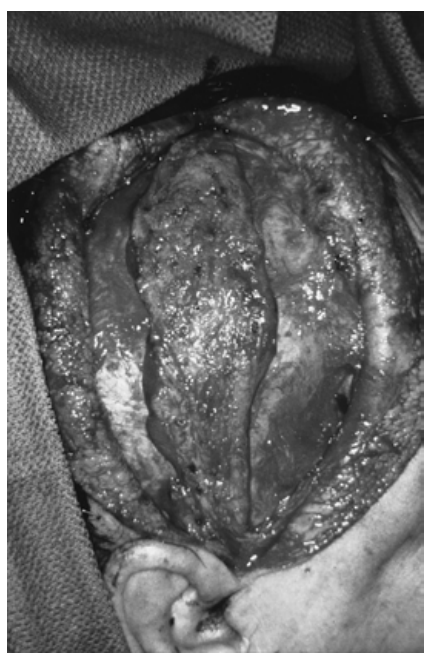

Figure 47–11 The superficial temporoparietal fascia flap raised. Note the thinness of the flap and the length from the root of the helix to near the vertex.

using each pedicle. The deep inferior and deep superior epigastric arteries anastomose to form a plexus around the umbilicus. Head and neck reconstructions have typically relied on the deep inferior epigastric vessels because they are larger in caliber and tend to capture a larger distribution of the subcutaneous tissue.[54] The deep inferior epigastric artery is a branch of the external iliac artery. The vessel travels upward, penetrating the rectus fascia at the level of the arcuate line. The vessel then progresses transversely across the muscle, giving off perforators to the skin and muscle until it reaches the area of the umbilicus. In the periumbilical area, the deep inferior epigastric vessels anastomose with the deep superior epigastric, intercostal, lumbar, deep groin vessels, and epigastric vessels from the contralateral side. This vascular-rich region also has a high concentration of musculocutaneous perforators. The venous drainage of the flap is matched to arterial inflow and usually consist of two venae comitantes, which join to form a single vein before reaching the external iliac vein.

The skin paddle can be oriented over the rectus muscle in any fashion, and flap design plays a large role in the skin paddle orientation. Vascular studies have shown that the skin on the ipsilateral side of the umbilicus can be safely harvested both over the muscle and lateral to the linea semilunaris; interestingly, due to the vascular network in the periumbilical area, the contralateral skin over the rectus can reliably be used.[54] This provides numerous flap designs to the reconstructive surgeon.

The nervous input to this region is segmental from the intercostal nerves, providing both sensory and motor function. Unfortunately, no reliable technique for neurotization of this flap has been described.[55]

Surgical Technique

This flap is harvested with the patient in the supine position. Because repositioning of the patient is not required, a two-team approach is very possible. The flap harvest begins by outlining the skin paddle. The thickness of the flap is highly dependent on the patient's body habitus. To take a thinner flap, the orientation of the paddle can be oblique, thus providing thinner tissue laterally.[56,57] The flap should be based on the periumbilical region and then extended over muscle or at a 45-degree angle toward the scapular tip (Fig. 47–12). When outlined the flap harvest can proceed either from the lateral margin or from the superior aspect of the incision. Elevation from the lateral aspect is superficial to the fascia of the external oblique musculature (Fig. 47–13). At the lateral aspect of the rectus muscle, the skin perforators can be identified. An incision is made through the rectus fascia to incorporate the perforators. The dissection then turns to the superior aspect where the desired cuff of rectus muscle is included (Fig. 47–14). During the ensuing elevation of the muscle off the posterior rectus sheath, it is critical to maintain the posterior fascia to prevent disruption of the integrity of the abdominal wall and postoperative hernia. At the level of the arcuate line, the deep inferior epigastric vessels can be identified and traced to the external iliac vessels to obtain a long pedicle. The insertion of the rectus in the pubic bone is then divided, and the flap is ready for transfer.

Closure of the defect is by wide elevation. It is critical to ensure that the anterior rectus fascia is closed below the arcuate line to prevent postoperative hernia.[56] Therefore, design of a skin paddle beneath the arcuate line is discouraged. If possible, the anterior rectus fascia is closed above the arcuate line.

Figure 47–12 Incisions for the rectus flap. The flap is based on the paraumbilical perforators and extends at a 45-degree angle toward the tip of the scapula.

Figure 47–13 The rectus flap is raised from laterally to medial off the external oblique muscle, until the rectus fascia is encountered. Then the fascia is divided and the muscle elevated.

Figure 47–14 The rectus muscle is divided superiorly and elevated inferiorly to the pubis. It is divided at the pubis and the pedicle dissected. Note the large skin paddle.

Advantages and Disadvantages

The rectus free flap provides a flap that is very useful in the reconstruction of multiple defects. The advantages of the flap are its long vascular pedicle, the variety of composite tissue types that can be transferred, and the two-team approach with the patient in the supine position. Unfortunately, its bulk in most patients relegates its use primarily to the reconstruction of large defects where mobility of the surrounding tissue is not critical to the reconstruction. The most common complications are abdominal wall hernia, wound dehiscence, and infection. These complications can be minimized with attention to detail during flap design and donor site closure.

Latissimus Dorsi Free Flap

The latissimus dorsi free flap was first described by Baudet in 1976, nearly 80 years after the first description of the pedicled latissimus flap.[58,59] The flap provides a large source of skin and soft tissue for reconstruction of head and neck defects. The principal use of the flap has been skull base reconstruction, but innovative techniques with motor reinnervation have made this flap useful in the repair of total glossectomy defects and facial paralysis defects. The large skin flap has been used to fill soft tissue defects, and the latissimus flap can be included in the combined megaflap off the subscapular system (latissimus and scapular flaps).

Anatomy

The latissimus muscle is large, fan-shaped, and occupies the majority of the back. Its insertion is on the humerus whereas its origin is broadly across the lower back, including the external oblique, serratus, and teres major musculature, the lower six thoracic vertebrae, the lower four ribs, and the fascia attaching to the lumbar and sacral vertebrae and the iliac crest. The skin paddle can be placed in a variety of locations across this large muscle. The size of the skin paddle is usually limited by the ability to obtain primary closure.

There are two vascular pedicles associated with this flap. The primary pedicle is the thoracodorsal artery and vein; the secondary pedicle is perforators from the intercostal vessels. Free transfer of the musculocutaneous flap is based on the thoracodorsal artery and vein. The thoracodorsal artery is a branch of the subscapular artery, which is in turn a branch of the third portion of the axillary artery. The pedicle for the flap can be traced to the origin of the subscapular system from the axillary system to obtain a large-diameter artery (3 to 4 mm) and vein (3.5 to 4.5 mm) and significant pedicle length. This maneuver sacrifices the circumflex scapular artery, or this artery and its tributaries can be included for the megaflap. Finally, as the thoracodorsal artery terminates into the muscle, it frequently (85%) divides into two branches (medial and superior), which then allows two separate skin paddles to be used.[60]

The motor nerve to the flap is the thoracodorsal nerve. It is a branch of the posterior cord of the brachial plexus. The nerve parallels the course of the vascular pedicle facilitating its harvest. The sensory innervation of the flap is via the segmental, cutaneous branches of the intercostal nerves. Both motor and sensory reinnervation of the latissimus free flap have been successfully performed.[61,62]

Surgical Technique

The topical landmarks used in the harvest include the midpoint of a line connecting the anterior iliac spine to the posterior iliac spine, the midpoint of the axilla, and the tip of the scapula. The anterior edge of the latissimus muscle is estimated by a line from the midaxilla to the midpoint of the iliac crest. The pedicle typically enters the muscle 8 to 10 cm below the level of the midaxilla. The skin paddle is centered over the midportion of the muscle (Fig. 47–15). Skin paddles over the distal aspect of the muscle are not reliable.[63] The harvest is begun posteriorly with the skin incision down to the level of the muscle. The volume of muscle harvested is dependent on the reconstructive needs and can range from the entire muscle with a portion of the thoracolumbar fascia to just the muscle under the skin paddle. The muscle is elevated off its sites of origin with blunt and sharp dissection. The anterior incision is made in an analogous fashion. As the dissection proceeds superiorly along the anterior border of the muscle, the pedicle should be identified entering the muscle. This can be accomplished by spreading the fat in the axilla along the border of the muscle. Frequently, the first vessels identified are the branches to the serratus anterior muscle. These vessels can be traced to their origin at the thoracodorsal vessels to identify the pedicle. After the pedicle is protected, the elevation can continue, including release of the humeral insertion. The final aspect of the harvest is mobilizing the pedicle medially to the subscapular and axillary systems if desired.

Advantages and Disadvantages

The latissimus offers the reconstructive surgeon another large musculocutaneous flap. The pedicle is long and has relatively large-vessel diameters. The ability to achieve rein-

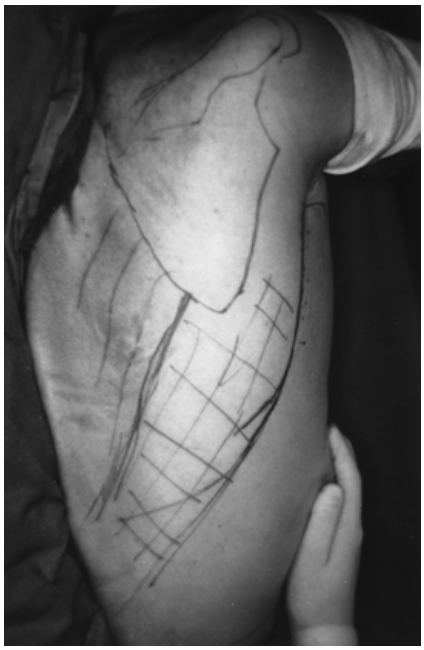

Figure 47–15 The area from which the skin paddle of the latissimus myocutaneous flap is most commonly harvested.

nervation from both a sensory and motor perspective makes this flap unique. The location of the latissimus flap is the primary disadvantage. To harvest the flap, the patient must be in the lateral decubitus position. This requires a position change and may make the tumor extirpation more awkward. Furthermore, its proximity to the head and neck makes a two-team approach difficult. Other disadvantages relate to decreased arm function following muscle sacrifice, possible injury to the long thoracic nerve, and possible injury to the brachial plexus.

Free Jejunal Flap

The free jejunal flap was first performed in an animal model in 1906 by Alexis Carrel.[64] The technique was performed in humans in 1958 by Seidenberg and colleagues.[65] It has subsequently become a standard in hypopharyngeal reconstruction. The free jejunal flap is used for circumferential defects of the hypopharynx and cervical esophagus or as a patch graft for incomplete defects.

Anatomy

The jejunum is the portion of the small intestine bounded by the duodenum and the ligament of Treitz. Its blood supply comes from segmental jejunal arteries of the superior mesenteric artery. The jejunal arteries form vascular arcades that supply the bowel. Typically, the second loop of jejunum provides an adequate segment of bowel (15 to 25 cm) on a single artery. The arterial vessel ranges from 1 to 5 mm in diameter, whereas the vein ranges from 2 to 4 mm in diameter. The nervous supply of the bowel is intrinsic, and contraction of the bowel resumes with revascularization of the tissue.

Surgical Technique

The jejunal free flap can be harvested with a two-team approach. At our institution, the general surgery department is charged with harvest of the flap. The flap is harvested via a midline incision. Recently, there has been considerable interest in laparoscopic flap harvest.[66] The laparoscopic harvest has led to a decrease in the abdominal pain and morbidity associated with harvest. Translumination of the bowel aids in identification of the vascular arcades. The bowel is left in the abdomen profused until the head and neck recipient site is prepared. It is imperative to minimize the ischemic time of the bowel. A gastrostomy and jejunostomy tube are usually placed to facilitate postoperative rehabilitation.

There are several key principles to the surgical technique once the bowel is transferred. If possible, the venous anastomosis is performed first.[67] By releasing the vein, reverse flow of oxygen to the bowel can occur. If the arterial anastomosis is performed first and released, then the bowel swells and peristalsis begins, rendering the venous anastomosis more difficult. Moreover, it is critical that the harvesting physician mark the proximal end of the bowel to ensure isoperistaltic orientation in the head and neck. Finally, although the size of the jejunum is a good match for that of the esophagus, the jejunum must be fish-mouthed to allow adequate approximation with the oropharynx. This maneuver is best performed on the antimesenteric border of the jejunum to maintain graft vascularity.

Following revascularization, the flap becomes pink, the peristaltic contractions begin, and mucus is released by intestinal glands. Monitoring of the flap can easily be accomplished by isolating a small segment of the bowel outside the neck closure so that direct visual inspection of the bowel can be performed (Fig. 47–16).

Advantages and Disadvantages

The advantages of the free jejunal flap over more traditional methods of total pharyngeal reconstruction include shorter hospitalization, shorter time period to successful oral alimentation,

Figure 47–16 The jejunal flap in place during reconstruction of a total laryngopharyngectomy defect. Note the segment of jejunum brought out to the left neck for monitoring, still based on its mesentery.

and lower incidence of fistula.[67] Disadvantages of the jejunal flap include the laparotomy, postoperative dysphagia caused by peristalsis of the flap and stricture formation, and the poor vocal result with tracheoesophageal puncture.[68] The most common abdominal complications are dehiscence and gastrointestinal bleeding. The dysphagia is improved by orienting the flap in an isoperistaltic fashion, but it still exists because of a lack of coordination of the contraction of the native tissue with the transferred segment. Use of a lock-and-key approach to the jejunoesophageal anastomosis reduces the incidence of postoperative dysphagia by reducing the risk of stricture. The poor vocal result is unavoidable due to the folds within the jejunum and the intrinsic mucus production. These features produce the characteristic "wet voice."

Bone Flaps

Fibula Osteocutaneous Free Flap

The free transfer of the fibula was first proposed by Taylor et al in 1975.[69] As microvascular technique has developed, this flap has become the workhorse for oromandibular reconstruction. It provides a long bone segment, a long pedicle, and a potentially sensate skin flap. The bone is readily contoured and can reconstruct any mandibular defect. The flap can also be used for palatal and midface reconstruction.

Anatomy

The fibula is the smaller and relatively non-weight-bearing bone of the lower extremity. The bone segment available is up to 25 cm. It is necessary to leave a 6- to 8-cm segment of fibular bone superiorly and inferiorly to protect the knee and ankle joints. The average cross-sectional area of the bone is 90 mm^2.[70] Although this volume of bone is easily adequate to support dental implants, it will leave a height discrepancy with the native mandible bone.[71]

The fibula free flap is based on the peroneal artery and venae comitantes. The peroneal artery is a branch of the posterior tibial artery. It provides a nutrient artery to the fibula bone and segmental blood supply to the periosteum of the bone. This dual segmental and central blood supply allows for safe placement of multiple osteotomies (up to every 2 cm) when contouring the bone.[72] Although uncommon, the peroneal artery can have a large role in the perfusion of the foot or can be absent.[73] We obtain preoperative lower extremity arteriograms in all patients undergoing fibula free flap. Recently, magnetic resonance angiography and color flow Doppler have been proposed as alternatives to arteriography.[74]

The skin paddle is centered over the lateral intermuscular septum at the junction of the lower one third and upper two thirds of the lower leg. The paddle is supplied by septocutaneous perforators from the peroneal artery. There tends to be a higher concentration of perforators at the inferior aspect of the leg. If multiple septocutaneous perforators exist, then the skin paddle can be divided to resurface different sites in the head and neck. The skin paddle is the least dependable of the bone flaps that will be discussed, but recent studies have found the skin paddle to be reliable in 95% of cases.[75] The sensory input to the flap is the lateral sural cutaneous nerve. This is a branch of the common peroneal nerve. The successful sensory innervation of the skin paddle based on the lateral sural cutaneous nerve has been described.[76,77] The final anatomic point is that the peroneal artery also gives off muscular perforators, allowing a cuff of the soleus and flexor hallicus longus to be included with the flap if needed in the reconstruction.

Surgical Technique

The harvest of the fibula free flap takes place with the patient in the supine position with a slight bump under the hip causing an internal rotation. A two-team approach is easy given the distance from the head and neck. The harvest can be performed under tourniquet control providing a bloodless dissection. The skin paddle is drawn over the lateral intermuscular septum, which is estimated by a line connecting the lateral epicondyle inferiorly with the fibular head superiorly (Fig. 47–17). Larger skin paddles are needed to capture the major septocutaneous perforators that allow successful transfer of the skin with this flap. The elevation is begun on the anterior surface with the skin incision down to the peroneus longus and brevis muscles. The dissection proceeds in a subfascial plane over these muscles toward the intermuscular septum. Septocutaneous perforators can be identified as they course through the intermuscular septum to the skin (Fig. 47–18). If necessary, the location of the skin paddle can be altered once the perforators have been identified. The posterior skin incision is then made down to the level of gastrocnemius and soleus muscles; the elevation is again in a subfascial plane and proceeds to the intermuscular septum. The fibula bone cuts are performed to allow traction on the bone to assist with the dissection. The peroneus muscles are released from the fibula and the interosseous membrane is divided. The pedicle is identified and divided inferiorly and traced superiorly. The posterior tibialis muscle is then released. As the flexor hallicus longus and soleus are released, a cuff of each muscle can be harvested. The pedicle can then be traced to its origin at the posterior tibial vessels.

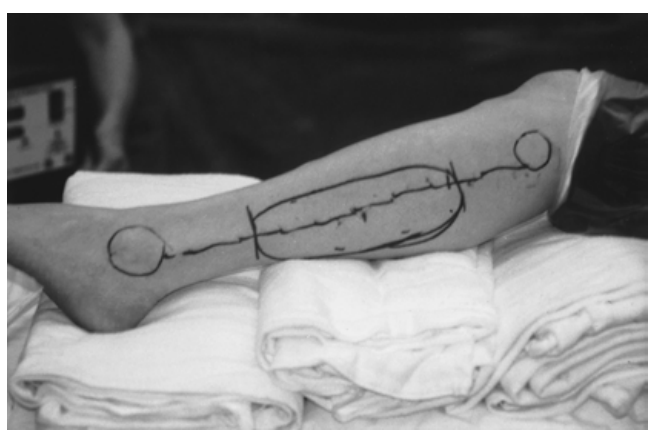

Figure 47–17 Proposed incisions for a fibula osteocutaneous flap. The flap is centered on a line from the posterior aspect of the lateral malleolus to the posterior aspect of the fibular head. The flap is oval and is made large to include all possible perforators.

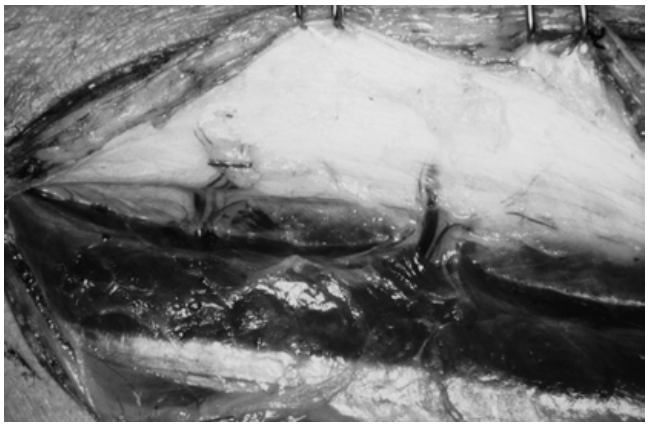

Figure 47–18 Septocutaneous and myocutaneous perforators to the fibula osteocutaneous flap skin paddle. The skin paddle has been elevated over the soleus muscle posteriorly, approaching the intermuscular septum. The left perforator is running in the septum alone, whereas the right perforator is coursing through the soleus muscle as well.

Closure of the leg can be done primarily if a large skin paddle is not taken. If primary closure is not possible, a skin graft is placed. A posterior splint is placed to immobilize the leg for the immediate postoperative period.

Advantages and Disadvantages

The fibula free flap provides the reconstructive surgeon with sufficient bone to address any defect, and the bone stock is adequate to accept osseointegrated implants (Fig. 47–19). The skin paddle is reliable and can be made sensate, and, finally, the harvest can be done with two teams in a bloodless field. The disadvantages of the fibula free flap include postoperative weakness of great toe flexion, potential instability to the ankle, stiffness and pain in the ankle, the need to skin-graft the donor site, the risk of an ischemic foot from peroneal artery sacrifice, and the limited height of fibular bone.

Scapula Free Flap

The scapula free flap was introduced for mandibular reconstruction by Swartz and colleagues in 1986.[78] The scapular free flap is the most versatile flap available with bone stock. Using a single pedicle, the reconstructive surgeon can transfer a combination of three different skin paddles (scapular, parascapular, and latissimus), two muscles (latissimus and serratus), and two bone segments (lateral scapular border and tip). This wide variety of tissue options makes a component of the subscapular flap system a choice for many reconstructions.

Anatomy

The available bone is derived from either the lateral edge or the tip of the scapula. Together they can provide up to 14 cm of bone for reconstruction. The cephalad extent of the bone harvest is limited to preserve the glenohumeral joint. The bone stock is thin and has minimal vertical height, but cadaveric studies have shown that up to 75% of scapular bone samples can support osseointegrated implants.[75] The tip of the scapula can provide up to 4 cm of bone based on a separate pedicle.[79] This bone is thicker than the main bone segment.

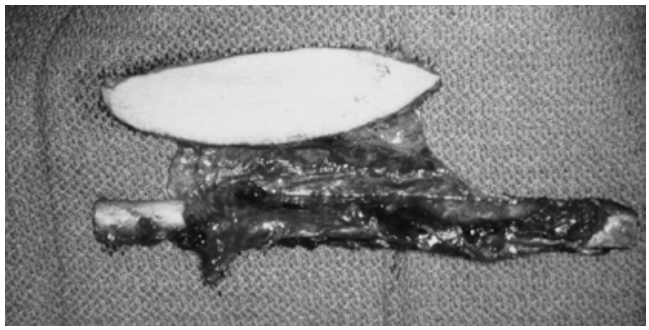

Figure 47–19 The fibula osteocutaneous flap with its long stock of bone and the skin paddle attached via the lateral intermuscular septum.

The vascular pedicle to the scapular free flap is the circumflex scapular artery and vein. The circumflex scapular artery is a branch of the subscapular artery, which in turn is a branch of the third division of the axillary artery. The circumflex scapular artery sends periosteal perforators to the lateral aspect of the scapular bone and terminates as two distinct cutaneous branches. Each of the cutaneous branches can be used for a separate skin paddle. The transverse branch corresponds to the scapular skin paddle, whereas the parascapular skin paddle is supplied by the descending branch. The angular artery supplies the periosteum of the scapula tip and is a branch of the thoracodorsal artery. The venous drainage parallels the arterial inflow.

As previously noted, two skin paddles are possible based on the two cutaneous branches of the circumflex scapular artery. The skin flap thickness is thicker than a radial forearm but thinner than a rectus. Moreover, the subcutaneous tissue can be harvested by itself to be used as a vascularized fat graft. Innervation to the skin paddles is via the segmental, intercostal cutaneous nerves, the cervical plexus, and the circumflex branch of the brachial plexus.[80] There is not a single dominant sensory nerve, and there have been no reliable reports of reinnervation of the skin paddles.

Surgical Technique

Like the latissimus free flap, the scapula flap is harvested with the patient in the lateral decubitus position. The arm is completely prepped and draped so that free manipulation of the arm is possible to aid the dissection. The omotricipital triangle is the key body surface landmark. This triangular space is bordered by the teres minor, the teres major, and the long head of the triceps. The circumflex scapular pedicle exits the omotricipital triangle before giving rise to the cutaneous branches that supply the scapular flap. The skin paddle(s) is(are) outlined on the back, including the omotricipital triangle and paralleling the appropriate cutaneous perforator (Fig. 47–20). The transverse branch typically runs parallel to and 2 cm inferior to the scapula spine, whereas the descending branch runs perpendicular to scapular spine and 2 cm medially to the lateral border of the spine.[81] The two skin

Figure 47–20 The scapula skin paddle design for an osteocutaneous flap. Both scapular and parascapular paddles are designed, both based on the omotricipital triangle shown.

paddles can be harvested completely separately or as a large bilobed flap.

The harvest proceeds from medial to lateral. The plane of dissection is superficial to the fascia of the infraspinatus musculature. The skin flap is elevated to expose the cutaneous branches of the circumflex scapula as it exits the triangle. The teres major musculature must be released from the lateral border of the scapula to expose the bone. Limited periosteal exposure is performed to leave intact as much of the blood supply to the bone as possible. The pedicle is then traced into the axilla through the triangular space. Once the pedicle has been isolated completely (usually the thoracodorsal vessels are sacrificed), a cutting saw or drill is used to remove the bone, leaving an adequate cuff superiorly to preserve the glenoid fossa. Later, desired osteotomies in the bone to contour the shape are performed with as little periosteal elevation as possible.

Closure of the wound includes the reapproximation of the teres major to the lateral aspect of the scapula. Drill holes should be placed in the scapula and nonabsorbable suture used to accomplish this goal. The skin donor sites are closed primarily with tissue elevation for widths up to 12 to 14 cm.[82] Intensive physical therapy in the postoperative period, which can begin as early as 3 days after the operation, is crucial to the restoration of preoperative arm and shoulder function.

Advantages and Disadvantages

The advantages of the scapula free flap are the diversity of flap options available based on the single pedicle, the abundant skin and soft tissue that can be harvested, and the three-dimensional maneuverability of the skin and muscle paddles in relation to the bone paddle. Donor site morbidity can be minimized with early, aggressive physical therapy.[83] Other disadvantages include the positioning for the flap, the difficulty of two-team surgery, and the thinness of the bone stock, particularly at the central aspect of the harvested bone.

Iliac Crest–Internal Oblique Osseomyocutaneous Flap

The iliac crest osteocutaneous flap was first described by Taylor et al in 1979.[84] The flap was adapted by Ramasastry et al in 1984 to include the internal oblique musculature to enhance its reconstructive potential.[85] Urken and his colleagues at Mount Sinai have popularized this modification for oromandibular reconstruction.[86] The iliac crest–internal oblique osseomyocutaneous flap provides a large segment of naturally curving bone, a long vascular pedicle, a muscle paddle with good mobility, and a skin paddle with limited mobility. These flap features make the iliac crest a versatile flap for head and neck reconstruction.

Anatomy

The iliac crest is the superior aspect of the lateral pelvic girdle. It is a source of cancellous bone with a rich blood supply through the bony matrix. Up to 16 cm can be harvested from the anterior iliac spine to the posterior iliac spine. The bone is harvested with a natural curve that allows mandibular reconstruction up to a hemimandibulectomy without an osteotomy.[87] If needed to cross the midline, osteotomies can be safely performed. The graft can be harvested to the desired volume to match the native mandible and easily accepts osseointegrated implants.[88]

The vascular pedicle to the internal oblique–iliac crest flap is the deep circumflex iliac artery and vein. These vessels are branches of the external iliac artery and vein and join the external iliac system just above the inguinal ligament. The vessels then course through a fibrous tunnel formed by the decussation of fascia transversalis and iliaca. At approximately the level of the anterior iliac spine, the deep circumflex iliac artery gives off a large ascending branch, which provides the dominant vascular supply to the internal oblique muscle. The artery then runs along the medial aspect of the iliac crest giving rise to numerous musculocutaneous perforators. These perforators penetrate the three layers of the abdominal musculature and supply the skin above the iliac crest. The deep circumflex iliac artery also provides periosteal perforators to the iliac bone and a nutrient artery to the bone. Finally, the venous drainage parallels the arterial inflow as dual venae comitantes that form a single vein before joining the external iliac vein.

The skin paddle is located over the iliac crest and can vary dramatically in thickness with the body habitus of the patient. Flaps up to 20 $\times$ 10 cm have been successfully transferred.[87] The skin paddle is tethered to the medial aspect of the iliac bone and has a very limited arch of rotation with relation to the bone. The internal oblique muscle is a broad, flat muscle that forms the middle layer of the abdominal musculature. The entire internal oblique can be transferred based on a large ascending branch giving a muscle paddle of up to 8 $\times$ 15 cm.[89] In contrast to the skin paddle, the muscle paddle has a significant arch of rotation and can even be wrapped around the harvested bone.[86] The lateral cutaneous branch of

the twelfth thoracic nerve provides the dominant sensory innervation to the skin paddle. Reinnervation of the skin paddle based on this nerve has been described, but no large series have reported substantive data on reinnervation.[90]

Surgical Technique

The iliac crest–internal oblique free flap is harvested with the patient in the supine position, allowing a two-team approach. The skin paddle is outlined over the iliac crest and extends along an imaginary line from the anterior iliac spine to the tip of the scapula. It is critical that the skin paddle incorporate the highest concentration of perforators. This occurs approximately 8 cm from the anterior iliac spine along the imaginary line. The medial skin incision is done to the level of the external oblique musculature. The skin and subcutaneous tissue are then elevated in a suprafascial plane laterally to a point approximately 3 cm from the iliac crest. The 3-cm cuff of muscle ensures that the musculocutaneous perforators are protected. At this point, the muscle is divided and fibers of the internal oblique are seen. The internal oblique muscle is harvested by detaching its lateral, medial, and superior insertions. A plane is then developed at the superior lateral margin of the muscle between the internal oblique and the transversus abdominis. The ascending branch of the deep circumflex iliac artery will be identified on the undersurface of the internal oblique muscle. The elevation of the internal oblique muscle drops through the transverse abdominis 3 cm from the iliac crest to protect the perforators. As the pedicle is traced, the iliacus musculature is divided, leaving at least a 2-cm cuff to protect the vessels. The vessels are then traced to the external iliac system. The lateral skin incision is made and elevation is in a suprafascial level to the iliac crest over the tensor fascia lata and gluteus medius. The bone cuts are then made with the abdominal contents safely retracted and the pedicle protected. Monocortical cuts from the medial surface are typically made, but bicortical cuts can be made if additional dissection is performed on the lateral surface of the crest. The closure of the wound, as with the rectus, must be meticulous with a liberal use of prosthetic mesh to prevent postoperative hernia or contour irregularities. The transverse abdominis is closed to the iliacus, the external oblique is closed to the tensor fascia lata, and the skin is closed primarily.

Advantages and Disadvantages

The iliac crest–internal oblique osseomyocutaneous flap offers the surgeon a dependable source for well-vascularized bone. The primary advantage of this flap is the large, curved bone segment. The bone volume can match the native mandible, and the natural curve of the bone can improve contour match, thus avoiding the need for multiple osteotomies (Fig. 47–21). Flap options include both a skin and a muscle paddle, allowing multiple surfaces to be lined with one flap (e.g., the skin can be used for a chin defect whereas the muscle is used for a floor-of-mouth mucosal defect). Finally, the incision can be completely hidden by standard clothing. The disadvantages of this flap include the arc of rotation of the skin paddle, the risk of hernia or contour irregularity, gait distortion, and sensory changes. To successfully transfer the skin, a cuff of the abdominal muscles must be preserved to protect the perforators. Not only does this add to the thickness of the flap, but it also limits the skin paddle mobility due to the investing mesentery. The skin therefore cannot reconstruct defects superior to the lateral oral commissure. Contour irregularities and hernias are significant complications. In one large series, they occurred in 20.0% and 9.7% of patients, respectively.[91] These numbers can be minimized by close attention to the closure. In the same large series, gait disturbance occurred in 10.9% and sensory change (predominantly numbness) in 27.0% of patients.

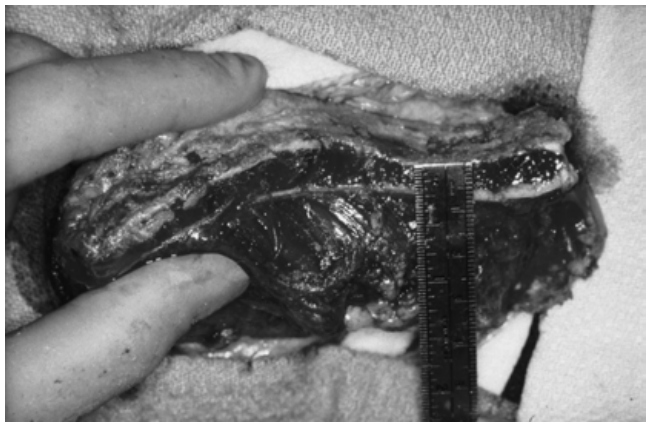

Figure 47–21 The iliac crest bone segment of the iliac crest–internal oblique osteocutaneous flap. Note the shape of the bone harvested, which approximates the mandibular shape and height, and the thick bone stock available with this flap.

FUNCTIONAL REVIEW OF FLAP OPTIONS

In this final section we will review the flaps discussed in this chapter applying them to defects encountered by the head and neck reconstructive surgeon. We will frequently interject our opinion in this final section to demonstrate how one major medical center approaches head and reconstruction. We will examine soft tissue and oral defects, hypopharyngeal defects, skull base defects, and mandibular defects.

Soft Tissue and Oral Defects

Soft tissue and oral defects involve similar flaps albeit for different reasons. Factors to be taken into account during soft tissue reconstructions are the amount of skin needed, native tissue bulk, and native skin color. Oral cavity reconstructions require pliable, thin, potentially sensate tissue that can be contoured in three dimensions to prevent tethering of mobile tissue.[92] Options include the superficial temporoparietal fascial flap with skin graft, the radial forearm, the lateral arm, the lateral thigh, the scapula, the latissimus, and the rectus free flaps. Although it will vary with the patient's body habitus, the previous list is provided in order of typical thicknesses from thinnest to thickest. None of the flaps provides excellent skin color match for facial skin, but arm skin tends to be a better match than back or leg skin.

The superficial temporoparietal fascial flap is rarely used primarily but should be kept in mind should the principal

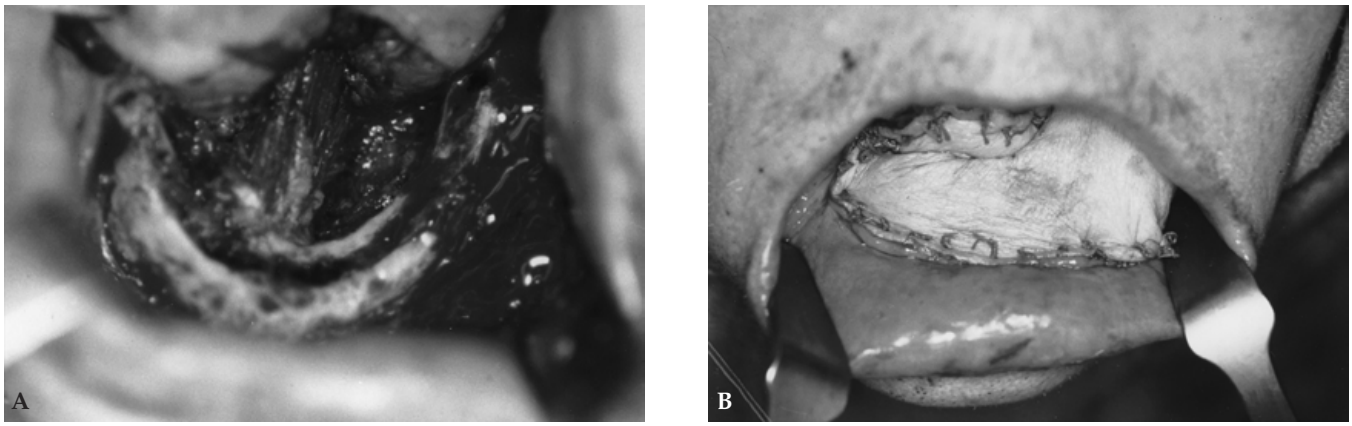

Figure 47–22 **(A)** A composite floor of mouth defect after resection included a partial mandibulectomy and bilateral floor of mouth mucosa. The genioglossus muscle is evident. **(B)** The same view with a radial forearm flap in place.

option not be available or fail. Its use so far has been limited to floor-of-mouth reconstructions. The radial forearm is the workhorse of oral cavity reconstruction and can serve nicely for soft tissue defects where bulk is not necessary. It provides ample flap size for nearly all oral cavity defects, a long and dependable vascular pedicle, limited morbidity if collateral ulnar flow is sufficient to support the hand, and reliable sensory innervation (Fig. 47–22). In comparison, the advantages of the lateral arm free flap are the variable flap thicknesses and the fact that terminal vessels that form the vascular pedicle have no impact on hand or arm viability. The comparative disadvantages are the smaller flap size limited by the ability to primarily close the arm and the difficulty of flap harvest. The lateral arm is particularly useful for tongue base reconstructions where thicker, sensate flaps are preferred. It has also been useful in midface reconstructions due to its bulk and color match (Fig. 47–23).

The lateral thigh is technically difficult to harvest, and its variable blood supply further complicates its use. Although it does provide a large skin paddle with variable tissue bulk, it is rarely used in oral cavity reconstructions. The scapular cutaneous flap is usually too thick to be used for oral cavity reconstruction; its advantage is two skin paddles allowing the resurfacing of through-and-through defects with skin on each side as found with large cheek defects. The bulk of the scapula flap also makes it ideal for reconstruction of total parotidectomy defects; in this case, almost all of the flap is deepithelialized prior to its placement under the parotid skin flaps.

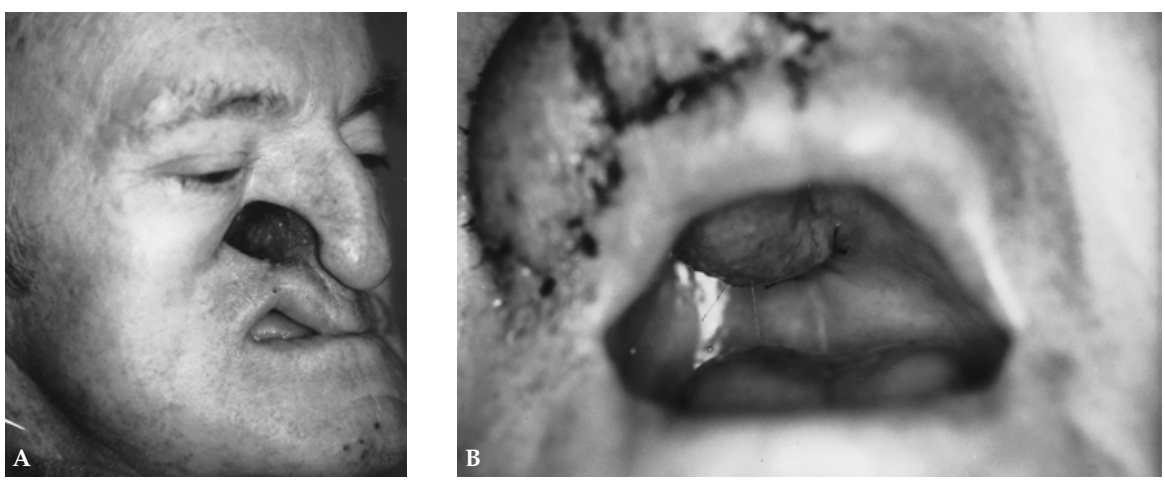

Figure 47–23 **(A)** A combined facial and palatal defect after partial maxillectomy and postoperative radiation therapy for cancer. **(B)** The same defect after reconstruction with a lateral arm flap. A portion of the flap was deepithelialized to allow both defects to be closed with a single skin paddle.

Figure 47–24 **(A)** A combined skin and skull base defect after resection of an invasive, massive facial skin cancer. Note the facial nerve graft in the depth of the wound. **(B)** The same view with a latissimus myocutaneous flap in place.

The latissimus flap forms the cornerstone for large soft tissue defects. A very large skin paddle can be harvested with a long, dependable pedicle. Long-term atrophy of the muscle can be used to the surgeon's advantage to achieve better contour. This flap is particularly useful for combined skull base and scalp defects (Fig. 47–24). The relatively thin nature of this flap allows it to be folded to reconstruct combined maxillectomy and orbital exenteration defects. Finally, the muscle alone with skin grafts on the surface can be used for near-total scalp defects with reasonable color and thickness match (Fig. 47–25). The rectus flap provides a large paddle but frequently is thick. The vascularized fat does not atrophy to a significant extent; therefore, this flap is only used when bulk is acceptable. It is commonly used after extensive resections of the skull base including large maxillectomy defects (Fig. 47–26).

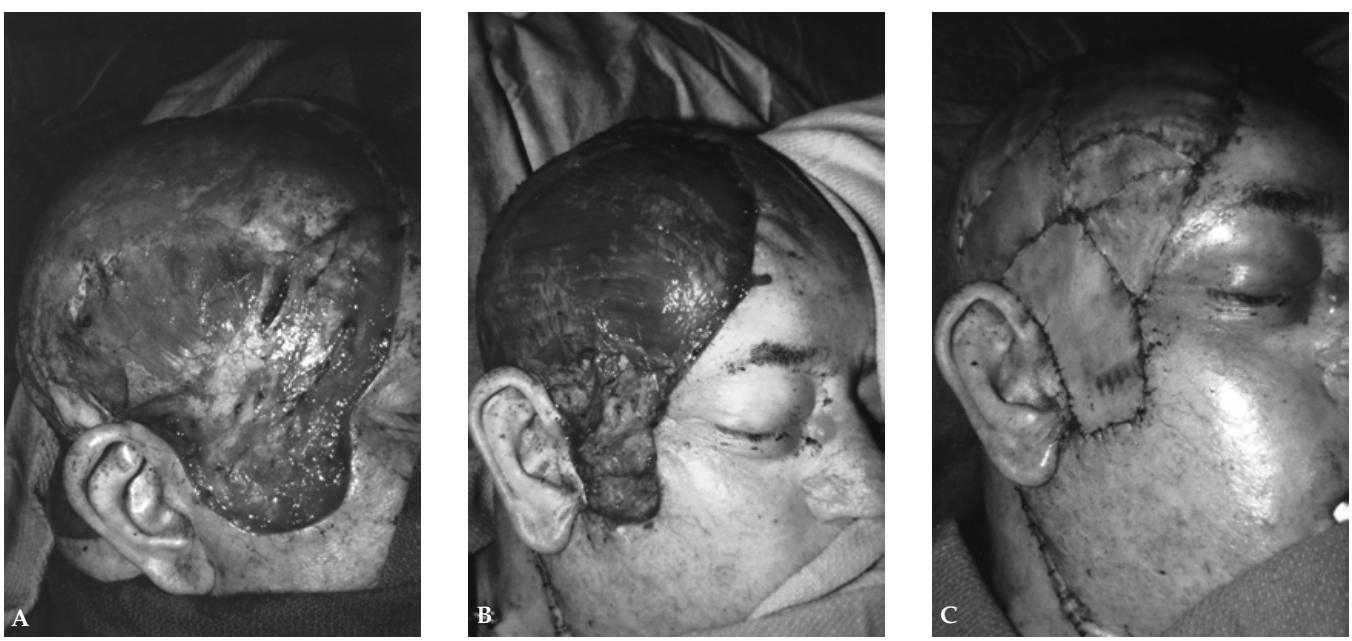

Figure 47–25 **(A)** A massive resection of the scalp for angiosarcoma. **(B)** The same defect with a latissimus myogenous flap in place. **(C)** The same view after split-thickness skin grafting of the free flap.

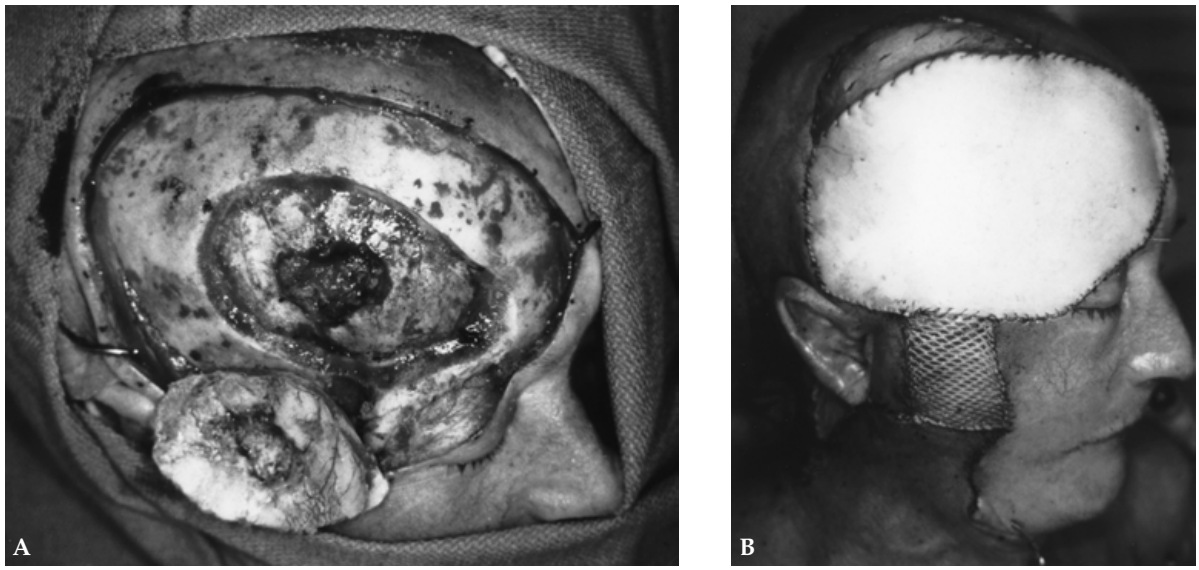

Figure 47–26 **(A)** Another massive scalp and skull base defect after resection of a skin cancer. Note the tumor still adherent to the dura, prior to dural resection. **(B)** The same defect with a rectus myocutaneous flap in place. Note that the muscle in the neck was skin-grafted to avoid unnecessary tension over the pedicle.

Hypopharyngeal

The choice of reconstructive options in the hypopharynx is primarily dependent on the extent of the defect in terms of both length and circumference, the availability of different donor sites, and patient characteristics including body habitus and wishes for vocal rehabilitation. For defects above the thoracic inlet and less than 270 degrees, we principally use pedicled rotation flaps (pectoralis and latissimus myocutaneous flaps). Patch grafting can be successfully done with the cutaneous flaps (radial forearm and lateral thigh), a jejunal flap opened completely along its antimesenteric border, or the gastro-omental flap (not previously discussed in this chapter). In these cases the main reason that we choose a free-tissue option is excessive bulk of the patient's rotational flaps. Large, bulky myocutaneous flaps tend to form poor tubes, and this leads to postoperative dysphagia.

For defects greater than 270 degrees circumference and above the thoracic inlet, we tend to use free-tissue transfer with either a cutaneous flap or the jejunal flap. The cutaneous flaps provide a soft, supple conduit with a thickness that parallels the native pharynx and esophagus.[93] There are several differences that should be noted between the radial forearm (Fig. 47–27) and lateral thigh flap. The radial forearm provides less tissue than the lateral thigh. A flap width of 9 cm tubed provides an adequate neopharynx to prevent dysphagia; this dimension can be obtained from the radial forearm site without difficulty but is easily obtained from the lateral thigh region. The length of the flap harvested can also be much greater from the lateral thigh than from the radial forearm. This allows the reconstruction of defects that span from the nasopharynx to the thoracic inlet (greater than 15 cm) with the lateral thigh flap. The radial forearm is always thin and supple. The lateral thigh thickness is dependent on the patient's body habitus and can be quite thick. The thicker the flap the more difficult it is to tube and the higher the chance of postoperative dysphagia. The radial forearm is easier to harvest and has a longer pedicle. Finally, the radial forearm flap has been shown in long-term studies to be effective with vocal rehabilitation.[94] For a reconstructive distance greater than 10 cm or in patients with thick cutaneous flaps, we prefer the jejunal free flap. In defects greater than 10 cm, the dry epithelial lining of a tubed cutaneous flap can promote stasis and dysphagia. The jejunal flap with its mucosal lining matches these longer defects above the thoracic inlet well. The disadvantages of the jejunal flap for more routine use are the morbidity of its harvest, the dysphagia caused by mucosal folds and incoordinated muscular contraction, and the "wet" voice with tracheoesophageal speech.[95]

For defects greater than 270 degrees that extend below the thoracic inlet, we use the gastric pull-up. Unfortunately, this reconstructive option carries a 5% mortality and a 32% morbidity.[96]

Skull Base

Skull base defects can be divided into anterior and posterior reconstructions. Anterior reconstructions involve the midface, sinus contents, and orbital contents; posterior skull base defects involve the ear and temporal bone.

The central principle in anterior skull base reconstructions is the separation of the dura and brain from the contamination of the sinuses and oral cavity or pharynx.[97] Secondary considerations include the obliteration of dead space, restoration of bone and soft tissue, and external cosmesis.[98] Multiple flaps can be used for this region based on the specific requirements of the reconstruction. For anterior defects that involve the orbit or the sinuses and require limited bulk, we find the superior temporoparietal fascial flap and radial forearm fascial flap to be particularly useful.[99] As the need for bulk increases, we tend to use musculocutaneous flaps. Both the rectus and the latissimus are excellent choices for these defects. They provide large skin paddles that can be divided to resurface different

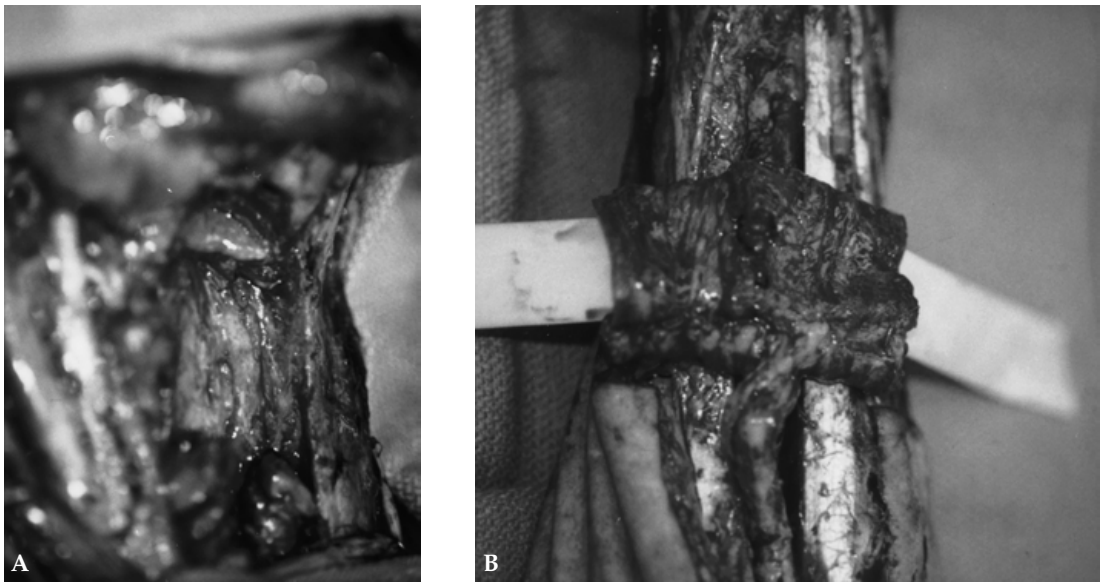

Figure 47–27 **(A)** A total laryngopharyngectomy defect with residual tongue base visible superiorly. **(B)** A radial forearm flap tubed with a Penrose drain through the lumen, still with the pedicle intact at the donor site. This technique decreases operative time and is performed simultaneously with the tumor resection.

areas, long vascular pedicles to reach the neck vessels for anastomosis, and sufficient bulk to obliterate dead spaces and enhance cosmesis. The key differences between the rectus and latissimus flaps are the harvest position and the component of the flap providing bulk. The rectus muscle is harvested in the supine position with a two-team approach; the flap bulk is derived from the vascular fat over the muscle and therefore does not atrophy with denervation.[97] In contrast, the latissimus is harvested in the lateral decubitus position, making a two-team approach difficult; the bulk of the flap is from the muscle and tends to atrophy over time with denervation. These factors have led to the rectus myocutaneous flap being the workhorse flap for anterior skull base reconstruction.[100] For reconstructions where bone is necessary, the scapula free-flap system is the preferred option. The bone is thin, and multiple bone flaps can be transferred on a single pedicle. In addition, the surgeon has a myriad of skin and muscle paddle options available to complete the reconstruction.

Posterior skull base defects also require separation of the dura and contamination of the external or middle ear spaces. Typically, the versatility of the superficial temporoparietal fascial flap and the latissimus flap can repair the majority of these defects. Both flaps are available with the patient in the lateral decubitus position, which is convenient for the resection; and both flaps can be used either as pedicled or free. The STPFF is used to seal cavities, whereas the latissimus is used for skin, bulk, and form. If these flaps are not available, then we choose a flap as described previously for anterior defects.

Mandibular Reconstruction

Reconstruction of the mandible has changed dramatically with the introduction of free-tissue transfer. The success of the reconstruction (greater than 95%) and the ability to restore function with osseointegrated implants has revolutionized this reconstructive technique.[101] We choose between the fibula, scapula, and iliac crest free flaps for these repairs.

We use the same technique for all three bone flaps when reconstructing mandibular defects. A plate is fashioned to span the defect with the patient in occlusion. This can be accomplished with mandibular-maxillary fixation or an external fixator after the resection or prior to the resection using the native mandible as a template. We use a single 2.4-mm mandibular reconstructive plate and prefer the locking-screw systems. The bone is then contoured to and secured to the internal aspect of the template using osteotomies to create tight bone–plate interfaces. The vascular anastomoses are completed, osseointegrated implants are placed if appropriate, and the soft tissue is positioned and sutured (Fig. 47–28).

The fibula free flap represents our workhorse flap for oromandibular reconstruction. It provides a long, well-vascularized bone segment and a potentially sensate skin paddle. The bone can be readily contoured with its central and periosteal blood supply, and the skin paddle can be rotated to replace either the oral or the cutaneous surface (Fig. 47–29). Finally, although the mandibular height may not match, the bone stock is excellent and easily accepts osseointegrated implants. It is most useful in cases of mandibular loss involving significant skin or mucosal loss. Although extra skin or muscle can be harvested with the flap in those cases of through-and-through defects of the oral cavity, it is not our primary choice in those cases as wound tension with breakdown is not uncommon. It can reconstruct up to a near-total mandibulectomy defect because of the length of bone available with the flap. In cases of previous trauma, previous surgery, or an ischemia to the lower limb, we typically use one of the other flaps.

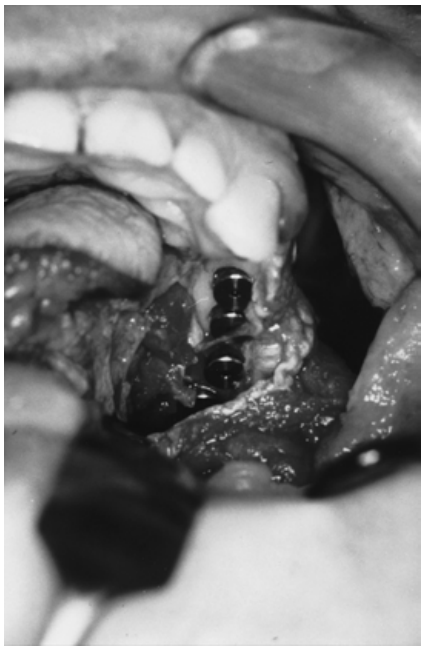

Figure 47–28 Osseointegrated implants visible in a fibula flap, used for reconstruction after near-total maxillectomy.

The scapula flap is used for through-and-through cheek or mandible defects that extend above the oral commissure and for defects that require a megaflap.[102] The mobility of the muscle and skin paddles in relation to the bone paddle and the ability to transfer multiple skin, muscle, and bone paddles on a single pedicle allows this flap to be used for most defects (Fig. 47–30). The disadvantages include the patient position (lateral decubitus) and the thin bone that is available.

The iliac crest–internal oblique is most useful for through-and-through defects below the oral commissure and for cases involving massive tissue loss secondary to trauma. The limited motion of the skin paddle relative to the bone makes the skin paddle ideal for reconstructing the cutaneous surface of the neck, chin, and jowl. The internal oblique musculature can then be used with or without a skin graft to line the floor of the mouth. The iliac crest has excellent thickness and height, making placement of osseointegrated implants easy, and symmetry with the native mandible is good (Fig. 47–31). A two-team approach is relatively easily accomplished. The disadvantages include the risk of postoperative hernia, contour irregularity, gait disturbance, and pain at the donor site. Finally, the bulk of this flap can be prohibitive for small composite defects of the oral cavity and mandible.

CONCLUSION

We witnessed a revolution in the 1990s as free-tissue transfer was proven to provide safe and effective reconstructions of head and neck defects. The ability to reconstruct nearly all defects has released the head and neck surgeon to aggressively resect tumors with confidence that the reconstructive surgeon can restore form and function. Free-tissue transfer has also allowed surgeons to attempt the reconstruction of severe traumatic defects even when tissue and bone have been destroyed. The creativity and skill of the reconstructive surgeon continue to grow as variations and uses of different flaps evolve in our literature. The reader is encouraged to continue to follow the remarkable changes that free-tissue transfer will bring to our field but is also challenged to analyze each defect independently to determine if free-tissue transfer is needed and, if so which flap provides the best match.

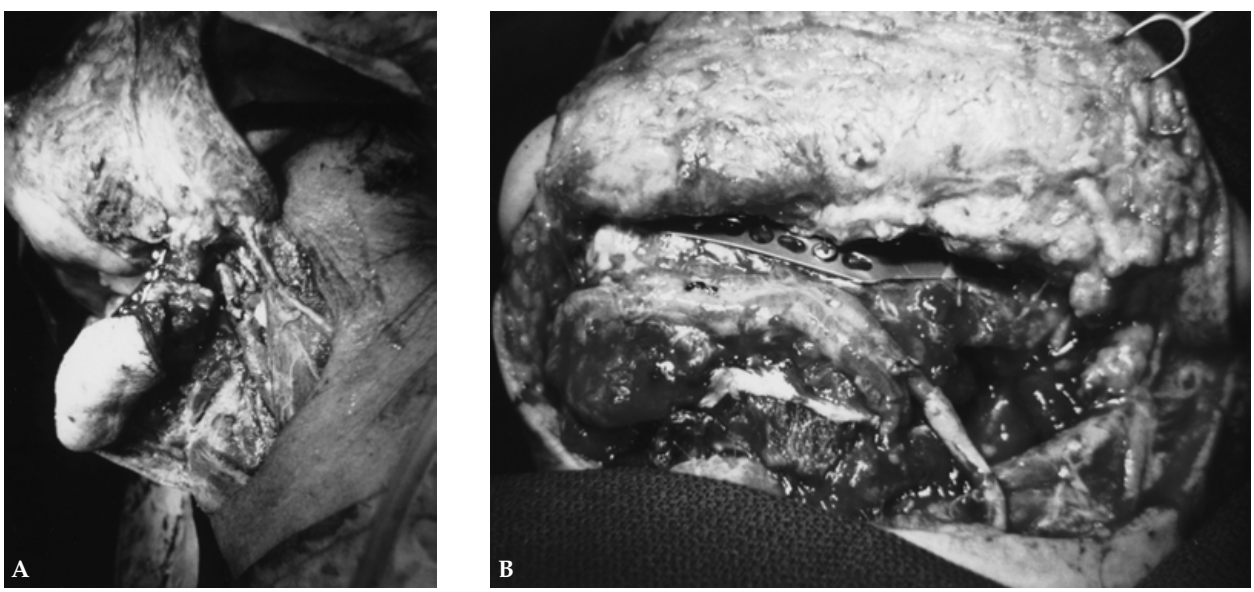

Figure 47–29 **(A)** A fibula osteocutaneous flap in place, viewed from the posterior neck. Note the skin paddle, which can be rotated internally for mucosal reconstruction or left externally for skin reconstruction. **(B)** A fibula flap in place, attached to the mandibular reconstruction plate.

Figure 47–30 **(A)** A view of the right neck after composite resection of the skin, mandible, and mucosa for a right oromandibular tumor. Note the mandibular condyle present superiorly. **(B)** The same view with a mandibular reconstruction plate placed prior to inset of the scapula osteocutaneous flap. **(C)** The final result immediately postoperatively. Note that one skin paddle was used for intraoral reconstruction.

Figure 47–31 The iliac crest–internal oblique osteocutaneous flap used for reconstruction of an angle-to-angle oromandibular defect. The bone is plated to a mandibular reconstruction plate, the skin paddle is used for a submental skin defect, and the muscle is rotated intraorally to line the floor of the mouth (at suture).

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Chapter 48

Mandible Reconstruction and Osseointegrated Implants

Eric M. Genden, Daniel Buchbinder, and Mark L. Urken

Since Crile introduced the concept of en bloc resection to head and neck surgery almost a century ago,[1] cure rates for head and neck cancer have improved significantly. However, as a result of this approach, extensive postablative defects were not uncommon. In the early nineteenth century, these defects were either closed primarily or left to heal by secondary intention, often resulting in debilitating oral dysfunction. Contraction of the surrounding soft tissues following composite resection resulted in mandibular drift, malocclusion, and often a compromise in speech, mastication, and swallowing. Gradually it became evident that the morbidity associated with a mandibulectomy defect varied depending on the location of the defect. Anterior defects of the mandible resulted in a structural disruption leading to collapse of the airway and a profound disturbance in oral function and facial appearance. In contrast, extensive lateral defects led to shifting of the mandible, resulting in pain and malocclusion. In spite of these repercussions, the clear curative advantage of wide-field ablation was evident. The profound cosmetic and functional disturbances associated with composite ablation provided the impetus for numerous attempts to ameliorate the impact of the segmental mandibulectomy defect through a variety of reconstructive methods.

The primary purpose of mandibular reconstruction is to restore the patient's oromandibular function to the predisease state. Aside from anchoring dentition and supporting mastication, the mandible also plays a crucial role in supporting the tongue and larynx, thus providing for a patent airway. Alloplastic implants, autogenous nonvascularized bone grafts, reconstruction plates, and free-tissue transfer all have a role in contemporary mandibular reconstruction; however, each case must be evaluated critically, taking into consideration not only the size and position of the defect but the pathology of the disease process and the comorbid status of the patient. This chapter reviews the options for mandibular reconstruction with an emphasis on free-tissue transfer, followed by a discussion regarding special considerations in contemporary mandibular reconstruction.

OPTIONS FOR RECONSTRUCTION OF THE MANDIBLE

Alloplasts

Alloplasts can be grouped into spacers, gap-bridging appliances, and reconstruction plates, all of which have been used to reconstruct the mandibulectomy defect. Temporary spacers, such as Kirschner wires and Steinmann pins, prevent collapse of the overlying tissues, which would otherwise occur. They are inserted into the intramedullary space of both the proximal and distal segments of bone. Retention bolts and contouring techniques have been employed to increase the stability of spacers, but the results have been disappointing. This method of reconstruction has largely been abandoned because of lack of stability, external extrusion, and an unacceptably high rate of infection.

Alternatively, gap-bridging devices, such as mesh cribs, can be used to bridge continuity defects in the mandible (Fig. 48–1). A metallic or polyurethane tray is tailored and contoured in situ to reconstruct the exact dimensions of the defect. The tray is fixed in place using wire or screws, and particulate bone grafts can then be placed in the tray and wrapped in vascularized tissue (pedicled myocutaneous flap). The trays are fenestrated, allowing for revascularization; however, salivary contamination can inhibit integration and lead to resorption of the graft.

Currently, reconstruction plates are the most commonly used form of alloplastic materials. Either alone or in combination

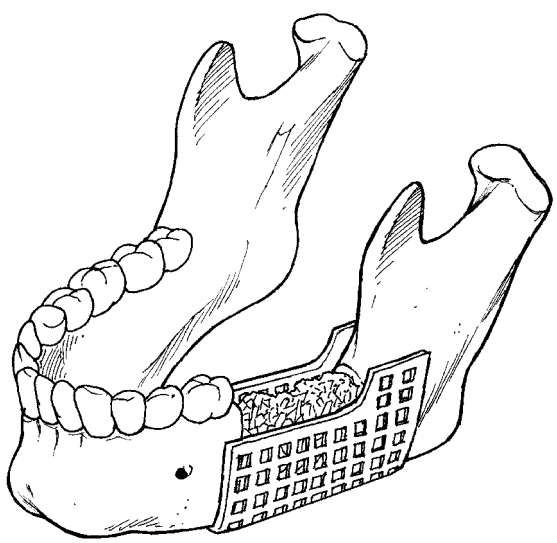

Figure 48–1 Mesh tray for reconstruction of a lateral mandibular defect. The titanium mesh crib is filled with particulate bone graft.

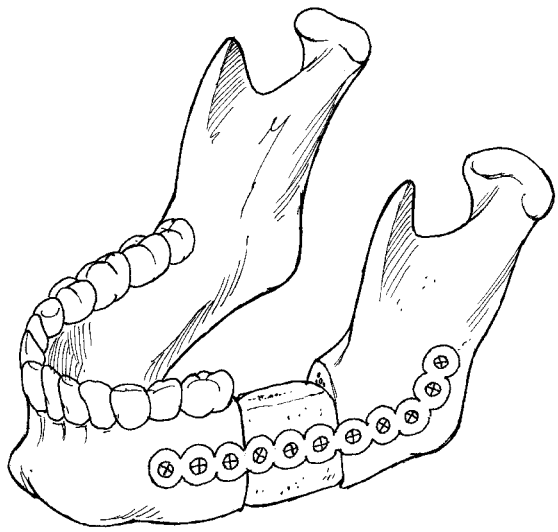

Figure 48–2 Reconstruction plate and a nonvascularized bone graft for reconstruction of a lateral mandibular defect.

with a bone graft, the titanium reconstruction plates and screws offer a reliable method of short-term fixation (Fig. 48–2). These plates can be conformed to recreate a variety of mandibular defects and provide a rapid method of reconstruction; however, problems such as extrusion and plate fracture occur when these plates are placed in an irradiated field or when they are left in place for a prolonged period. This is particularly problematical in a functional mandible where the plate is subject to the forces of mastication. Although enveloping the reconstruction plate in vascularized muscle may delay plate exposure, extrusion rates remain as high as 45%.[2]

Finally, the insertion of osseointegrated dental implants is not possible with metal plate reconstruction; therefore, this type of reconstruction will not support dental rehabilitation, which is necessary for optimal oral rehabilitation.[3] As a group, alloplasts serve as a simple and temporary tool for the rapid bridging of small to medium-size lateral mandibular defects. However, larger and more complex defects of the anterior mandible require a more definitive method of reconstruction.[4]

Bone Grafts

Throughout the reconstructive era, bone grafting has been the most reliable method to achieve long-term mandibular reconstruction. Bone grafts can be classified as vascularized or nonvascularized. This section will focus on nonvascularized bone grafts, which can be categorized as autogenous, homologous, and xenogenic. Currently, autogenous bone grafts are most commonly used. The host–graft immunologic response characteristic of homologous and xenogenic grafts inhibits their osteoconductive properties and, as a result, has limited their application in contemporary mandibular reconstruction.

Autogenous Bone Grafts

Autogenous bone is recognized as the most osteoconductive material and the least likely to extrude. As a result, it has been considered the gold standard of treatment for limited mandibular defects. Autografts are harvested from one of several donor sites (Table 48–1). Three forms of autogenous bone grafts can be harvested: cancellous, cortical, and corticocancellous. The location of the defect commonly dictates the type of graft required for the reconstruction.

TABLE 48–1 Donor Sites: Autogenous Bone

Calvarium
Rib
Ilium
Tibia
Fibula
Scapula
Humerus
Radius
Metatrsus

Cancellous bone grafts consist of both bone marrow and medullary bone matrix. They contain the highest concentration of viable cells and, as a result, have the highest potential for osteoconductivity. The large surface area associated with the cancellous matrix permits rapid revascularization, leading to a better chance of graft survival. However, because these grafts lack a cortical component, they have no source of structural rigidity and therefore must rely on a concomitantly placed scaffold, such as a mesh crib.

In contrast, cortical grafts are composed of lamellar bone, which is largely composed of osteocytes. The compact nature of this graft does not facilitate revascularization; hence, osteocytes rarely tolerate transplantation.

Corticocancellous grafts are composed of a cortical segment combined with a cancellous portion (Fig. 48–3). These grafts possess the ideal composition of structurally sound cortical bone and viable osteoblastic cancellous bone. However,

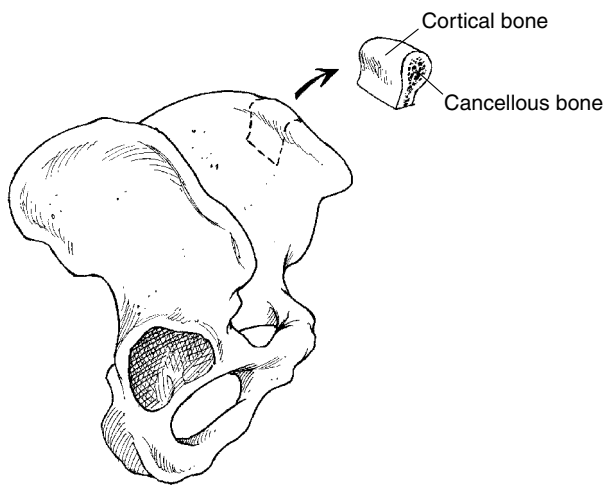

Figure 48–3 Nonvascularized iliac bone graft. The corticocancellous block is composed of an external cortical graft and an internal cancellous graft.

the cortical segment of bone can inhibit rapid revascularization, essential to graft integration, and as a result lead to decreased graft survival.

Each of the three forms of autogenous bone grafts have advantages and disadvantages. Cortical bone grafts offer the dense structural bone necessary to reconstruct load-bearing areas; however, they do not permit revascularization and hence tend to undergo resorption. Conversely, cancellous bone grafts offer porous bone with a greater surface area, ideal for revascularization and hence new bone formation, but these grafts offer no structural component. In what appears to be an ideal balance, the autogenous corticocancellous bone graft may inhibit revascularization and undergo resorption, particularly in a previously irradiated field or a field exposed to salivary contamination. Although each of these grafts has a place in facial skeletal reconstruction, none is ideal for mandibular reconstruction.

Homologous Bone Grafts

Homologous bone grafts are harvested from individuals of the same species. Because of the major histocompatibility complex mismatch, these grafts are allogeneic. Lyophilization, irradiation, and cold pretreatment are methods used to reduce the antigenicity of the grafts; however, unlike autogenous bone, these grafts do not possess viable osteoblasts. It is theorized that these grafts harbor osteoconductive elements that induce the host's pluripotential cells to differentiate into osteoprogenitor cells. Homologous bone grafts are usually placed in a bioresorbable crib when autologous bone is unavailable.

Xenogenic Bone Grafts

Xenogenic bovine grafts were popular in the 1950s. However, they are no longer used because of host–graft antigenicity.

BONE GRAFT INCORPORATION: THE TWO PHASE THEORY

Graft incorporation occurs in two phases.[5] Phase I occurs during the first 4 weeks as new osteoid is formed by osteoblastic cells in transplanted bone. This phase determines the ultimate volume of bone because new-bone formation does not occur in the second phase. In the second phase, osteogenesis occurs as a result of the transformation of pluripotential stem cells into osteoblastic and osteoclastic cells—a process mediated by bone morphogenic protein. Phase II peaks at 6 weeks and is complete by 6 months. Failure to transfer living bone cells within the graft results in a nonvital sequestrum that will eventually be resorbed. As discussed earlier, the combination of particulate cortical bone and cancellous marrow offers the best long-term results because it offers the most reliable osteogenic potential and maintains the highest concentration of viable endosteal osteoblasts as well as mesenchymal cells to support both phase I and phase II osteogenesis. Unfortunately, the particulate nature of this bone graft is such that it lacks the structural integrity to support the stresses of mastication and must be placed in an alloplastic or allogeneic crib. This form of reconstruction has inherent shortcomings and requires an extended period before the newly formed bone is fully integrated and capable of withstanding the forces of mastication.

BONE GRAFT INCORPORATION: THE RECIPIENT BED

The success of a free bone graft is dependent on the number of viable osteoblastic cells in the transplanted bone and the vascularity of the recipient bed. Osteoblastic cells provide mediators necessary for new-bone formation and the vascular supply within the recipient bed provides the nutrients essential to the survival of the osteoblasts. Radiotherapy has a negative impact on bone graft survival by causing a hypocellular, hypovascular reaction in the recipient bed.[6,7] In this circumstance, hyperbaric oxygen can be used to improve the quality of the recipient tissue bed by improving local oxygen tension and increasing neovascularity, which can aid in the incorporation of nonvascularized bone graft.[8,9] In the absence of a well-vascularized tissue bed, the nonvascularized bone will become a sequestrum and resorb.

PEDICLED OSTEOMYOCUTANEOUS FLAPS

In the early 1960s, it became apparent that bone grafts exposed to salivary contamination commonly became infected, resulting in resorption. As a result, the application of nonvascularized bone grafts in the contaminated recipient bed, was limited. These shortcomings led to a series of animal experiments in the 1970s that defined the advantages of vascularized bone grafts.[10] Investigators found that pedicled vascularized rib resisted infection and extrusion, and maintained the osteogenic capacity, integrating with the adjacent mandible. Further investigation revealed that vascularized bone healed in an irradiated bed without a significant risk of infection or extrusion.[11,12] Combined, these studies demonstrated the unique advantages of vascularized bone over nonvascularized bone and subsequently led to a cascade of reports on mandibular reconstruction using pedicled vascularized bone.

In an effort to establish a form of definitive mandibular reconstruction, a variety of pedicled flaps incorporating an attached segment of bone were attempted in the early twentieth century. Rydygier first reported the use of a vascularized clavicular segment based on the sternocleidomastoid muscle for mandibular reconstruction in 1908.[13] Soon after, Blair described the use of composite flaps containing both clavicle and rib.[14] However, it was not until the 1970s that this concept was reapplied by Snyder et al[15] and Siemssen et al.[16] Conley reported the first large series of 50 cases of bone containing pedicled flaps for mandibulofacial reconstruction.[17] In this report, he applied a host of newly described techniques, including a deltopectoral acromion flap, a trapezius-scapular flap, and a temporalis-calvarial flap. Although novel in technique, the attendant donor site morbidity and poor bone volume limited the popularity of these flaps. The widespread use of the pectoralis major myocutaneous flap in the mid 1970s led Cuono and Ariyan to use muscle to carry a segment of the fifth rib. However, reports by Biller et al.[18] and Bell and Barron[19] reflected poor results as a result of bone exposure and bone necrosis, highlighting the limited vascular supply to these bone segments as well as the lack of mobility of the soft tissue relative to the bone.

Panje and Cutting reported on the use of the lateral trapezius osteomyocutaneous flap for mandibular reconstruction in 1980.[20] This technique was originally described by Demergasso and Piazza.[21] Bone is harvested from the medial portion of the scapular spine, pedicled on the trapezius muscle. This composite flap is supplied by the transverse cervical vascular pedicle as well as contributions from the occipital artery and the paraspinous perforators. Unreliable vascular anatomy and sacrifice of this artery during a radical neck dissection prevented the routine use of this flap in head and neck reconstruction.

In summary, the limitations of pedicled osteomyocutaneous reconstruction are self-evident. However, the insights gained during these trials have led to a better understanding of the importance of vascularized bone and the role of periosteal blood supply. Consequently, these concepts have given rise to the development of bony free-tissue transfer, presently considered the gold standard for definitive reconstruction of significant composite defects of the mandibulofacial complex.

FREE-TISSUE TRANSFER

In 1974, Ostrup and Fredrickson were the first to report on experimental mandibular reconstruction using revascularized rib in the canine model.[12] Shortly thereafter, McKee[22] and Daniel[23] applied this technique clinically, reporting the first vascularized bone containing free flap for mandibular reconstruction. Revascularized rib is no longer used in this capacity; however, this pioneering work revolutionized mandibular reconstruction. For the first time, composite defects of the mandible and adjacent soft tissue could now be reliably reconstructed with vascularized bone as well as skin, obviating the need for a second soft tissue flap. Additional work in this area demonstrated that contouring osteotomies could be performed safely without jeopardizing the vascularity of the bone.[24] Baker and Sullivan later demonstrated that transferred bone healed within 8 weeks, forming a strong union with the adjacent native mandible, even in irradiated patients.[25] As the advantages of transplanted vascularized bone for mandibular reconstruction became evident and the techniques to perform this procedure were refined, a number of new donor sites were described (Table 48–2). However, this review will cover only those most commonly used in contemporary mandibular reconstruction, such as fibular, iliac crest, and scapular donor sites.

Fibula

In 1975, Taylor et al introduced revascularized fibular bone for the repair of an open fracture of the lower extremity.[26] Chen and Yan[27] subsequently examined and reported on the vascular supply to the fibula. It was not until 1989 that Hildalgo reported on the use of the fibular free flap as a method of mandibular reconstruction.[28] Soon thereafter, Hayden and O'Leary expanded the utility of the fibular free flap for oromandibular reconstruction by introducing a sensate flap innervated by the lateral sural cutaneous nerve.[29] The straightforward anatomy and the accessibility of the fibula have been responsible for the popularity of this flap in mandibular reconstruction.

TABLE 48–2 Donor Sites: Vascularized Bone Containing Free Flaps

Rib
Scapula
Fibula
Ilium
Radius
Ulna
Humerus
Metatarsus

The peroneal artery provides the primary blood supply to the overlying skin of the lateral aspect of the calf and the fibular bone by giving rise to an endosteal vascular supply via a nutrient medullary artery as well as numerous periosteal feeders. The vascular pedicle is limited in length by its bifurcation from the posterior tibial artery. The pedicle can be lengthened by the harvesting of more bone from the distal aspect of the fibula and the discarding of unneeded bone from the proximal aspect. By performing a subperiosteal dissection of the proximal bone, the blood supply to the distal flap can be maintained while pedicle length is gained proximally. Because it is a non-weight-bearing structure, up to 25 cm of dense cortical bone can be harvested with minimal donor site morbidity. The maximum length of bone harvested is predicated on preserving 6 to 7 cm of bone both proximally and distally to preserve normal function of the knee and ankle joints. The ability to harvest such a large portion of bone makes the fibula ideal for reconstruction of subtotal or total defects of the mandible.[30] Aside from supplying the fibula periosteum, the peroneal artery also gives rise to fasciocutaneous perforators located in the posterior cural septum, which supply the overlying skin.

Early reports of skin paddle necrosis were discouraging[28]; however, this was in part due to a poor understanding of the nature of the blood supply to the skin paddle, prompting numerous studies to better define this issue. Yoshimura et al[31] and others[32,33] have performed exhaustive investigations to better define the arterial anatomy as it relates to harvesting a skin paddle. The skin of the lateral aspect of the lower leg is supplied by either musculocutaneous or septocutaneous perforators that derive from the peroneal artery and vein (Fig. 48–4). Most surgeons use the approach described by Flemming et al, which favors an anterior subfascial dissection, creating a long flap that allows for variations in the location of the septocutaneous perforators.[34] Wei et al have since demonstrated the reliability of the skin paddle in reconstruction of composite defects, reporting 100% success rate in a total of 80 cases.[35]

The dense cortical bone is ideal for mandibular reconstruction as it effectively withstands the forces of mastication and easily accommodates osseointegrated implants.[36] Curvature of the neomandible can be achieved by the performance of multiple osteotomies without compromising vascularity to the distal bone. In pediatric patients or patients with unusually narrow fibula, the bone can be osteotomized and "double barreled," increasing the height of the bone stock.[37] We have found the fibula to be particularly useful in reconstruction of mandibular defects that involve the condyle. As discussed previously, a subperiosteal dissection of the proximal bone can be performed and the proximal bone may be discarded. The remaining fibula and proximal periosteal sheath can then be used to recreate a protective barrier over the cut end of the bone to prevent the risk of skull base erosion. The narrow fibula can easily be passed through a small

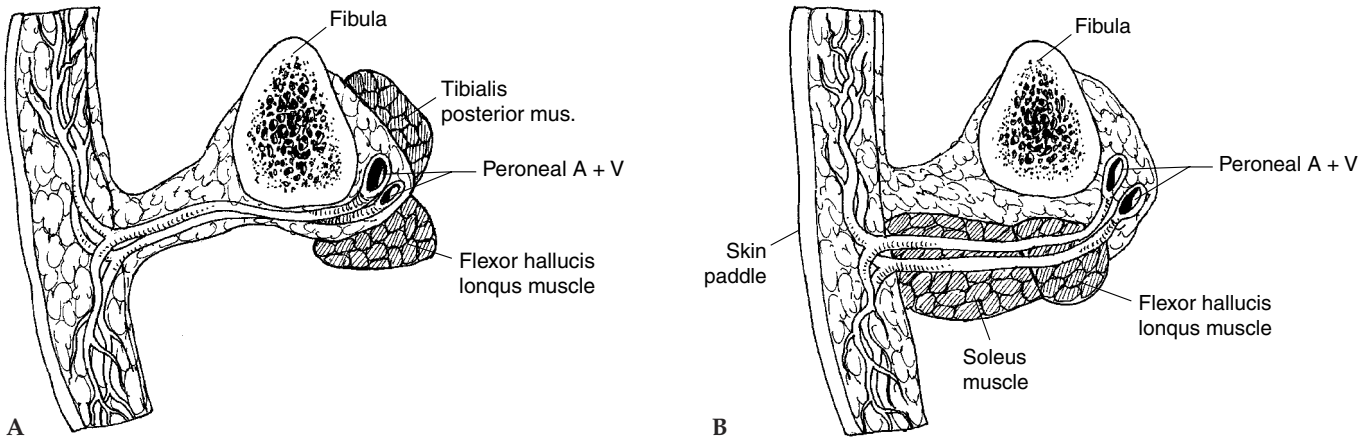

Figure 48–4 Vascular supply to the fibula skin paddle. **(A)** Septocutaneous perforators. **(B)** Musculocutaneous perforators. A cuff of soleus and flexor hallucis longus muscle is harvested to protect the perforators.

tunnel up into the condylar fossa and secured to the glenoid fossa with a nonabsorbable suture. The suture is placed through the periosteal cuff, which serves to anchor the fibula as well as protect the glenoid fossa and prevent ankylosis.

The advantages of the fibular free flap include its uniquely dense cortical bone, which affords excellent primary stability when placing osseointegrated implants. With the vascular pedicle oriented on the lingual surface, multiple osteotomies can be safely performed to contour the bone, and the skin paddle can be transposed over the buccal surface, delivering the skin intraorally. Shortcomings include the limited pedicle length and restricted mobility of the skin paddle relative to the bone, which inhibits the reconstruction of complex composite defects. Finally, because of the high prevalence of peripheral vascular disease in head and neck cancer patients and the risk of vascular anomaly, we perform preoperative angiograms on all candidates for fibular free-flap reconstruction. In 10 to 20% of patients, either the anterior or posterior tibial artery may become attenuated distally.[38] Although a communicating branch from the peroneal artery supplies the region of the diminutive vessel, if this anomaly is unrecognized, harvest of the fibula may result in ischemia of the foot. In cases where vascular compromise prohibits harvest of a fibula, we review the nature of the anticipated postablative defect and prepare for an alternative donor site.

Scapula

Although Saijo[39] was the first to recognize the potential for transferring free vascularized scapular skin, Swartz[40] popularized the scapular composite free flap for head and neck reconstruction. In contrast to the fibular free flap, the scapular free flap possesses several unique advantages, such as a long vascular pedicle with a large-vessel caliber, the potential for multiple soft tissue options, and mobility between the soft tissue and the bone flap. The independent nature of the vascular supply to the bone, skin paddle, and associated muscles provides an opportunity to reconstruct complex three-dimensional defects and the ability to combine the latissimus dorsi and/or serratus anterior muscles with an overlying skin paddle.[41] It is because of the wide range of hard and soft tissue options that this donor site is best referred to as the subscapular system of flaps.

The vascular pedicle, which is quite constant, is based on the subscapular artery. The subscapular vessels arise from the third part of the axillary artery and give rise to the circumflex scapular vessels (CSVs) and the thoracodorsal vessels (TDVs). The CSVs run through a triangular space formed by teres major, teres minor, and the long head of the triceps brachii muscles. They then divide into and terminate as a cutaneous horizontal branch and a vertical branch, allowing for the harvest of a scapular or parascapular skin paddle, respectively.[42,43] Up to 14 cm of pedicle length can be harvested when the subscapular vessels are included. When the circumflex scapular artery is harvested at its take-off from the subscapular vessels, the pedicle ranges from 7 to 10 cm with a diameter of 4 mm.[43] The diameter of the subscapular pedicle averages 6 mm, with a range of 4 to 8 mm.[42]

The unique ability to freely maneuver the skin flaps relative to the bone segment facilitates the capacity to restore complex three-dimensional defects that would otherwise require two separate flaps. The skin can be manipulated to resurface large intraoral defects and external skin defects, or it can be deepithelialized and used for soft tissue augmentation. Furthermore, the fact that the lateral scapular border can be harvested separately from the scapular tip adds versatility to this flap. The scapular tip is supplied by the angular artery, a branch of the thoracodorsal artery or the serratus artery (Fig. 48–5). The medial half of the scapular tip is characteristically a thin area of bone that is ideal for palatal and orbital reconstruction. We have found that the harvesting of bone from the scapular tip and lateral scapula together is an excellent method for reconstructing combination defects of the palate, retromolar trigone, and mandible. The scapular tip is separated and secured to the remaining palate or adjacent maxilla. The bone from the lateral scapular border is used to reconstruct the lateral mandibular defect. A bilobed scapular-parascapular skin paddle design serves to reline the palate and buccal-gingival sulcus.

In comparison with the medial aspect of the scapular bone, the lateral scapular border provides a more substantial segment of bone measuring up to 10 to 14 cm, which

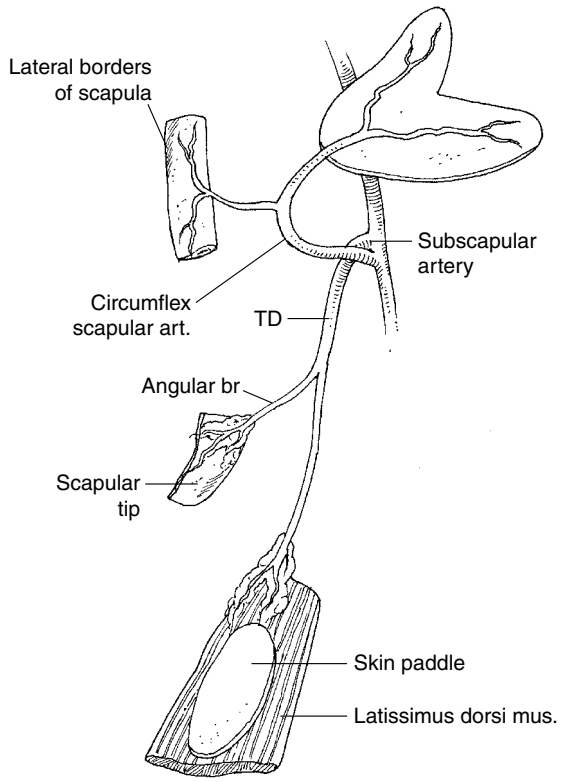

Figure 48–5 The subscapular system of flaps.

will comfortably accommodate the placement of osseointegrated implants.[36] As with the fibula, the periosteal blood supply of the scapular bone permits the performance of osteotomies for bone contouring. For particularly large orofacial defects, the latissimus dorsi can be harvested on the thoracodorsal artery, in combination with the scapular flap, and used either for intraoral lining or to protect exposed vessels in the neck.

One of the major drawbacks of the subscapular system of flaps is the intraoperative position required for harvest. Aside from precluding a two-team approach, patient positioning can be cumbersome and make an extensive surgery more tedious. As discussed earlier, the scapular bone will accommodate osseointegrated implants; however, pediatric patients may have insufficient bone stock for mandibular reconstruction. For this patient population, a donor site is advisable.

Iliac Crest

The groin and pelvis represent an area that has been the subject of much interest with regard to microvascular transfer. The four distinct vascular suppliers of the ilium—the superficial circumflex iliac artery (SCIA), deep circumflex iliac artery (DCIA), superior deep branch of the gluteal artery, and ascending branch of the lateral circumflex artery—have been responsible for a number of soft-tissue and bone-containing free flaps. In 1980, Salibian reported one of the first free flaps, the groin flap, based on the SCIA.[44] He later found that the SCIA, which provides a rich vascular supply to the skin overlying the ilium, did not reliably supply the periosteum of the ilium.[45] In 1979, Sanders and Mayou[46] determined that the DCIA and DCIV reliably supplied the bone of the ilium as well as the skin overlying the ilium. Subsequent work by Ramasastry identified the ascending branch of the DCIA as the supply to the internal oblique muscle, setting the stage for the introduction of the iliac crest osteomusculocutaneous free flap for reconstruction of the lower extremity.[47] Subsequently, Urken et al applied the iliac crest internal oblique composite flap to oromandibular reconstruction.[48]

The DCIA and the DCIV, which supply the iliac crest osteomyocutaneous flap,[49] originate from the lateral aspect of the external iliac artery and vein, cephalad to the inguinal ligament. From there, they course toward the anterior superior iliac spine where they enter a tunnel formed by the attachment of the transverse fascia and the iliac fascia to the inner table of the iliac crest. As the DCIA and DCIV course along the inner aspect of the iliac bone, they give rise to several branches, including those that supply the iliac bone, the muscular abdominal wall, and the overlying skin. These branches perforate all three layers of the abdominal wall; hence, a cuff of iliacus, transversus abdominis, internal oblique, and external oblique must be included in the harvest to preserve the deep circumflex iliac vessels and the vascular supply to both the internal oblique muscle and the overlying skin (Fig. 48–6). Through injection studies, Ramasastry et al defined a single dominant ascending branch of the DCIA in 80% of cases. However, in 20% of cases, there were several smaller branches supplying the muscle.[47] This independent axial blood supply affords mobility to the muscle relative to the bone such that it may be wrapped around the neomandible or transposed intraorally.

Over the past decade, the iliac crest has become commonly applied for reconstruction of complex composite defects that would otherwise require multiple flaps. A maximum of 14 to 16 cm of corticocancellous bone can be harvested, which is ideal for the placement of osseointegrated implants.[36] The nature of the donor bone is such that a ramus and condyle can be sculpted according to the principles described by Manchester.[50] The vast periosteal blood supply permits contouring osteotomies, making the iliac crest ideal for lateral and anterior mandibular arch reconstruction. Reconstruction of the mandible is usually achieved by harvesting from the ipsilateral hip. This configuration

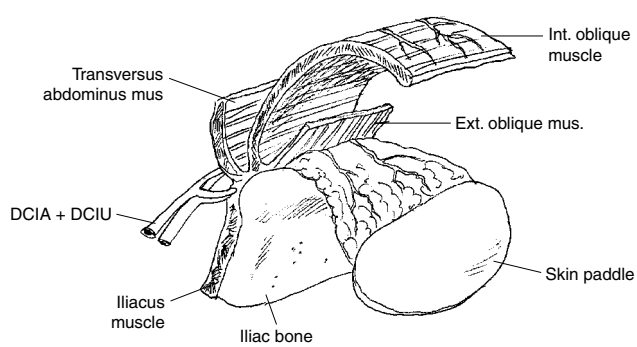

Figure 48–6 The iliac crest free flap. A tripartate flap composed of a skin paddle, the internal oblique muscle, and the iliac crest.

allows the anterior superior iliac spine to serve as the angle of the neomandible while the iliac crest forms the inferior border. The vascular pedicle remains on the lingual aspect of the neomandible so that the microvascular anastomosis is easily accessible. Urken and colleagues have demonstrated that whereas the bulky nature of the skin paddle often precludes its use for intraoral reconstruction, the thin pliable characteristics of the internal oblique muscle make it ideal for reconstituting intraoral defects.[48,51] In contrast to the scapular flap, the iliac crest skin paddle is often bulky and has poor mobility relative to the bone. Closure of the donor site must be meticulous to prevent a ventral hernia. Careful attention must be paid to the position of the femoral nerve to prevent incidental injury. We have been liberal in our use of synthetic mesh in obese patients or in patients whose closure is compromised by a thin transversus abdominis muscle, which limits the integrity of the abdominal wall.

The advantages of the iliac crest free flap include its unique tripartite design, ideal for complex three-dimensional reconstruction of composite defects of the mandible and oral cavity. In contrast to the scapula, it facilitates a two-team approach, which shortens operative time. Its most significant shortcoming is the bulky nature of the skin paddle, particularly in heavy-set patients; however, this problem is circumvented by using the internal oblique muscle for intraoral reconstruction.

RECONSTRUCTION OF THE TEMPOROMANDIBULAR JOINT

One of the most important considerations related to evaluating and reconstructing the mandible is the presence of the temporomandibular joint (TMJ). Tumors involving the tonsillar fossa or the retromolar trigone often require resection of a portion of the ascending ramus, and extensive disease may necessitate resection of both the condyle and the coronoid process. In cases where a subcondylar ostectomy is appropriate, unless the mandible is primary reconstructed, the coronoid process should not be left intact because contraction of the pterygoid and temporalis muscles will draw the remaining bone superior and medial. Over time, progressive fibrosis leads to pain—a process that may be accentuated by external-beam radiation therapy. The optimal situation arises when an oblique subcondylar ostectomy can be performed. In this situation, the condyle and the posterior border of the ascending ramus are preserved, whereas the coronoid process and its attachments to the temporalis muscle are resected. The neomandible can be secured to the residual ascending ramus, and the coronoid process and its adverse muscular attachments have been eliminated.

If the primary disease process necessitates complete ablation of the ascending ramus, there are several reconstructive options available. Alloplastic joint replacement systems are available,[52] although our experience with these systems has been disappointing. However, autogenous bone or a costochondral graft integrates quite naturally with minimal resorption. As discussed earlier, the fibula can be fashioned with a periosteal cuff, which can then be secured to the glenoid fossa with nonabsorbable suture.

PRIMARY VERSUS SECONDARY MANDIBULAR RECONSTRUCTION

There has been a great deal of debate regarding the timing of mandibular reconstruction. In the past, delayed management of the mandibular defect was considered standard for two reasons. First, prior to the implementation of free vascularized mandibular reconstruction, nonvascularized bone grafts were exposed to salivary contamination during primary reconstruction, which often resulted in an unacceptably high rate of graft infection and resorption. Second, because of the high recurrence rates associated with oral cavity carcinoma, some surgeons required a disease-free interval before embarking on a complex reconstruction.

Although there is merit to this logic, advocates of primary reconstruction contend that patients should not be forced to live with the cosmetic and functional consequences that commonly result from ablative surgery. The goal of primary oromandibular reconstruction is to restore both function and appearance in a manner that will allow the patient to assume as normal a lifestyle as possible. Furthermore, contraction and fibrosis of the operated field often complicate secondary reconstruction, increasing the risk of facial nerve paralysis and, in some cases, increasing the risk of postoperative morbidity.

DENTAL REHABILITATION

Despite advances in free-tissue transfer and the capability of restoring continuity defects as well as soft tissue lining, the ultimate goal of occlusal and masticatory function restoration had remained elusive.[53] The quality of the soft tissue transplant or native mucosa, often irradiated, did not provide for a good environment for the retention of a conventional, removable dental appliance. The use of osseointegrated fixtures, popularized by the work of Branemark et al,[54] provided the solution to this problem. Endosteal titanium fixtures, strategically placed in the bone flap and allowed to osseointegrate, could provide for anchorage and allow for load sharing of the dental prosthesis, minimizing the risk of injury to the radiated native mucosa as well as the possibility of radiation-induced osteomyelitis of the underlying bone.

Over the past decade, a number of reports have described the importance and efficacy of this type of functional masticatory restoration.[55–57] However, one of the controversies in the use of this technique relates to the timing of the fixture placement and the effect of radiation on the process of integration of the endosteal fixtures. Whereas we have long advocated for the primary placement of the fixtures at the time of the reconstructive procedure,[58] others prefer to place the implants in a secondary procedure.[59] In theory, delayed placement of the fixtures allows one to position them in a more ideal location and inclination in terms of the opposing arch. The reality is that the buccolingual positioning of the fixtures is essentially dictated by the initial contouring of the bone flap. Furthermore, primary placement affords the best surgical access for assessment of the interarch relationship. Finally, primary placement of the fixtures takes advantage of a "window of opportunity"

before the damaging effect of radiation affects the bone.[60] Implant placement in irradiated bone would require preoperative hyperbaric oxygen therapy,[61] thus adding to the cost and inconveniencing the patient.

DONOR SITE SELECTION

Donor site selection for oromandibular reconstruction is predicated on several factors, including:

1. The nature of the soft tissue defect.
2. The relationship of the composite defect to the tongue and oropharynx.
3. The nature of the bone defect.
4. Donor site availability.

The scapular, iliac, and fibular donor sites may all be used to successfully reconstruct composite defects involving the mandible; however, the nature of the soft tissue defect often dictates the donor site. As mentioned earlier, the mobility of the skin paddle relative to the bone segment plays an integral role in determining the optimal donor site. The immobile skin paddle, characteristic of the fibular free flap, often precludes its use in complex three-dimensional reconstructions. If the fibular skin paddle is used to reconstruct composite defects involving the tongue base, the restricted mobility of the skin relative to the bone flap may tether the tongue during deglutition, thus preventing optimal functional rehabilitation. However, this skin paddle is best suited for anterior and lateral floor-of-mouth defects as well as external defects of the neck.

In contrast, the iliac and scapular free flaps can be manipulated to resurface complex defects of the oral cavity, oropharynx, and the neck. The scapular donor site possesses the added advantage of allowing for harvest of the latissimus dorsi or serratus anterior muscle, which can be used to reline the oral cavity or insulate the great vessels. The iliac tripartite design allows for the internal oblique muscle to be used for relining the oral cavity, whereas the skin paddle can be employed to reconstruct the lateral tongue or external neck.

The nature of the bone stock associated with each donor site seldom dictates donor site selection. An exception is during the reconstruction of a total or near-total mandibular defect, which requires a long segment of bone that will tolerate multiple contouring osteotomies as well as sustain the forces of mastication. The fibula is the only donor site that will accommodate a total mandibular reconstruction because it offers the appropriate length as well as the ability to safely reconstruct both condyles. Another consideration is that total mandibular reconstruction and condylar replacement can place the facial nerve at risk. The characteristically narrow dimensions of the fibular bone are ideal for this purpose. The fibular bone can be drawn cephalad into the condylar fossa through a small tunnel and secured into the glenoid fossa with little risk of neural injury.

Finally, contraindications to using a donor site are rare, but they do occur. We recommend preoperative lower extremity angiography for all patients who are candidates for a fibular free flap. The role of preoperative angiography has been assessed in several recent studies, and angiographic findings preventing the use of the fibula have ranged from 10% to 25%.[62–64] Congenital vascular anomalies, vascular disease, and prior lower extremity injury are the most common contraindications to the use of this flap. However, the iliac crest can be evaluated by physical examination. Prior surgery to the hip, groin, or lower abdomen makes up the majority of contraindications to use of this donor site. Similarly, use of the scapular donor site has few contraindications; prior injury or surgery to this area should be evaluated.

CONCLUSION

Although there are a host of options for mandibular reconstruction, vascularized bone flaps are unique in that they permit reconstruction of the oromandibular complex even though the recipient bed is often compromised by salivary contamination and prior irradiation. In contrast to nonvascularized bone grafts, vascularized bone grafts remain capable of healing to the adjacent native mandible and eventually withstand the loading forces associated with mastication.[65,66] The fibular, iliac, and scapular donor sites all provide bone stock sufficient for dental implants in the majority of patients,[36] which has been demonstrated as an essential factor for full oral rehabilitation.[3] Furthermore, the soft tissue components harvested with each of these three composite flap donor sites provide a source of tissue for either intraoral lining or extraoral coverage.[67] Inherent differences with regard to bone stock, soft tissue quality, potential for sensory reinnervation, and pedicle geometry dictate which of the available donor sites will provide the optimal source for reconstruction.

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Chapter 49

Major Nasal Reconstruction

Shan Baker

Over the last decade, reconstruction of the nose has reached a high level of sophistication, with enhancement of aesthetic results.[1–3] This has been achieved by emphasizing the necessity of replacing surgically ablated tissue with like tissue. Skin is replaced with skin that matches it in color and texture as closely as possible. Cartilage and bone are replaced, and mucosa is used to replace any loss of the nasal lining. The concept of nasal aesthetic units has emerged with an emphasis on reconstructing an entire unit, if the majority of the unit is missing. Another important concept that has led to enhancement in the results of restorative surgery has been the emphasis on the placement of incisions for local flaps along borders of aesthetic regions or units to maximize camouflage of scars. Whenever possible, local flaps are designed so that they are not transferred across the borders of aesthetic regions, particularly if the border has a concave topography. An example of such a border is the alar facial sulcus, which represents a concave border between three aesthetic facial regions: the nose, the cheek, and the upper lip.[4,5]

FACIAL AESTHETIC REGIONS

The face can be divided into topographic regions, each with its individual intrinsic characteristics of skin color, texture, contour, and hair growth.[5] Each has an individual shape created by the underlying facial skeleton. The nose is one of the aesthetic regions of the face and can be divided into several aesthetic units (Fig. 49–1). Each unit may be proportionally over- or underdeveloped relative to other noses, but there is a consistent general configuration from nose to nose. There are nine aesthetic units of the nose identified by distinctive convex or concave surfaces, including the lobule, dorsum, paired sidewalls, paired ala, paired soft tissue facets, and the columella. The shape of the lobule is determined, in general, by the size and contour of the alar cartilages, and specifically by the domal portion of the nasal cartilages. The lobule is covered by relatively thick sebaceous skin. Each dome causes a point of reflected light. Above the lobule is a supratip depression which separates the lobule from the dorsum. The skin of the dorsum tends to be less thick and sebaceous than that of the lobule, becoming progressively thinner as it ascends to the rhinion and thicker again as it approaches the glabella. The nasal bones together with the upper lateral cartilages and cartilaginous septum provide skeletal support for the dorsum. The lateral borders of the dorsum are defined by the lateral shoulders of the upper lateral cartilages and the junction of the nasal bones with the frontal processes of the maxillae. These structures separate the dorsum from the sidewalls and create a line of reflected light and shadows separating the lateral walls from the dorsum. The nasal sidewalls are most often a combination of convex and concave elements extending laterally from the dorsum to the junction of the nose and cheek.

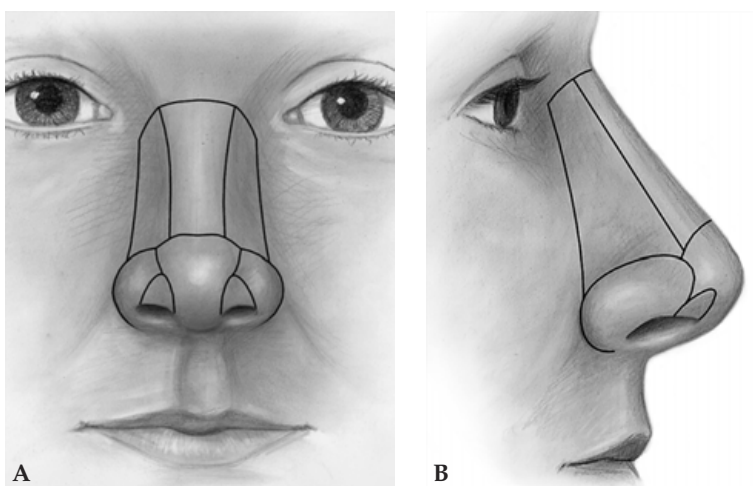

Figure 49–1 **(A, B)** Topographic aesthetic nasal units.

Structurally, the sidewalls are supported by the lateral extensions of the nasal bones and upper lateral cartilages and the medial extension of the frontal processes of the maxillae. The skin of the sidewalls is thin and less sebaceous than that of the dorsum and lobule, and it is separated from the ala by the alar nasal crease, which is the deepest contour line of the nose. This crease is continuous laterally with the alar facial sulcus, and together they circle the alae, delineating them from the lobule, sidewalls, and cheeks. The alar unit itself is a smooth bulge reflecting a single spot of light and is covered with thick sebaceous skin similar in texture and porosity to that of the lobule. The structural support of the ala is provided by thick fibrofatty tissue that does not contain cartilage.

The soft tissue facets contribute to a portion of the nostril margin and span the notch between intermediate and lateral crura of each lower lateral cartilage. They are covered by thin, nonsebaceous skin and have only a small amount of fibrous connective tissue for structural support. They may be separated as distinct units by the shadow of the lobule. The columella, like the lobule and dorsum, is a nonpaired aesthetic unit extending from the caudal aspect of the lobule to the upper lip. It is covered by the thinnest of nasal skin and is supported structurally by the medial crura. The lining for each of the nine aesthetic units of the nose is also distinctive. Thin non-hair-bearing skin lines the lobule, whereas the soft triangles and ala are lined by thicker skin, the caudal aspect of which is hair bearing. The columella is backed by the membranous septum, which is skin-lined. At the piriform aperture, the lining transitions to mucosa that lines the dorsum and sidewall units.

Menick has stressed that the goal of restorative nasal surgery is not simply to fill a defect.[2] Depending on the extent of the defect, wounds should be altered in size, configuration, and depth to allow reconstruction of an entire unit. If the majority of the surface area of a unit is lost, resurfacing of the entire unit is usually preferable. This is accomplished by discarding the remaining skin of the unit and designing the surface flap so that it will compensate for the discarded skin. This arrangement places the scars in the junction between units where they will lie in depressions or along shadow lines, maximizing scar camouflage. By placing the scars in these junctions, they will blend with the normal contour lines of the nose and will not distract the viewing eye. Resurfacing the entire unit also takes advantage of the mild trap-door scar contraction phenomenon, which causes the entire unit to bulge slightly, simulating the normal convexity of the lobule, dorsum, and ala.[2] More important than resurfacing of an entire nasal unit, however, is the creation of the proper contour of the flaps so that it exactly duplicates the normal topography of the unit.

The surface area and pattern of each unit should be replaced so as to achieve exact duplication whenever possible. Because a fresh wound is always enlarged by retraction of the margins, the contralateral units should be used for the design of covering flaps. If the contralateral counterpart is missing or a unit does not have a matching pair, a template recreating the ideal unit size for that specific patient is used. Because the nose is a three-dimensional structure, each unit must duplicate the normal contour. This is accomplished by concomitantly integrating structural support in each step of the repair. Reconstructed skeletal elements must be attached to a stable foundation, such as remaining nasal cartilages or the bone of the maxilla, to prevent collapse or distortion during the healing process.[2] The reconstructed skeletal structures must span the entire defect. This is accomplished prior to wound healing to prevent distortion from scar contraction during the healing process.

Application of the aesthetic unit principles provides a logical cognitive approach to nasal reconstruction. Missing tissue must be replaced with like tissue at a quantity and quality that exactly replicates the pattern, surface area, and contour of the absent unit.

LINING FLAPS

Burget and Menick have studied the vascularity of the nasal septal mucosa and discovered that the entire ipsilateral septal mucoperichondrium can be transferred with a narrow pedicle containing the septal branch of the superior labial artery.[1] Likewise, the entire contralateral mucoperichondrium can be turned laterally as a dorsally based hinge flap to line the sidewall of the nose based on the anterior and posterior ethmoid arteries (Fig. 49–2).[1] Burget and Menick have also shown that if both right and left septal branches are included in the pedicle, the entire septum can be rotated out of the nasal passage as a composite flap containing a sandwich of cartilage between the two mucoperichondrial leaves (Fig. 49–3).[1] Such flaps, whether composite or simple mucoperichondrial hinge flaps, can be designed to extend from the floor of the nose to within 1 cm of the junction of the upper lateral cartilage and cartilaginous septum. The flaps may extend posteriorly well beyond the bony–cartilaginous junction of the septum, producing a hinged mucosal flap as wide as 3 cm and as long as 5 cm.[1] Burget and Menick advocate a backcut of the mucoperichondrium in the area of the anterior septal angle to facilitate flap transfer.[3] I prefer leaving the flap hinged on the entire length of caudal septum to maintain a wider pedicle and enhance the vascularity of the flap (Fig. 49–3B). These authors have also described a bipedicle flap of vestibular skin and mucosa based medially on the septum and laterally on the floor of the nasal vestibule. Such a flap is elevated from the undersurface of the lateral crus and mobilized inferiorly to reline alar defects (Fig. 49–4). All of these lining flaps have a reliable vascularity and are thin and supple, providing natural physiologic material for the interior of the nasal passage. They do not distort the external shape of the nose, nor do they compromise the airway. Importantly, these well-vascularized lining flaps allow the primary placement of cartilage grafts for framework, which when properly fashioned prevents nasal distortion resulting from scar contraction.

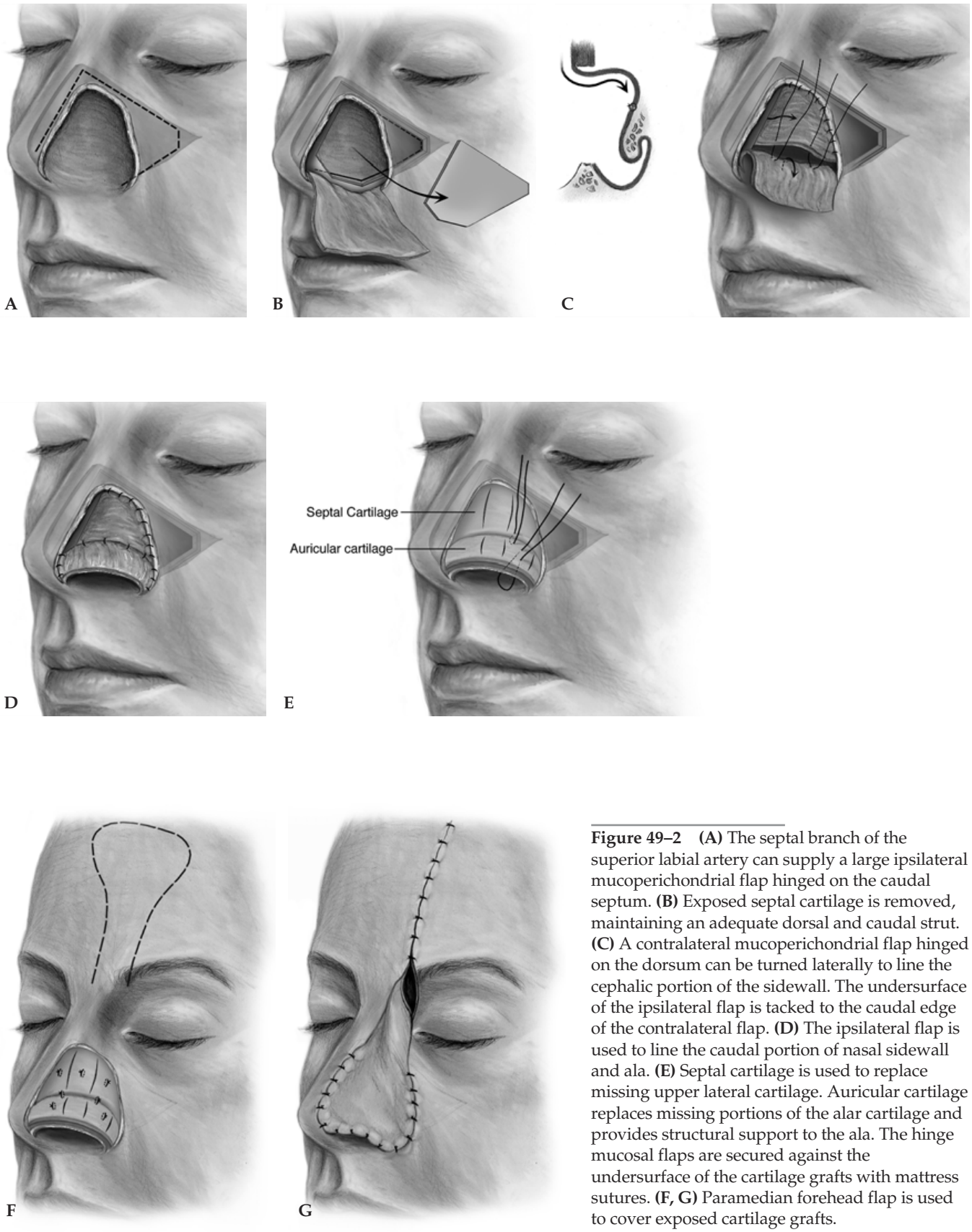

Figure 49–2 **(A)** The septal branch of the superior labial artery can supply a large ipsilateral mucoperichondrial flap hinged on the caudal septum. **(B)** Exposed septal cartilage is removed, maintaining an adequate dorsal and caudal strut. **(C)** A contralateral mucoperichondrial flap hinged on the dorsum can be turned laterally to line the cephalic portion of the sidewall. The undersurface of the ipsilateral flap is tacked to the caudal edge of the contralateral flap. **(D)** The ipsilateral flap is used to line the caudal portion of nasal sidewall and ala. **(E)** Septal cartilage is used to replace missing upper lateral cartilage. Auricular cartilage replaces missing portions of the alar cartilage and provides structural support to the ala. The hinge mucosal flaps are secured against the undersurface of the cartilage grafts with mattress sutures. **(F, G)** Paramedian forehead flap is used to cover exposed cartilage grafts.

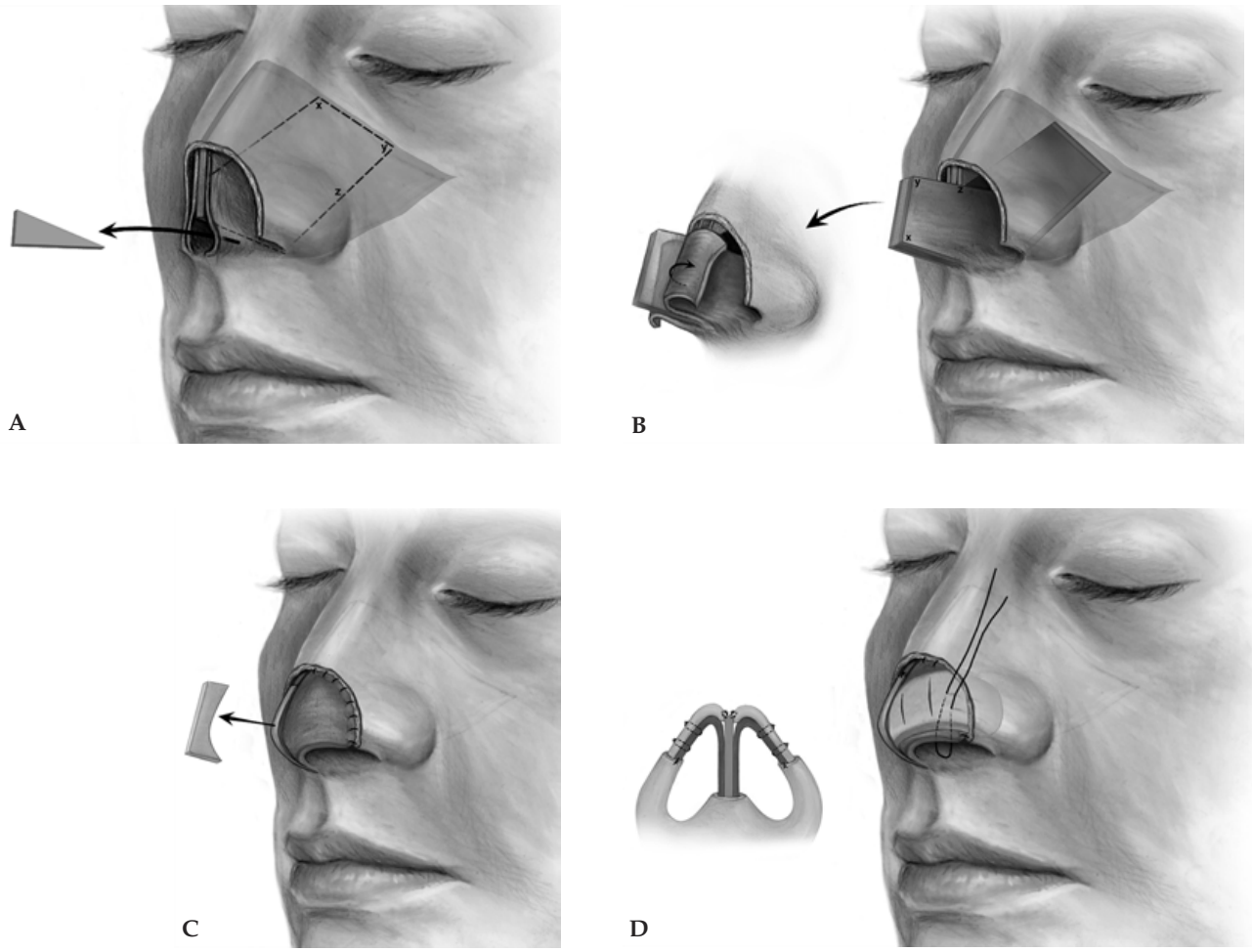

Figure 49–3 **(A)** Composite flap based on the dual blood supply of the septal branches of the superior labial artery. A wedge of cartilage is removed to allow the flap to be turned outward. **(B)** Bilateral hinged mucoperichondrial flaps are turned downward to provide lining for the reconstructed nasal vestibule. **(C)** Excess septal cartilage is trimmed, and flaps are sutured to the lateral and superior borders of the vestibule. **(D)** Auricular cartilage grafts are used to replace missing portions of alar cartilages. Hinged mucoperichondrial flaps are secured against the undersurface of the cartilage grafts with mattress sutures.

FRAMEWORK

The dorsum of the nose is supported by the nasal bones and cartilaginous septum: the sidewalls by the frontal processes of the maxillae and upper lateral cartilages, the lobule by the intermediate and lateral crura of the alar cartilages, the columella by the medial crura, and the ala and soft tissue facet by stiff fibrofatty connective tissue. If missing, the nasal framework of each unit must be completely replaced. Cartilage grafts can be used to replace the missing framework of the dorsum, lobule, and sidewalls. In addition, a strip of cartilage must be placed along the reconstructed nostril margin whenever the connective tissue framework is missing (Fig. 49–4C). In instances of alar reconstruction, this usually means placing a cartilaginous strip that spans the distance from the junction of the alar with the cheek to the region of the soft tissue facets, even though these areas do not normally contain cartilage. This is required to support the nostril rim and prevent upward migration of the nostril margin during wound healing.

The function of the framework is to provide contour and maintain a patent airway. Framework grafts must be placed at the time of initial reconstruction and should consist of grafts that replicate the exact size, shape, and contour of the missing framework as closely as possible. When covered by a thin, conforming cutaneous flap, the contour of the framework is distinctively manifested and produces a normal-appearing restoration of the missing part. Framework grafts fix in place the soft tissues used in nasal repair by virtue of providing a skeletal support for both lining and cover.

Bone and cartilage are the tissue-grafting materials available to the surgeon for replacing the framework of the nose. The framework of the nasal dorsum may be replaced with bone or cartilage. Cranial bone grafts are the preferred mate-

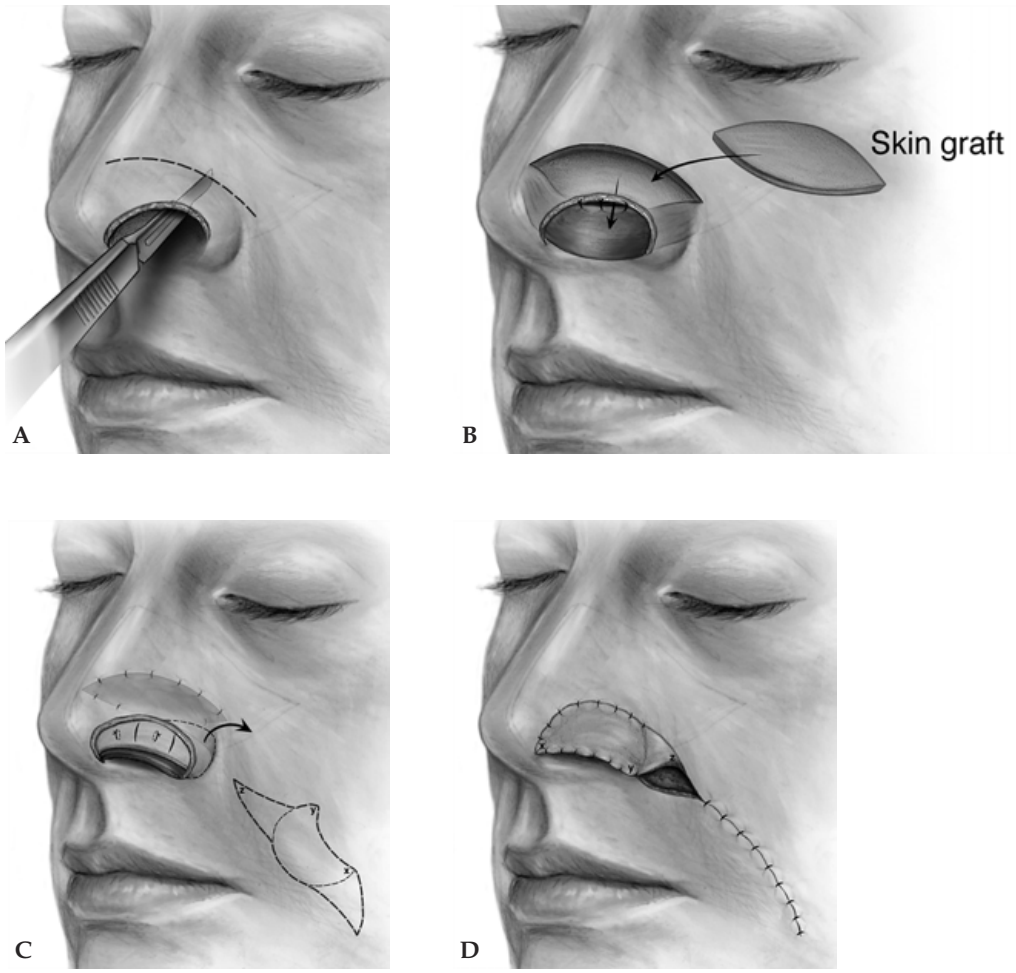

Figure 49–4 **(A)** Full-thickness defects of the ala that do not extend cephalad more than 1.5 cm may be lined by a bipedicle advancement vestibular skin flap based medially on the septum and laterally on the floor of the nasal vestibule. An extended intercartilaginous incision is needed to develop the flap. **(B)** The bipedicle flap is advanced caudally and the donor site is covered with a thin full-thickness skin graft. **(C)** Any remaining skin of the ala is discarded (*arrow*). Auricular cartilage provides structural support to the nostril margin. A superiorly based subcutaneous pedicled interpolated cheek flap is designed to cover the cartilage graft. **(D)** Interpolated cheek flap sutured in place. The caudal border of the cheek flap is sutured to the caudal border of the bipedicle advancement flap.

rial for more cephalic skeletal defects and are anchored to the frontal bone with miniplates. Limited caudal dorsal skeletal defects are best replaced with septal or auricular cartilage when available. The dorsal framework prevents cephalic contraction and subsequent shortening of the nose. It also provides shape and projection to the bridge. The framework of the sidewall can be replaced with septal bone and cartilage or cranial bone contoured into a trapezoid shape and fixed to the dorsum and maxilla. It supports the middle vault and prevents collapse. It also serves as a foundation for attaching the lower framework of the nose, specifically the alar cartilages or their replacements.

The lobule is shaped by the alar cartilages, and the preferred replacement framework is conchal cartilage grafts. By coincidence, when turned upside down, the contralateral conchal cymba often closely resembles the shape of the dome cartilage (intermediate crura) and the conchal cavum resembles the shape of the lateral crus. Grafts 5 to 8 mm wide from the auricle can be scored and bent to replace the entire lower lateral cartilages. These grafts can be used bilaterally or unilaterally as needed and are fixed to any residual stumps of the medial and lateral crura. They support the dome and recreate the contour of the nasal lobule. Additional projection and shaping of the tip can be accomplished with Peck-type septal cartilage grafts anchored atop the reconstructed alar cartilages[2] or the fabrication of shield-shaped septal cartilage tip grafts placed caudad to the auricular cartilages.

Structural support for the columella can be provided by conchal cartilage grafts described for the lobule, but placed in such a way as to span the gap in the medial crus or extend

all the way to the nasal spine if the entire medial crus is absent. Septal cartilage grafts are very effective for this purpose as well but must be thinned, scored, and bent so as to replicate the diverging angle that naturally occurs at the junction of the medial and intermediate crura.

An alar batten of septal or conchal cartilage 5 mm wide can be used for the framework of the ala and soft tissue facet. The natural curvature of the conchal cartilage makes this material preferable to septal cartilage when available. When all or portions of the lateral crus are missing in addition to the ala, the conchal cartilage graft can be designed as a wider graft (0.75 to 1.0 cm) to concomitantly replace the lateral crus and provide support to the ala. The graft should be placed along the proposed margin of the missing nostril from the alar base to the nostril apex (see Fig. 49–6D). It is inserted into a deep-tissue pocket in the alar facial sulcus and attached medially to the framework of the dome. The tissue pocket serves to stabilize the graft laterally. Similar to the grafts used to replace missing alar cartilage, grafts must be thinned, scored, and bent to replicate the bulging contour of the ala. If the nasal defect extends to the soft tissue facet, the batten should extend beneath the diverging angles of the intermediate and lateral crura to span any gap present. The batten fixes the reconstructed alar rim in position, preventing upward migration and notching of the rim.

In summary, the surgeon must determine what part of the nasal framework is missing and replace it completely. Each replaced element must be carefully shaped, thinned, scored, bent, and fixed with regard to nasal projection, contour, alar rim position, and symmetry, so that it exactly replicates the contralateral counterpart or the ideal if both components of the framework are missing. The better the surgeon can achieve this goal, the better the aesthetic and functional results.

COVERING FLAPS

Small defects of the nasal skin (2 cm or less) can sometimes be repaired with local flaps harvested from the remaining nasal skin if there is sufficient redundancy of skin. Most notable of the local flaps is the bilobe flap as modified by Zitelli.[6] The bilobe flap was originally designed for repair of nasal tip defects. Each lobe and the defect were separated by 90 degrees for a total transposition over a 180-degree arc. Although this recruited tissue for repair at some distance from the defect, it also maximized the standing cutaneous deformities and the likelihood of development of a trap-door deformity or pincushioning of both the primary and secondary flaps. Zittelli[6] emphasized the use of narrow angles (45 degrees) between lobes so that the total arc of tissue transferred occurs over no more than 90 to 100 degrees (Fig. 49–5). This reduces the standing cutaneous deformity and pincushioning effects. Bilobe flaps are double transposition flaps that transfer the wound closure tension from the initial defect through a 90-degree arc to the donor site areas. A major disadvantage of this flap is the extensive amount of linear scar that does not fall along nasal topographic borders. Postoperative dermabrasion is very helpful in obscuring the scar. The bilobe flap is the most commonly used local flap harvested within the confines of the nose itself. It is best limited to repair of

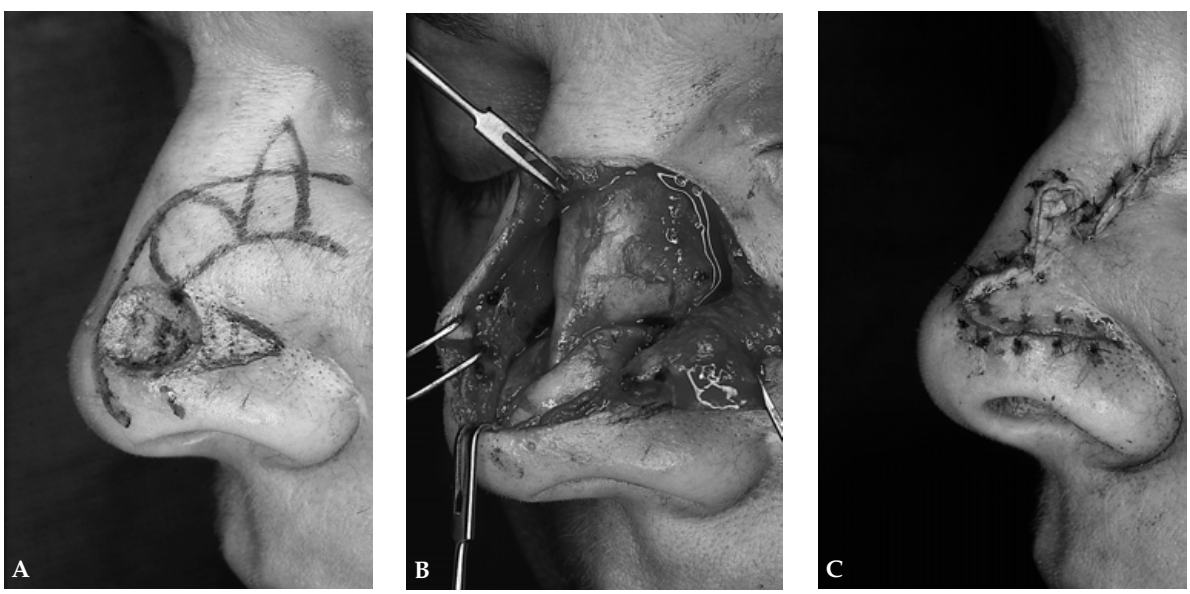

Figure 49–5 **(A)** Bilobe flap designed so that each lobe has a linear axis 45 degrees from the other. Each lobe is designed around one arc through the center of the defect and another through the peripheral border of the defect. The center of each arc is at the apex of the standing cutaneous deformity that will form on flap transfer. The pivotal point for designing the arcs is set at a distance equal to the radius of the defect. **(B)** The flap and entire adjacent nasal skin are undermined. **(C)** Flap in position and standing cutaneous deformity excised.

skin defects of the lower third of the nose. It is not well suited for cephalic dorsal defects because the donor site for the secondary flap must lie in the area of the medial canthus where the skin is immobile, making wound closure difficult.

As designed by Zitelli,[6] skin adjacent to the defect is used as the primary lobe of the flap, thus allowing for an excellent color and skin texture match. This lobe is designed nearly as large as the defect so that little wound closure tension is exerted at the recipient site. The second lobe is recruited from the lax skin of the upper dorsum and sidewall. The donor site for the second lobe is closed primarily. The base of the bilobe flap is usually positioned laterally, and the transverse nasalis muscle is included in the substance of the flap to enhance vascularity.

The ideal nasal defect for a bilobe flap is a small (less than 1.5 cm) defect at least 5 mm from the margin of the nostril located on the lobule or sidewall. The flap is preferably based laterally and is designed so that the standing cutaneous deformity or cone resulting from pivoting of the flap is removed parallel to or in the nasal alar crease. When designed as a laterally based flap, the base of the cone develops at the lateral border of the defect with its apex pointing laterally. The base of the cone is approximately one half to two thirds of the diameter of the defect. The apex of the cone-shaped excision serves as the pivot point for the flap. Each donor lobe is designed around one arc through the center of the defect and another through the peripheral border of the defect (Fig. 49–5).

The linear axis of each lobe is positioned approximately 45 degrees from the other, with the primary lobe axis positioned 45 degrees from the axis of the defect. The flap is elevated just above the perichondrium and periosteum of the underlying nasal framework. If the thickness of the primary lobe is greater than the recipient area, the distal portion of the lobe may require thinning even to the level of the dermis to match the thickness of the skin at the recipient site. Following incision of the flap, wide peripheral undermining of essentially all skin of the nose is important to reduce wound closure tension, facilitate flap transfer, and minimize trap-door deformity. The primary lobe of the flap is transposed to the defect and secured with sutures. Next, the donor site of the secondary lobe is closed primarily. Last, the secondary lobe is transposed and trimmed appropriately to fit, without redundancy, the donor defect of the primary lobe.

The bilobe flap is most useful in patients with thin nasal skin and laxity of skin along the nasal sidewall. The surgeon can estimate the laxity by pinching the lateral nasal skin between the thumb and index finger. Patients with thick sebaceous skin have a higher risk of flap necrosis and development of trap-door deformity. Dermabrasion, 6 weeks following flap transfer, is recommended for most patients reconstructed with a bilobe flap. Although local nasal flaps can be used to repair defects 2 cm or less on the nose, the majority of surface defects are best repaired with skin from the forehead or cheek.

MELOLABIAL INTERPOLATION FLAP

The ala is best resurfaced with cheek skin from the area of the melolabial fold. The sebaceous quality of the skin of the fold closely resembles that of the ala. Menik noted that as melolabial flaps contract they become rounded, resembling the contour of the normal ala.[2] Skin of the melolabial fold is limited, and its use can flatten the fold causing marked asymmetry of the face. Nor can it easily be transferred to the nasal lobule or dorsum. Skin from this fold should be transferred to the ala as an interpolated flap, the pedicle of which crosses over, but not through, the alar facial sulcus (Fig. 49–4). The pedicle is superiorly based and may consist of skin and subcutaneous fat or subcutaneous fat only. It is detached from the cheek 3 weeks after the initial transfer to the nose. Although 3 weeks is a lengthy period for the patient to endure the deformity caused by the flap, this interval allows the surgeon to aggressively defat and sculpture the flap both at the time of the flap transfer and at the time of pedicle detachment and flap inset.

For resurfacing the ala, the remaining skin of the ala is usually removed, preserving a 1-mm-wide cuff of alar skin at the base, rather than extending the excision into the alar facial sulcus. A template is fashioned to exactly represent the shape and surface area of the ala. The contralateral ala can be used for the template when present. The template is used to design a flap that is positioned so that the center of the flap is on a horizontal plane with the lateral commissure of the lip. The medial border of the flap should lie in the melolabial sulcus. The flap is designed as an interpolation flap in which the donor site scar will lie precisely in the melolabial sulcus. The flap is based on perforating vessels from the facial artery that penetrate just superior and inferior to the zygomatic major muscle. Incorporation of these perforators gives the flap an axial nature with an excellent blood supply and allows elevation of the flap on a subcutaneous pedicle. Designing it as an island flap on a subcutaneous pedicle enables the base to be tapered superiorly to facilitate transposition (Fig. 49–4). This also reduces skin loss from the upper portion of the melolabial fold where the fold is more prominently manifested. A standing cutaneous deformity resulting from closure of the donor site is marked distally so that the scar resulting from its excision will follow the line of the melolabial sulcus. The flap is pivoted toward the midline to reach the nose, crossing over the alar facial sulcus. Fat on the distal one third of the flap is excised, leaving 1 to 2 mm of subcutaneous fat in place. The donor site is closed primarily through advancement and necessitates the excision of a standing cutaneous deformity. The pedicle is divided 3 weeks later at which time the attached flap is partially elevated to allow removal of additional subcutaneous fat from the more proximal portion of the covering flap.[4] The flap is then trimmed of its tail of skin (carried with it from the superior melolabial fold at the time of the initial transfer) and inset into the ala by joining it to the preserved cuff of alar skin adjacent to the alar facial sulcus and to the nasal sil.

PARAMEDIAN FOREHEAD FLAP

A number of studies of the vascular anatomy of the forehead have been reviewed by Baker and Alford.[7] These studies confirm that the supratrochlear artery is the primary axial blood supply of midforehead flaps, which include the median and paramedian vertically oriented flaps. In addition, the studies have shown that in the medial canthal region a rich anastomotic network exists between the supratrochlear, supraorbital, and angular arteries. Identification of this vascular network and the surgical techniques of flap harvest that preserve this

regional blood flow have allowed surgeons to harvest paramedian forehead flaps based on pedicles narrower than those used for median forehead flaps. The narrower pedicle gives the flap more freedom to rotate about its pivot point and therefore provides more effective flap length. At the same time, this design reduces the donor site deformity in the glabellar area that results from transposition of the flap. Based on the supratrochlear artery and its anastomoses to surrounding vessels, the paramedian forehead flap is an axial pivotal interpolation flap with an abundant blood supply that allows transfer without delay.

Paramedian forehead flaps are the preferred local flap for resurfacing most large nasal defects. The flap is usually dissected under local anesthesia. The base of the pedicle is placed in the glabellar region centered over the supratrochlear artery on the same side as the majority of the nasal defect (Fig. 49–6). The origin of the supratrochlear artery is consistently found to be 1.7 to 2.2 cm lateral to the midline and usually corresponds to the vertical tangent of the medial border of the brow.[8] The artery exits the orbit by piercing the orbital septum and passing under the orbicularis oculi and over the corrugator supercilii muscle. At the level of the

Figure 49–6 **(A)** Preoperative photograph outlining resection borders for removal of a melanoma. **(B)** Following resection, a full-thickness defect of ala and lower sidewall is observed. **(C)** Ipsilateral septal mucoperichondrial flap hinged on the caudal septum will provide internal lining for the reconstruction. **(D)** Septal cartilage graft replaces caudal portion of the upper lateral cartilage. Auricular cartilage graft replaces missing lateral crus in addition to providing structural support to the ala. It is positioned caudad and lateral to septal cartilage graft. Forcep holds caudal border of hinge flap. **(E)** Curvature of auricular cartilage graft provides contour to the reconstructed ala and nostril. **(F)** Paramedian flap designed as cover for cartilage grafts. *(continues on next page)*

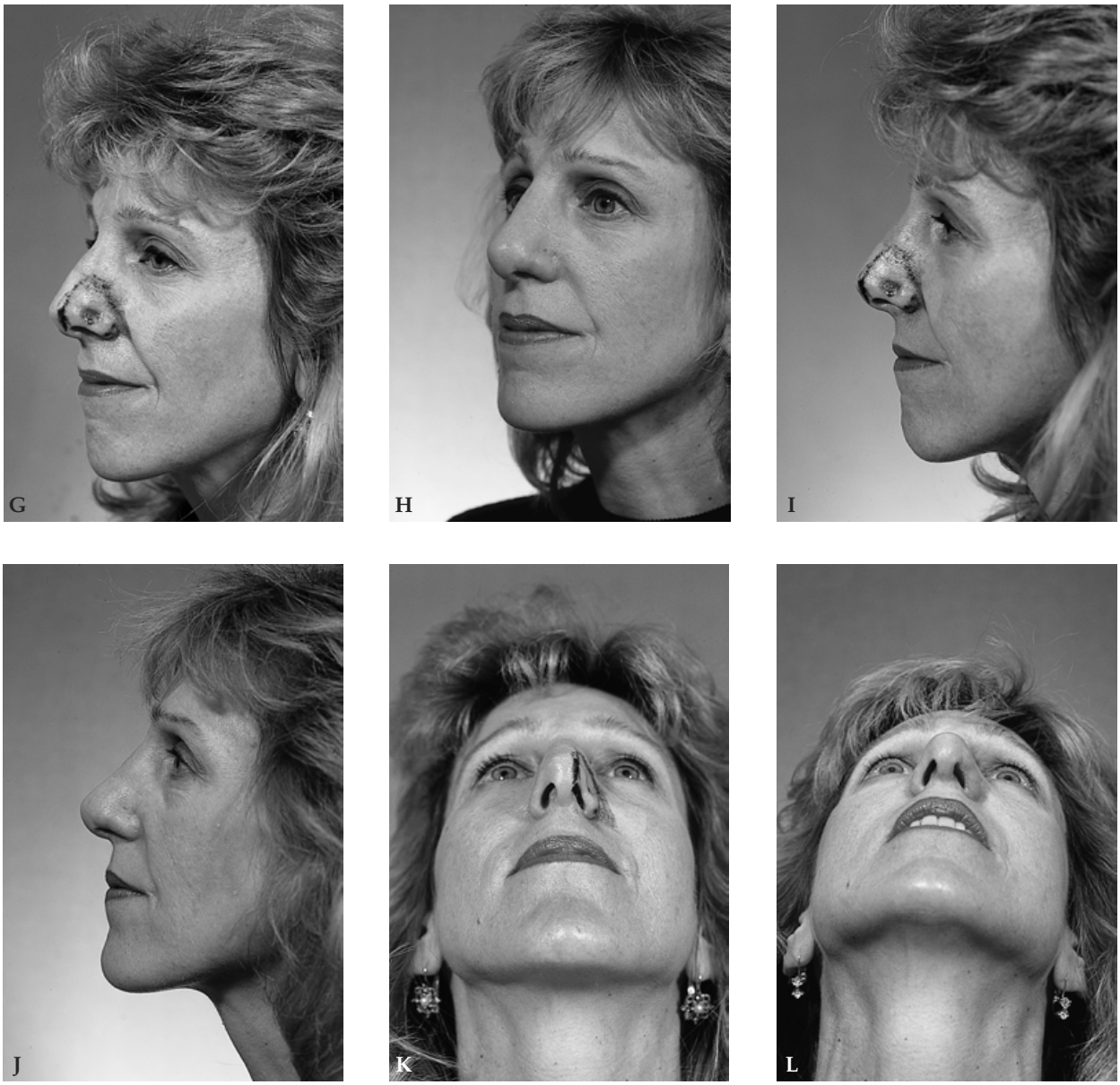

Figure 49–6 *(continued)* **(G, H)** Oblique view: preoperative and 1 year postoperative. **(I, J)** Lateral view: preoperative and 1 year postoperative. **(K, L)** Baseview: preoperative and 1 year postoperative.

brow, the artery passes through orbicularis and frontalis muscles and continues in a vertical direction upward in a subcutaneous plane. Because of this, the portion of the flap extending from the level of the brow to the hairline can be trimmed of its frontalis muscle and much of the subcutaneous fat without harming the blood supply to the overlying skin. The axial nature of the flap, based on a single supratrochlear artery, enables the pedicle to be as narrow as 1.2 cm.[8] The narrow pedicle minimizes the standing cutaneous deformity as the flap pivots (Fig. 49–7). An exact template of the defect is used to design the paramedian forehead flap, which is centered over the vertical axis of the supratrochlear artery. The length of the flap is determined by measurement. If an adequate length necessitates extending the flap into the hair-bearing scalp, the author prefers turning the flap obliquely along the hairline to prevent transfer of hair-bearing skin to the nose. However, this design may not be prudent if the flap must be more than 3 cm wide. Oblique forehead flaps wider than 3 cm remove excessive skin from the lateral portion of the forehead, sometimes causing unsightly scars or upward distortion of the central portion of the brow. Thus, flaps wider than 3 cm should be extended into the hair-bearing scalp rather than designed in an oblique fashion. The flap is elevated in a subfascial plane just superficial to

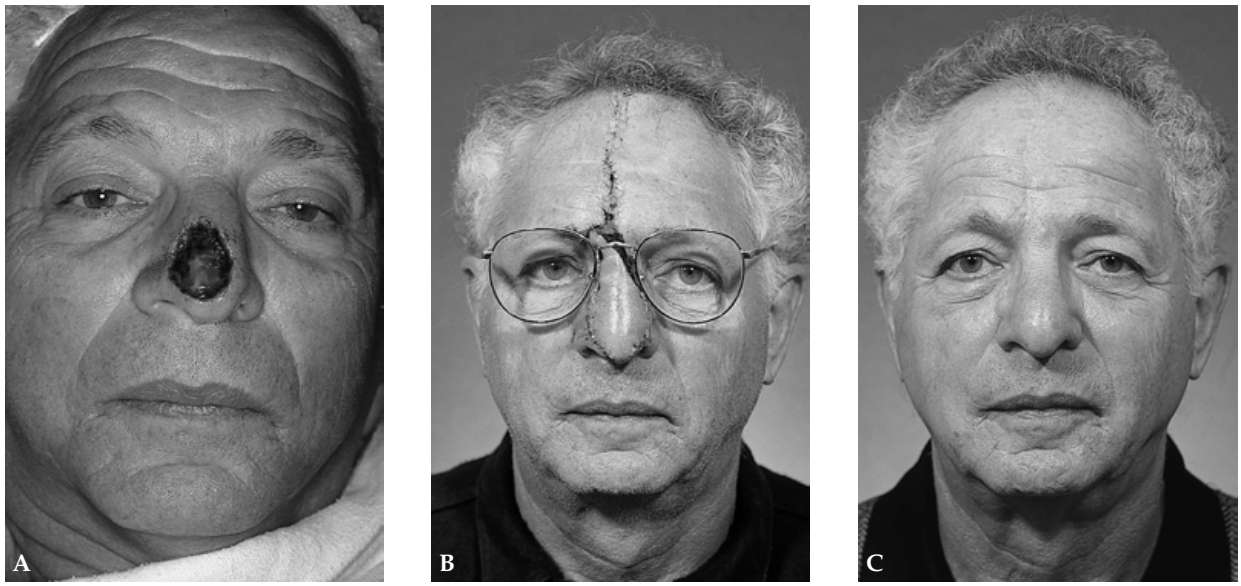

Figure 49–7 **(A)** Skin defect of lobule. **(B)** The narrow pedicle of the paramedian forehead flap minimizes the standing cutaneous deformity resulting from pivoting of the flap. This has allowed the patient to position eyeglasses comfortably over the flap. **(C)** Six months following detachment of flap pedicle. No revision surgery was necessary. Note restored relationship of the medial aspect of eyebrows.

the periosteum of the frontal bone. To avoid injury to the arterial pedicle, blunt dissection is used near the brow to separate the corrugator muscle from the flap and facilitate mobility. Incisions can be extended below the brow if necessary to enhance the length of the flap. Adequate flap mobilization usually requires complete sectioning of the corrugator supercilii muscle to achieve free movement. Prior to inset, the flap is sculptured and contoured to fit the depth of the defect perfectly by removal of all or some of the muscle and subcutaneous tissue from the distal portion of the flap. When necessary, all but 1 mm of fat beneath the dermis may be removed. It is sometimes even necessary to resect a portion of the dermis along the edge of the flap so that the thickness of the skin of the flap matches the adjacent nasal skin in instances where the adjoining nasal skin is thin. Only the distal three fourths of the flap required for reconstruction is sculptured; the proximal one fourth is left thick and is debulked at the time of pedicle detachment 3 weeks later. Prudence in thinning the flap is advised in patients who smoke. Donor site closure is accomplished by undermining the forehead skin in the subfascial plane from the anterior border of one temporalis muscle to the other. Several parallel vertical fasciotomies 2 to 3 cm apart may be helpful to achieve primary wound closure. However, one must take care not to injure the supraorbital nerves when initiating this maneuver. Any portion of the donor site that cannot be closed primarily should be left to heal by second intention, keeping the open wound moist at all times. Healing by second intention usually results in an acceptable scar but may take 6 weeks for completion.

Three weeks after the initial flap transfer, the pedicle is divided under local anesthesia. The nasal skin surrounding the defect superiorly is undermined for a distance of approximately 1 cm. The portion of the flap not thinned at the time of transposition is now thinned appropriately. In the case of reconstruction of skin-only nasal defects that extend to the rhinion, the flap must be aggressively thinned to the level of the dermis to duplicate the thin skin that is normally found in this area. Deep-layer closure is not necessary because the wound should not be subjected to any closure tension. The base of the pedicle is returned to the donor site in such a way as to restore the normal anatomic and spatial relationship of the two eyebrows (Fig. 49–7). Care should be taken to maintain the muscular component of the proximal pedicle that is returned so that a depression between the brows does not occur. Any excess pedicle should be discarded rather than returned to the forehead above the level of the brow.

LOCAL FLAPS AND SKIN GRAFTS

The skin of the cephalic two thirds of the nose, columella, and soft tissue facets is thin, nonsebaceous, and mobile. In contrast, the lobule and ala are covered with immobile, thick sebaceous skin. Single-lobe transposition flaps may be satisfactory for smaller defects of the cephalic nose because of the redundancy and mobility of the skin covering the sidewall of the nose where the donor site is located. They work less well for the nasal tip and poorly for the ala because of secondary movement of adjacent free margins from wound contraction. Full-thickness skin grafts harvested from the preauricular area or forehead along the hairline match the thickness and texture of the cephalic nose and, if dermabraded postoperatively, often produce a satisfactory result. A skin graft is also useful for limited defects of the columella and soft tissue

facets. Skin grafts are less favorable for the lobule and ala where they may appear as an island or patch rather than blend with adjacent nasal skin. If the depth of a nasal defect extends through the supporting framework, it must be restored with primary cartilage grafts. In such instances, a skin graft or covering flap harvested from the nose itself is no longer advisable because contraction of such grafts and flaps often obscures the delicate topography of the replacement framework; a cheek or forehead flap is the preferred covering flap. This approach replaces the missing skin rather than borrowing it from another area of the nose, keeping contracting forces of healing to a minimum.

DEFECT CLASSIFICATION

Defects of the nose may be classified according to location, depth, and size. Skin-only defects can be replaced with full-thickness skin grafts, local flaps (if the defect is small), or, preferably, skin transferred from the cheek or forehead. Defects involving loss of skeletal structure require replacement with like tissue. Full-thickness defects of the nose require replacement of the missing lining with flaps harvested from the interior of the nose when possible. These defects always require replacement of the missing skeletal framework and thus should be resurfaced with a paramedian forehead or melolabial interpolation flap.

The size of the nasal defect determines the source of the covering flap. In the case of defects greater than 2.0 cm in greatest dimension, there is rarely sufficient residual nasal skin for closure by a local flap without creating undue wound closure tension. Thus, the forehead or cheek should be used as a donor site.

RECONSTRUCTION OF COLUMELLA

The columella is the most difficult region of the nose to reconstruct. Small defects limited to 1.5 cm in greatest dimension can occasionally be repaired with composite grafts from the auricle in nonsmokers. The grafts should be chilled for 3 days following transfer, and systemic steroids should be administered for 1 week. It is preferable to allow the initial defect to heal by second intention and then perform the composite graft after preparing a fresh recipient site by removing all scar tissue and new epithelium. The graft should be oversized by 2 mm to accommodate wound contraction.

Depending on extent of the tissue loss, larger defects of the columella are best repaired with unilateral or bilateral superiorly based interpolated melolabial flaps. Septal cartilage grafts should be utilized for the framework. The initial flap transfer will produce a thick columella that will require secondary thinning. Defects that extend into the lobule from the columella require structural support with cartilage grafts and a paramedian forehead flap for cover. By extending the incision for the forehead flap into or below the brow, the flap can be made to reach the upper lip without excessive wound closure tension.

Full-thickness defects of the columella and lobule are best reconstructed with a tilt-out, hinged, composite nasal septal flap (Fig. 49–3). Mucosa of the flap is peeled downward bilaterally to provide internal lining. Auricular cartilage grafts are attached to the composite flap to provide structural support laterally. A paramedian forehead flap is best for exterior covering.

RECONSTRUCTION OF LOBULE

Small, skin-only superficial defects of the nasal tip may be covered with a local bilobe flap, as described in detail earlier, or a full-thickness skin graft. However, a paramedian forehead flap will usually give a more natural result because the entire aesthetic unit can be covered by the flap, placing scars in borders of aesthetic units. Cartilage grafts should be used routinely along the margin of the nostril when the defect extends from the lobule to the soft tissue facet. This is in addition to any missing lower lateral cartilage, which must be replaced as well.

Bilateral full-thickness defects of the lobule should be repaired with a tilt-out, hinged, composite septal flap as discussed (Fig. 49–3). However, unilateral full-thickness defects can be nicely reconstructed with an ipsilateral intranasal hinge mucosal flap for internal lining and paramedian forehead flap for cover. The lining flap spans the nasal passage on the affected side. Following restoration of the absent cartilaginous framework, a paramedian forehead flap provides surface replacement. In instances of a hemitip defect, I usually only resurface the hemilobule rather than the entire lobule. Concomitant with detachment of the forehead flap 3 weeks after transfer, the hinge mucosal flap is released from the septum, thus restoring patency of the nasal airway.

RECONSTRUCTION OF THE ALA

Defects confined to the ala with or without limited extension to the lobule or sidewall are best resurfaced with an interpolated superiorly based melolabial flap. I routinely resurface the entire ala regardless of the size of the alar defect.[4] The melolabial flap based on a subcutaneous pedicle is preferred because this design minimizes the amount of skin that is disturbed in the upper melolabial fold. Preserving the upper fold is paramount in maintaining symmetry of the cheeks following reconstruction of the ala with a cheek flap. Cartilage grafts are used in the majority of alar defects. This is because most lesions involving resection of alar skin also require removal of the underlying firm fibrofatty subdermal tissue, which gives the ala form and structural support. This must be replaced by cartilage to prevent upward migration of the ala and notching of the margin of the nostril.

Internal lining for full-thickness alar defects is provided by bipedicle vestibular skin flaps or unilateral hinge septal mucosal flaps (Fig. 49–6). Occasionally, an additional contralateral hinge mucosal flap, as discussed in the earlier portion of this chapter, may be necessary if the vertical height of the defect is such that a single hinged mucosal flap will not provide sufficient tissue to replace the entire missing lining.

RECONSTRUCTION OF THE NASAL DORSUM

The nasal dorsum is perhaps the least complex portion of the nose to reconstruct. Forehead skin in the form of a paramedian flap is usually preferred for resurfacing skin-only defects of the caudal dorsum. However, bilobe flaps or full-thickness skin grafts may also be used. Likewise, skin defects of the cephalic dorsum can be repaired with glabellar flaps, such as the dorsal nasal flap, or full-thickness skin grafts, but paramedian forehead flaps are preferred (Fig. 49–8). Small defects of the dorsal framework can be replaced with septal cartilage grafts. More extensive defects of the nasal skeleton extending from the frontal bone to the lobule are best replaced with calverial bone grafts secured to the frontal bone or remaining nasal bony root with plate-and-screw fixation. To prevent medialization of the nasal sidewall following wound healing, structural defects that extend into the nasal sidewall require replacement concurrent with replacement of the dorsal framework. Septal cartilage or additional cranial bone grafts plated to the dorsal graft work well for this purpose. Internal lining for full-thickness dorsal defects can usually be provided by mucosal hinge flaps reflected laterally from the exposed dorsum as long as there is sufficient height to the remaining septum. Unilateral or bilateral hinge septal mucosal flaps based on the caudal septum and including the septal branch of the labial artery can also sometimes be used for lining when there is considerable loss of dorsal septal height. A tilt-out composite septal flap, as discussed earlier in this chapter, should be used to provide lining and structural support for the

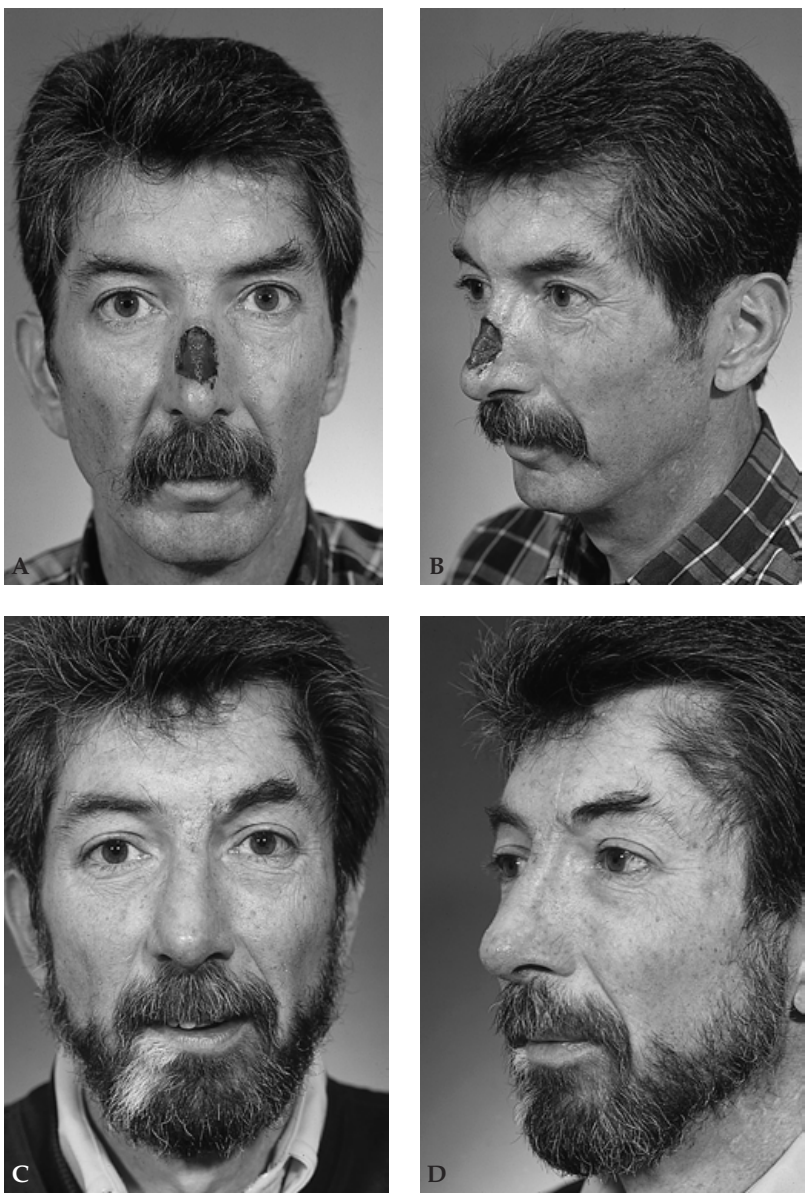

Figure 49–8 **(A, B)** Skin defect of nasal dorsum. **(C, D)** Six months following reconstruction with a paramedian forehead flap. No intermediate surgical stage or revision surgery's necessary.

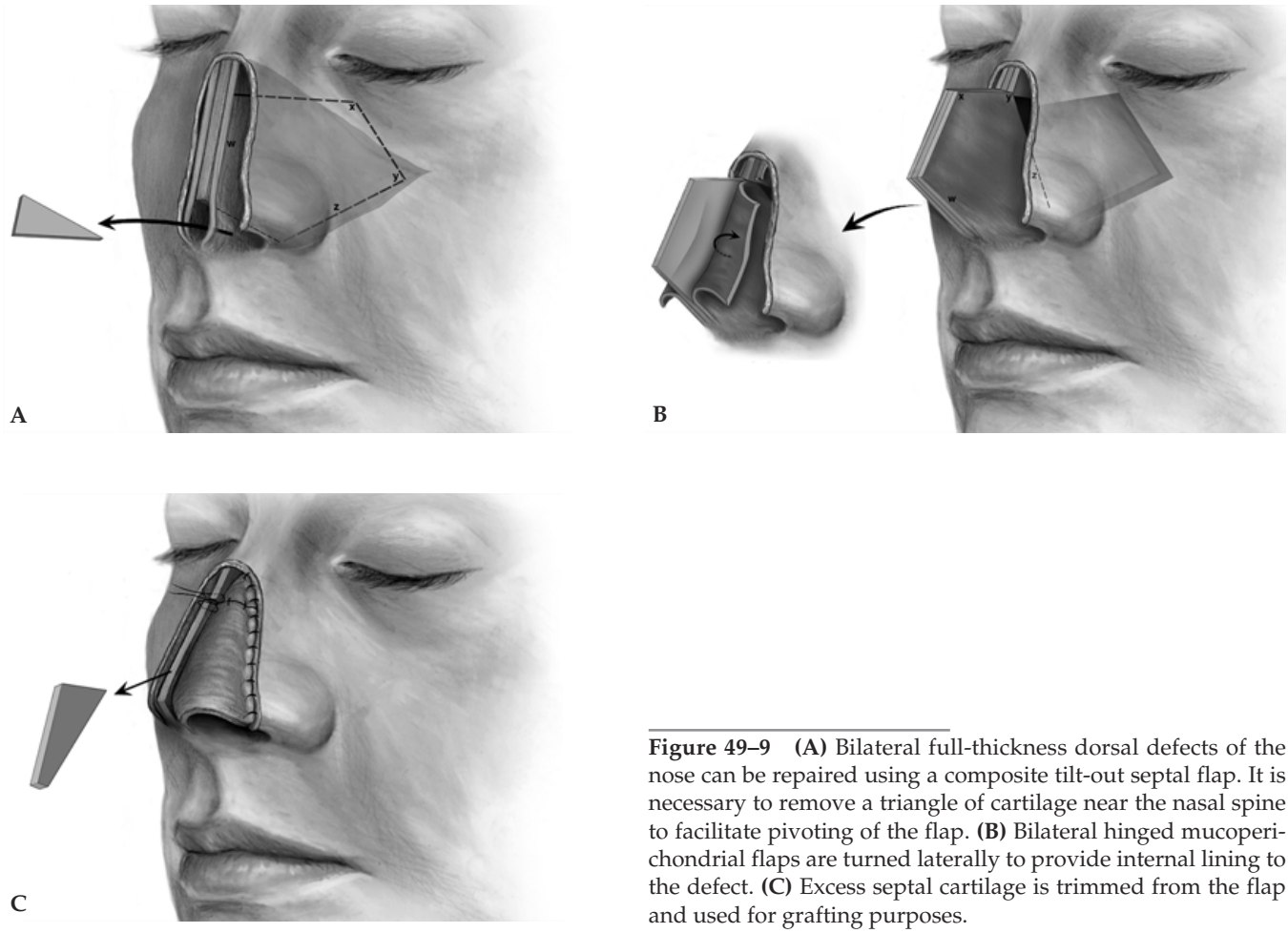

Figure 49–9 **(A)** Bilateral full-thickness dorsal defects of the nose can be repaired using a composite tilt-out septal flap. It is necessary to remove a triangle of cartilage near the nasal spine to facilitate pivoting of the flap. **(B)** Bilateral hinged mucoperichondrial flaps are turned laterally to provide internal lining to the defect. **(C)** Excess septal cartilage is trimmed from the flap and used for grafting purposes.

dorsum in extensive bilateral full-thickness dorsal nasal defects (Fig. 49–9). In instances where this approach will not provide sufficient tissue, bilateral paramedian forehead flaps are recommended. One flap provides internal lining and the other provides external coverage. A cranial bone graft is placed between the flaps for structural support.

RECONSTRUCTION OF NASAL SIDEWALL

Reconstruction of the sidewall of the nose is relatively uncomplicated. Small skin-only defects may be repaired with a bilobe flap harvested from the remaining nasal sidewall skin. Full-thickness skin grafts harvested from the preauricular area of the cheek also provide a reasonable option for covering defects located in the superior portion of the sidewall because of the thinness of the skin at this location. Larger surface defects are best covered with a paramedian forehead flap. When structural support is absent from the upper third of the nasal sidewall, it should be replaced with a calverial bone graft, whereas the lower two thirds of the sidewall skeleton is best replaced with septal cartilage grafts. Unilateral sidewall defects can be lined using contralateral hinged septal mucoperichondrial flaps based on the nasal dorsum and delivered through a superiorly positioned nasal septal fenestrum. For more caudally located sidewall defects, a unilateral mucosal flap hinged on the caudal septum may provide sufficient lining (Fig. 49–6). However, this arrangement requires subsequent detachment of the pedicle. It is usually necessary to use both the contralateral dorsally based flap and the ipsilateral caudally based septal hinge mucoperichondrial flap to provide lining for full-thickness defects that involve the ala and extend the entire length of the nasal sidewall (Fig. 49–2).

SUMMARY

During the last decade, reconstruction of the nose has progressed to a new level of finesse that allows the surgeon to restore near-normal form and function to all but the most extensive nasal defects. These advances are based on the contemporary concept of respecting the borders of aesthetic units of the nose. The nose is reconstructed separately from any extension of a nasal defect onto the cheek or lip, which in turn is repaired by tissue within the respective aesthetic region. The other concept that has contributed to this higher level of surgical achievement is that of replacing missing tissue with like tissue. Internal lining is replaced with nasal

mucosal flaps, which because of their nature provide adequate vascularity to nourish and sustain the cartilage and bone grafts used in skeletal replacement. Missing bone and cartilage are replaced with similar tissue, which is carefully crafted to replicate the exact size, configuration, and contour of the missing nasal skeleton. Surface defects are covered with cheek or forehead skin transferred by interpolation so as not to violate the aesthetic boundary between nose and the other regions of the face. This surgical approach provides natural building material precisely fitted to reconstruct nasal deficits to a condition as near normal as possible.

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Chapter 50

Auricular Reconstruction

Tom D. Wang

Auricular reconstruction poses one of the most difficult challenges in reconstruction surgery of the head and neck. This is due to the unique architectural topography of the external ear. The multiple concavities and convexities of the cartilage framework are enveloped by a very thin, tightly adherent skin envelope. This entire skin and cartilaginous framework exist as a protuberant three-dimensional structure standing alone and projecting away from the side of the head. The vascular supply for this unique structure, while well defined, can be tenuous and is often less robust than that of other regions of the face, such as nose and lips. In addition, this entire freestanding framework exhibits great delicacy in its various topographic convolutions, as well as a smooth, flowing curvature representing the outer helical rim. Finally, within the framework itself, there is variation of tissue type, blending varying amounts of cartilage with overlying skin and intervening soft tissue to create the components that make up the normal external ear.

RECONSTRUCTIVE PHILOSOPHY

The ultimate goal in any reconstruction is the precise duplication of the absent anatomic portions. This is certainly the intended goal in the auricular reconstructions as well. While this goal might be more achievable with smaller defects, it becomes much more challenging with the loss of significant portions of the ear. As important to the duplication of the precise anatomic landmarks, however, is the recognition and reproduction of normal auricular characteristics. A successful outcome, especially in the reconstruction of large auricular defects, depends more on respecting the characteristics of the normal ear than exact duplication of normal anatomic landmarks. The characteristics of the normal ear that need to be preserved in all reconstructive endeavors include the size, location, orientation, and, finally, anatomic landmarks. A reconstructed ear will appear instantly recognizable as such only if these characteristics are observed. Conversely, if one or more of these characteristics is absent—for instance, if the ear is significantly deviant in size, location, or orientation—then despite the most accurate reproduction of anatomic detail that ear will appear to be abnormal.

One of the most useful ways to approach auricular reconstruction is via accurate classification of the auricular defect. In this respect, the classification of defects of the ear is not unlike the classification of defects elsewhere on the face. Because different portions of the ear comprise different tissue compositions—that is, the varying ratio of cartilage to overlying skin and intervening soft tissue—the reconstructive demands will similarly vary. As with nasal reconstruction, different aspects of the ear can be thought of as representing different "aesthetic subunits" requiring attention to the specific topographic contours and demands within that specific missing unit. From this perspective, auricular defects can be categorized as follows:

1. Central defects involving the conchal bowl and helical root
2. Peripheral defects involving the upper third of the ear
3. Peripheral defects involving the middle third of the ear
4. Peripheral defects involving the lower third of the ear
5. Defects involving the periauricular tissues
6. Large defects involving both the central and peripheral portions of the ear

CENTRAL AURICULAR DEFECTS INVOLVING THE CONCHAL BOWL AND HELICAL ROOT

Central auricular defects can typically be successfully reconstructed by providing adequate skin coverage alone. We know this to be true from experience harvesting auricular cartilage for reconstruction elsewhere, leaving minimal—if any—residual donor site deformity (Fig. 50–1) As long as the remainder of the peripheral auricular cartilage framework is intact, an absence of conchal bowl cartilage is relatively inconsequential. In this respect, full-thickness skin grafting can work well in resurfacing defects in this region. If a more substantial amount of tissue is required, donor sites from the postauricular and retromastoid regions can be easily harvested for bulk and resurfacing requirements (Fig. 50–2).

The root of the helix is a preferred donor site for composite grafts for nasal reconstruction. The resulting donor defect can be easily reconstructed with a superiorly based preauricular flap with or without the introduction of cartilage to replace the missing tissue (Fig. 50–3).

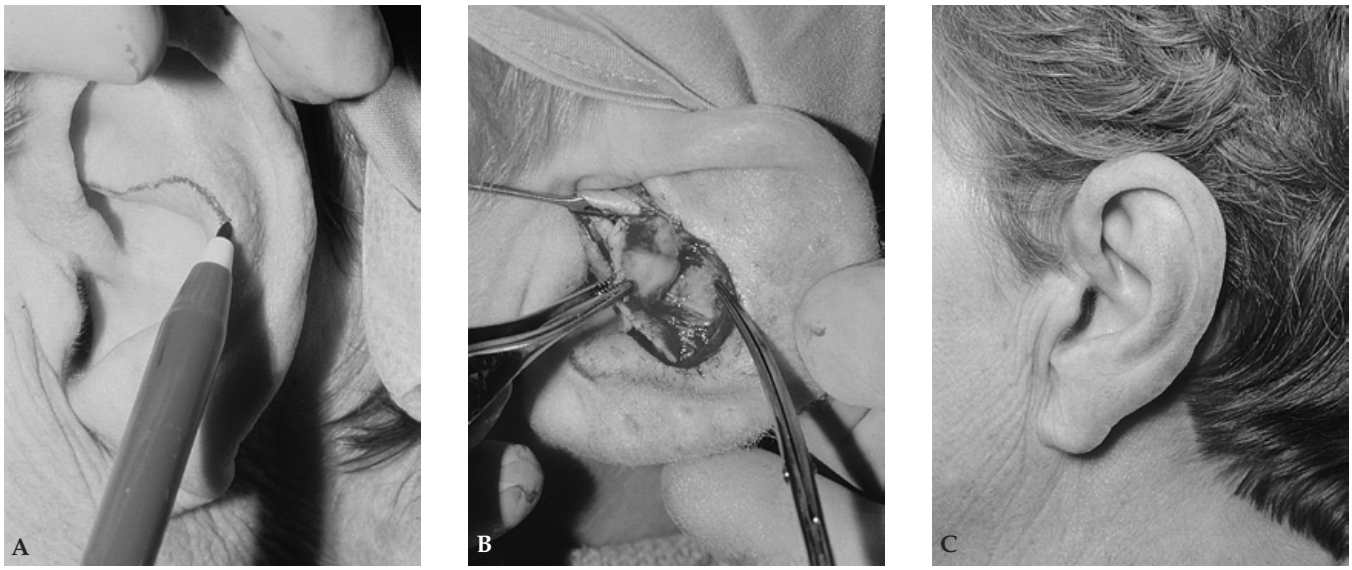


Figure 50–1 **(A)** Access incision used for obtaining conchal cartilage for grafting purposes. The incision itself is placed along the antihelical ridge for camouflage. **(B)** Harvest of conchal cartilage via the anterior approach. **(C)** Postoperative appearance of donor ear with no distortion or morbidity.

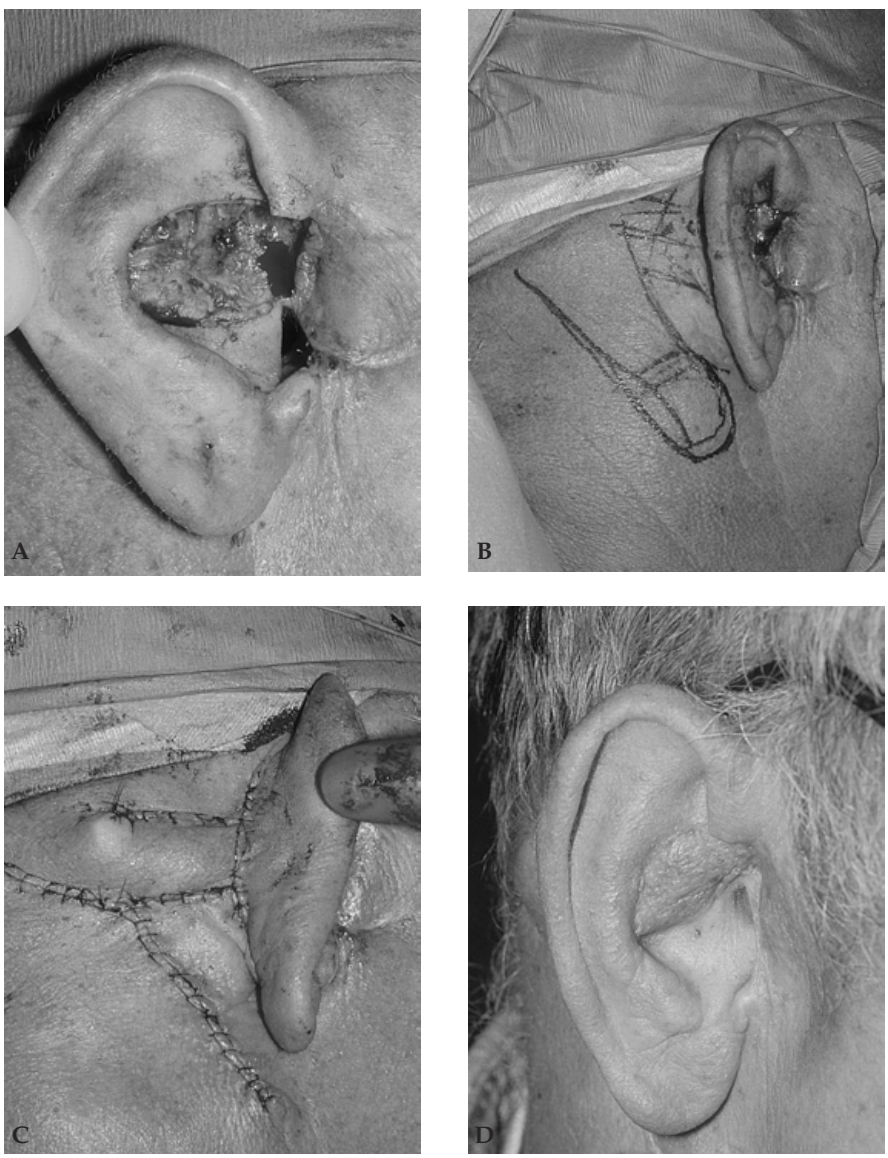


Figure 50–2 **(A)** Defect of the helical root and conchal bowl involving skin and cartilage tissue loss. **(B)** Pedicle flap reconstruction of defect with superiorly based mastoid flap. **(C)** Donor site closed and flap transposed in position. **(D)** Long-term result with uneventful healing and maintenance of auricular contour.

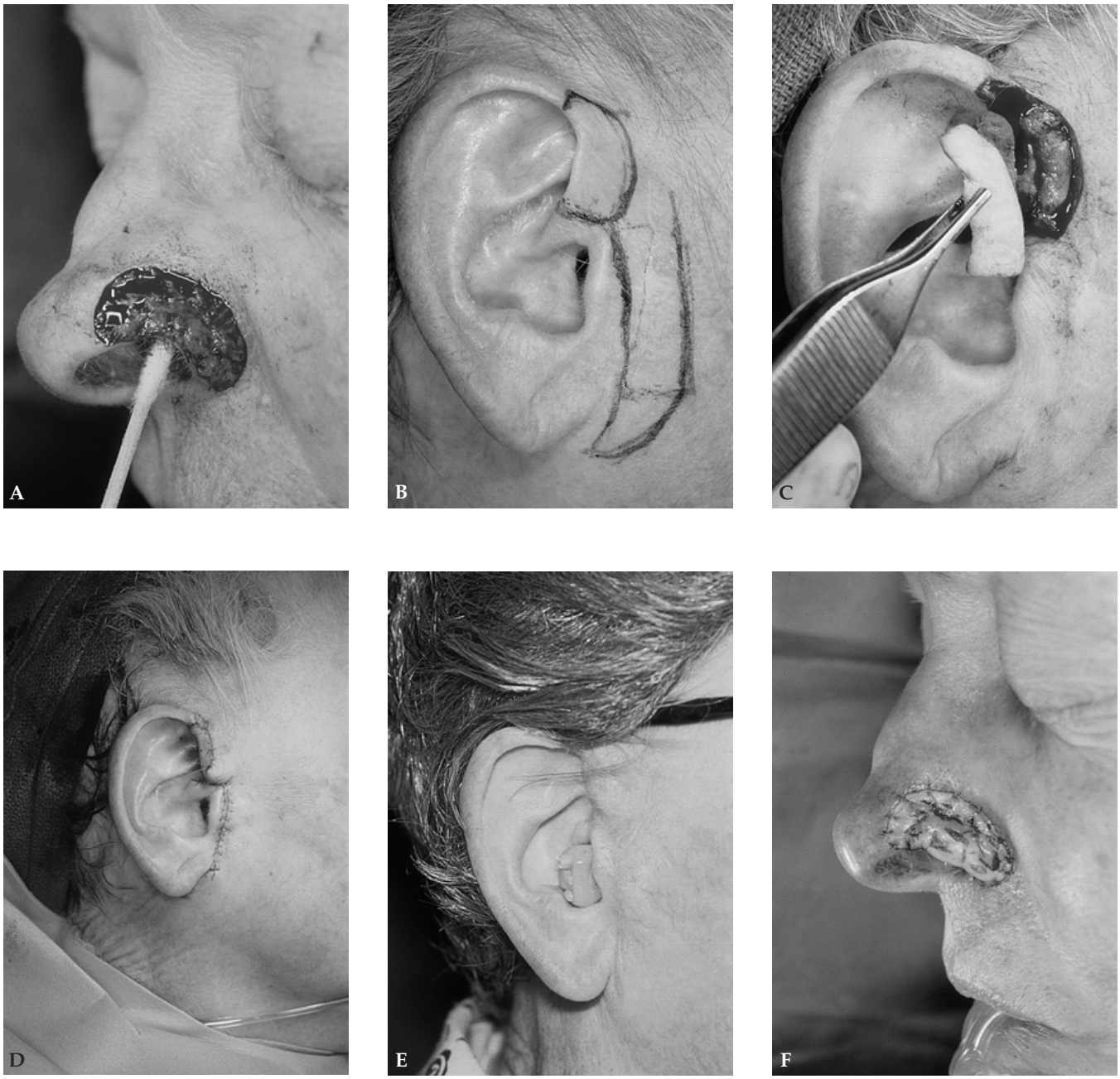


Figure 50–3 **(A)** Left nasal defect involving complete alar subunit following Mohs' resection for basal cell carcinoma. **(B)** Donor site for composite graft marked on auricular root and immediate reconstruction utilizing superiorly based preauricular skin flap. **(C)** Composite graft obtained. **(D)** Donor site reconstructed using superiorly based preauricular flap for the helical root. **(E)** Final appearance of reconstructed donor site demonstrating minimal deformity and morbidity. **(F)** Composite graft sutured in place in recipient bed. **(G)** Long-term result of composite grafting.

PERIPHERAL DEFECTS INVOLVING THE UPPER THIRD OF THE EAR

The primary consideration for defects involving the upper third of the rim is recreation of the normal anatomic curvature present here. When there is full-thickness loss, the postauricular and mastoid skin become convenient and suitable donor sites for reconstruction in this region (Fig. 50–4). These reconstructions can often be performed in a staged fashion with the use of skin grafts from the contralateral postauricular skin. In addition, excisions of lesions in this region require a stellate configuration to minimize pinching or notching of the helical rim contour.

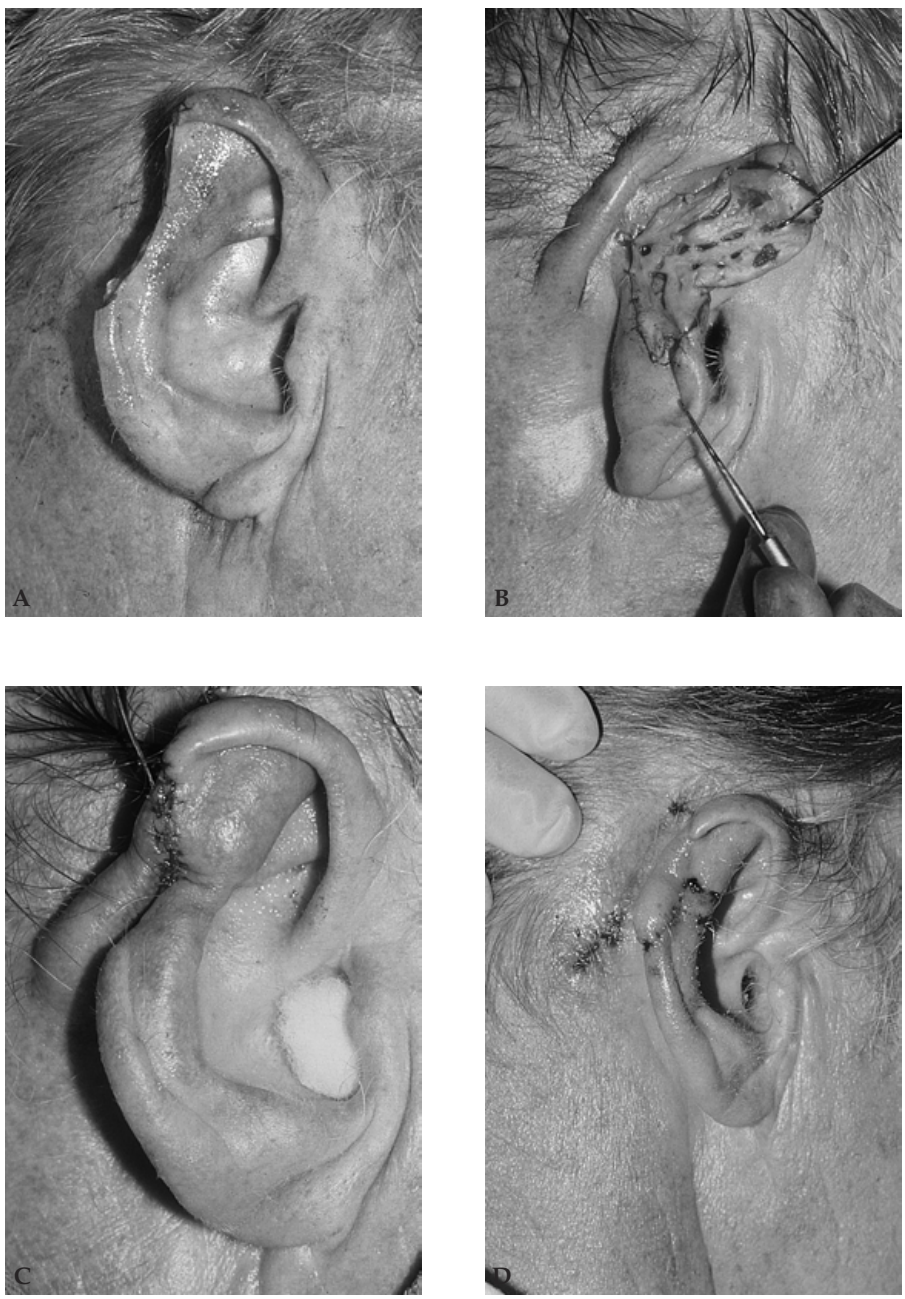


Figure 50–4 **(A)** Full-thickness defect status post Mohs' excision for squamous cell carcinoma involving helical rim and scapha of upper third of ear. **(B)** Staged reconstruction utilizing tube mastoid tissue and full-thickness skin grafting to postauricular defect. **(C)** First-stage attachment of superior portion of tube flap to superior aspect of defect. **(D)** Second-stage completion of reconstruction with attachment of inferior portion of tube flap to inferior portion of auricular defect to recreate auricular helical contour.

This approach allows appropriate apposition of the antihelix along with advancement of the helical rim to effect anatomic closure.

PERIPHERAL DEFECTS INVOLVING THE MIDDLE THIRD OF THE EAR

The predominant consideration in reconstruction of this portion of the auricular subunit once again is concerned with reestablishing the appropriate auricular contour. However, in contrast to the upper third of the ear, which is quite curved, the auricular contour in the middle third is relatively straight. The use of postauricular and mastoid tissue advancement flaps has proved to be extremely helpful in reconstructing the full-thickness defects involving this region (Figs. 50–5 and 50–6). Interpositioned cartilaginous grafts may be required in larger defects involving this region of the ear. An additional source of potential donor tissue is the contralateral normal ear, especially in the older patient who has experienced elongation of the soft tissue structures of the ear (Fig. 50–7). A full-thickness composite graft with replacement of both skin layers, as well as the intervening cartilage structure, can be used to restore appropriate helical architecture and contour. In addition, stellate excision and rim advancement of the donor site help achieve satisfactory closure and minimize donor site morbidity.

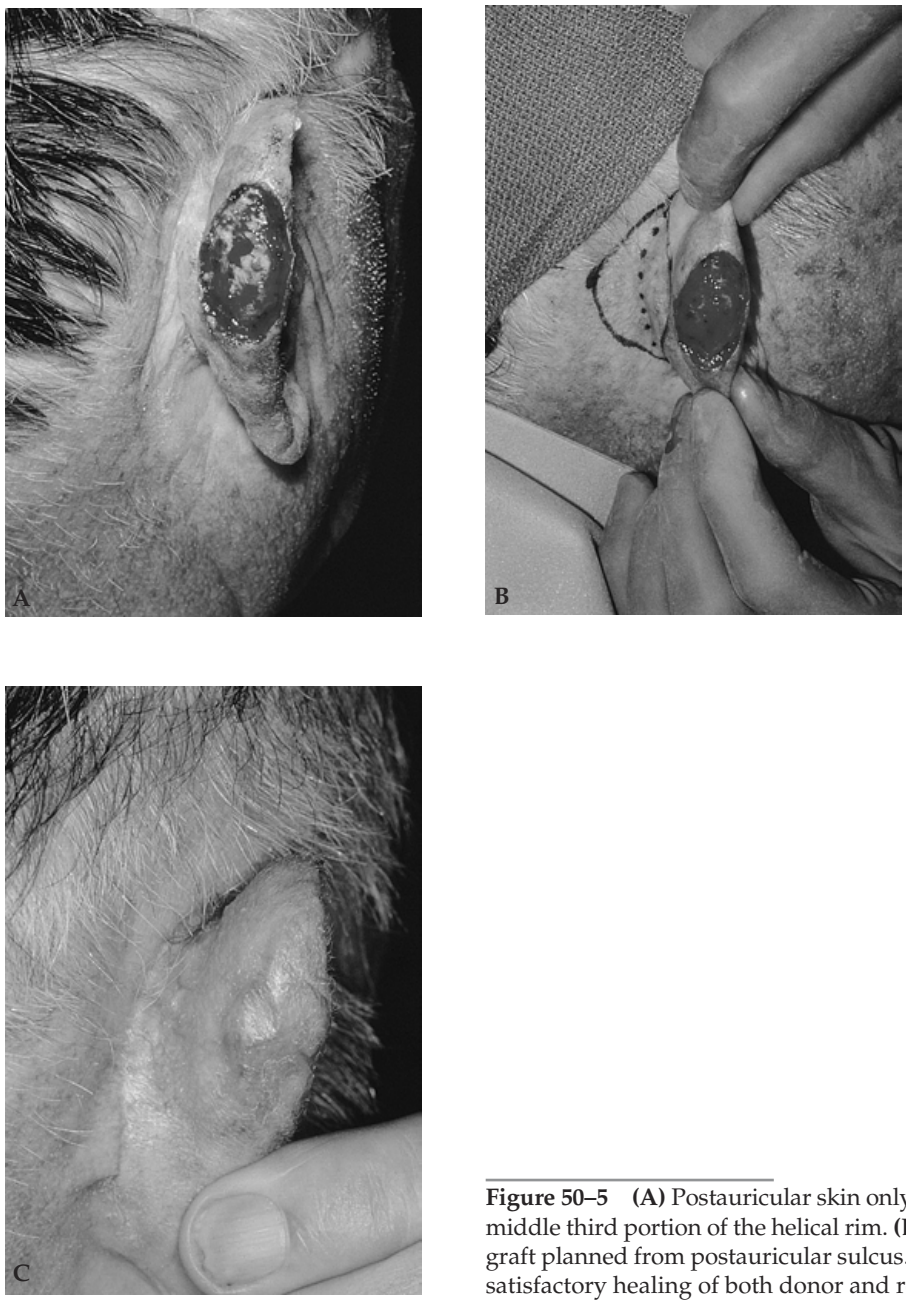


Figure 50–5 **(A)** Postauricular skin only defect involving the middle third portion of the helical rim. **(B)** Full-thickness skin graft planned from postauricular sulcus. **(C)** Final result with satisfactory healing of both donor and recipient sites.

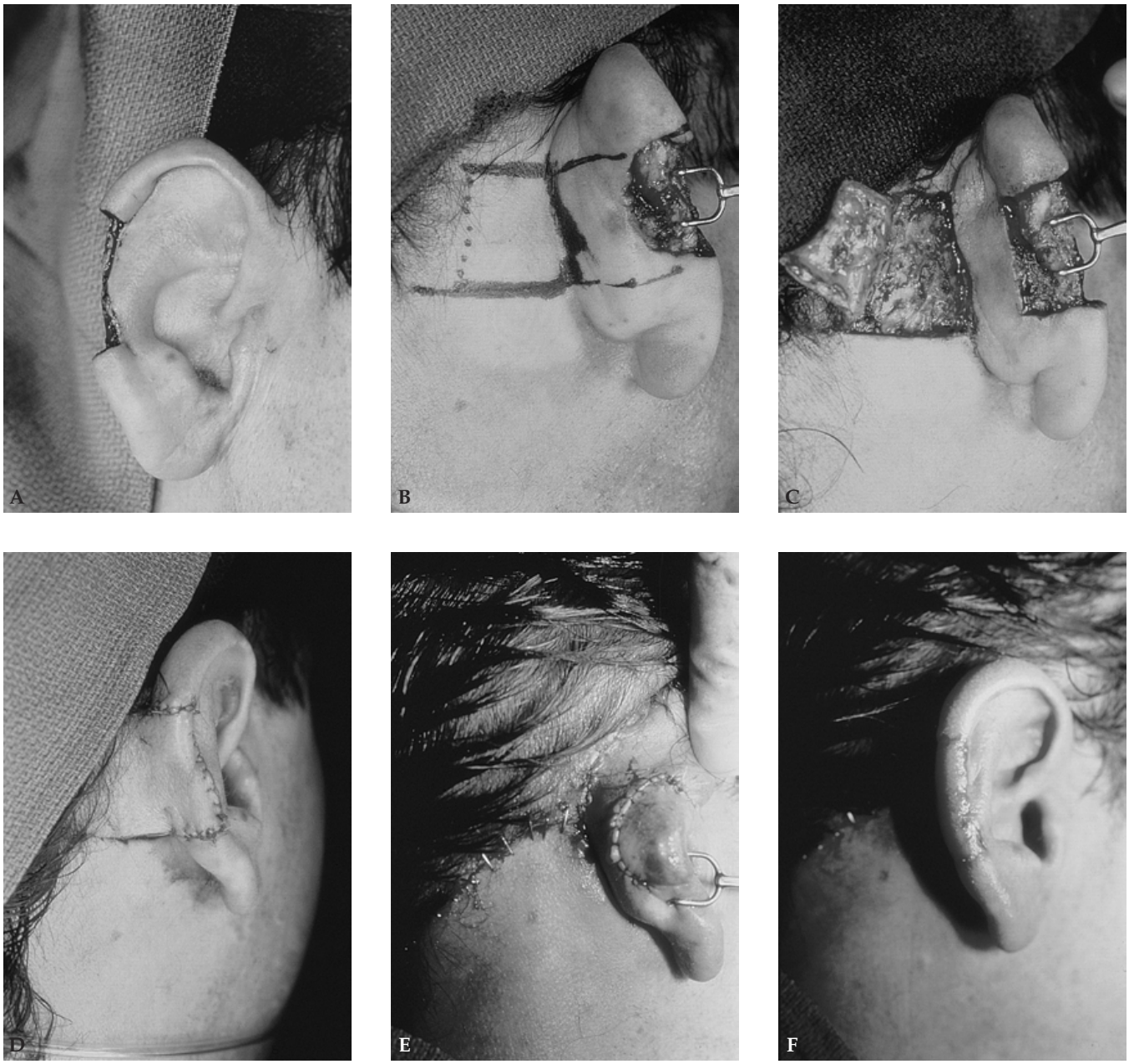


Figure 50–6 **(A)** Defect involving middle third of the auricle with full-thickness loss of the helical rim. **(B)** Postauricular mastoid flap planned for coverage of defect. **(C)** Elevation of flap prior to closure with view of intervening skin bridge. **(D)** Flap sewn into position. **(E)** Second-stage transsection of flap pedicle with repair of donor site. **(F)** Final outcome with satisfactory recreation of auricular helical contour.

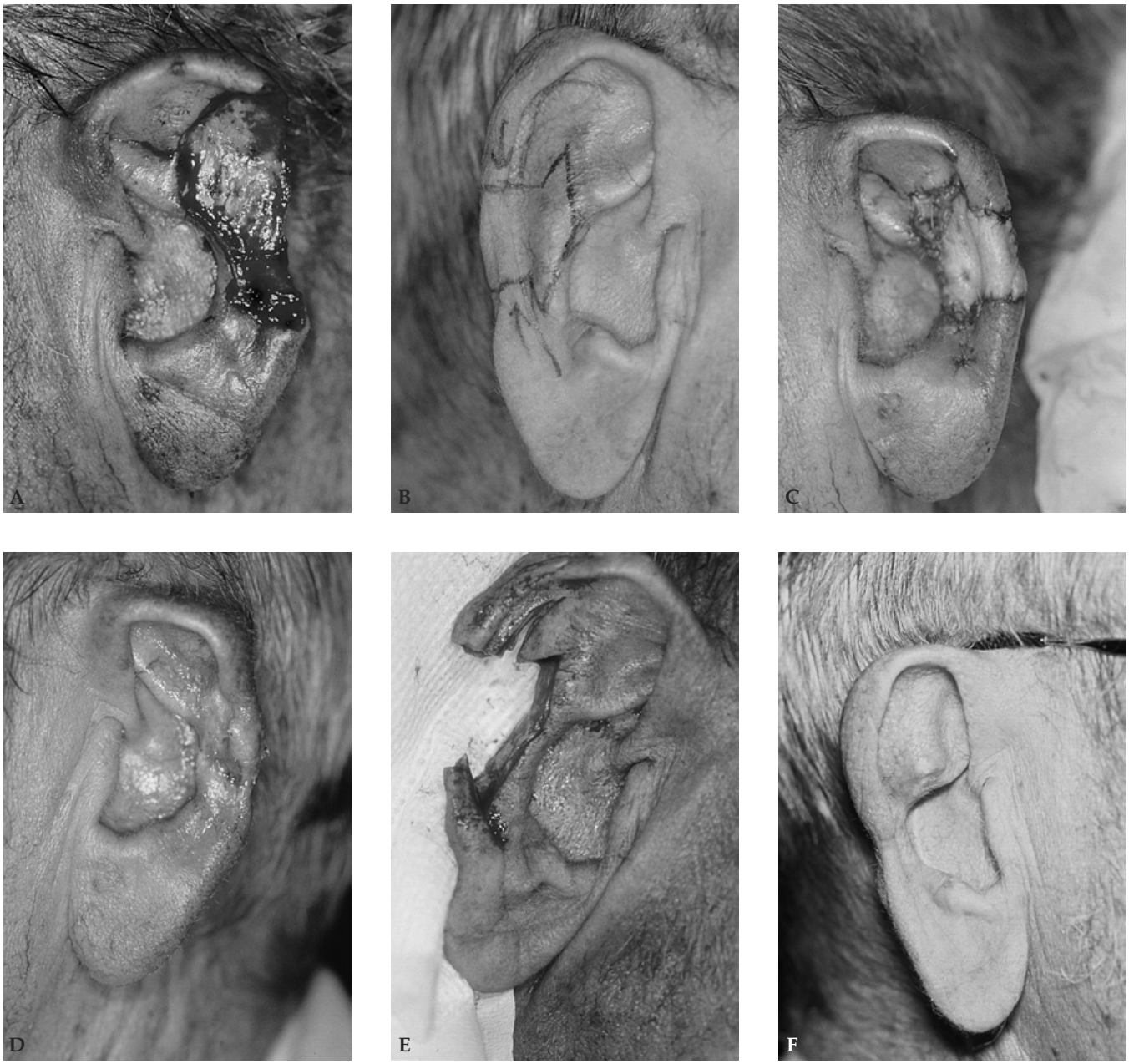


Figure 50–7 **(A)** Central third defect of left auricle following Mohs' resection for basal cell carcinoma. Defect involved skin and cartilage. This is an elderly patient with elongated ears. **(B)** Contralateral normal ear marked for full-thickness composite graft for reconstruction. Note a stellate pattern of excision, which will minimize notching deformities. Also note the helical rim advancements to reconstruct the donor site deformity. **(C)** Composite graft in position at recipient site. **(D)** Complete take of composite graft. **(E)** Donor defect following stellate excision and preparation of helical rim advancement. **(F)** Satisfactory healing of donor site with minimal morbidity and anatomic deformity.

PERIPHERAL DEFECTS INVOLVING THE LOWER THIRD OF THE EAR

In the area of the lower third of the ear, the predominant tissue is skin and subcutaneous fatty tissue with a minimal amount of intervening cartilage. For this reason, defects involving the earlobe can be simply and adequately reconstructed, again utilizing local soft tissue (Fig. 50–8).

When a more significant portion of the lower third of the ear is absent, local tissue is recruited along with contralateral auricular cartilage to recreate the normal auricular architecture (Fig. 50–9). Auricular lobule elongation occurs as part of the aging-face syndrome. This can result in a pendulous lobule that patients find objectionable. This is a condition that can be easily corrected via simple wedge excisions to recreate a more youthful lobule contour (Fig. 50–10).

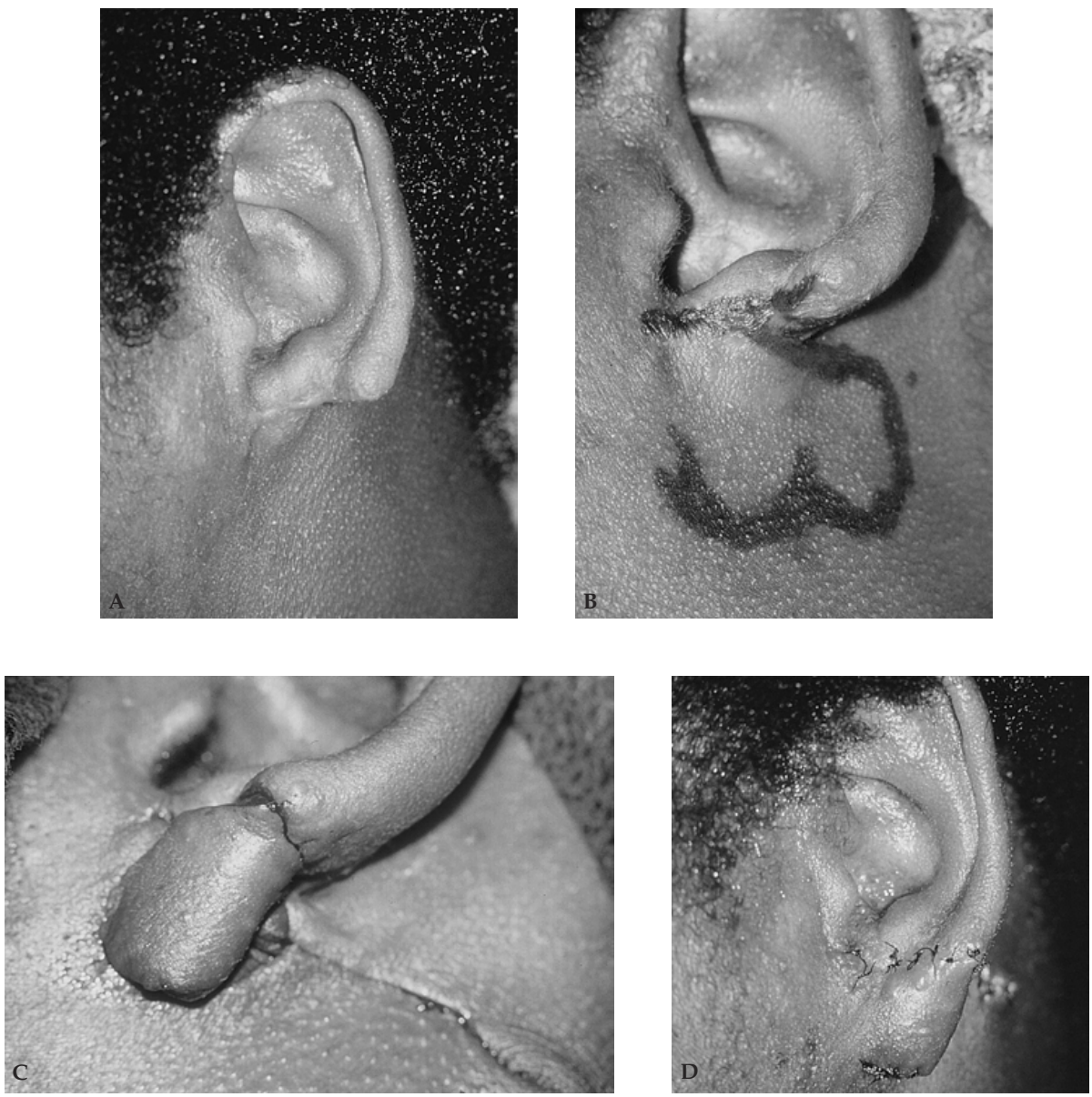


Figure 50–8 **(A)** Full-thickness loss of left earlobe. **(B)** Bilobed flap reconstruction of earlobe. **(C)** Flap sutured into position to reconstruct earlobe with closure of donor site. **(D)** Satisfactory recreation of earlobe.

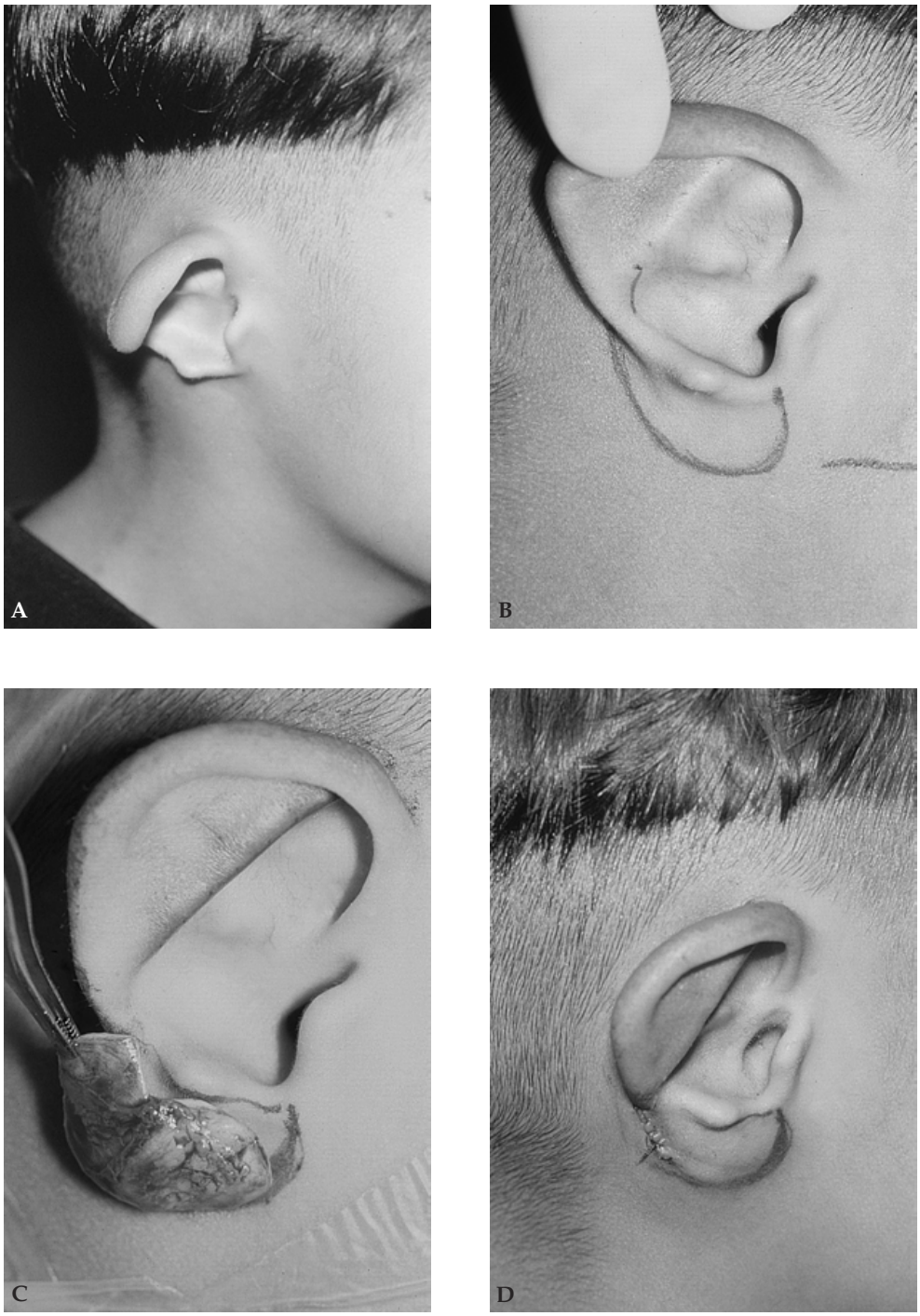


Figure 50–9 **(A)** Child with cup-ear deformity and congenital complete absence of lower third of right ear. **(B)** Absent portion of ear marked based on contralateral auricular contour. **(C)** Conchal cartilage graft from contralateral normal ear to be used as cartilage graft to help define lower third of ear. Note also creation of antihelical ridge for correction of cup-ear deformity. **(D)** Completion of first stage with implantation of cartilage. *(continues on next page)*

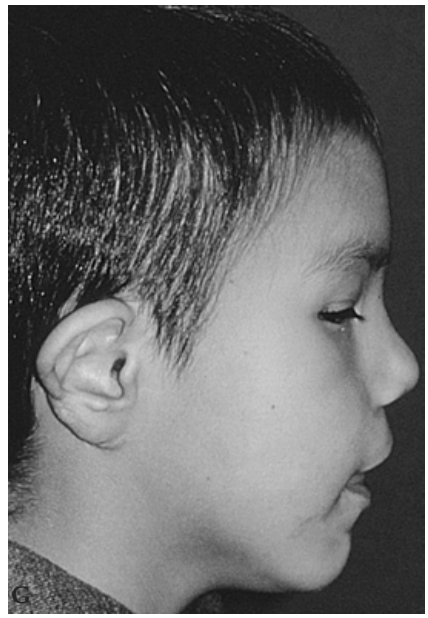


Figure 50–9 *(continued)* **(E)** Completion of second stage with elevation of cartilage graft and postauricular skin grafting. **(F)** Preoperative appearance with cup-ear deformity and congenital absence of inferior aspect of ear. **(G)** Complete postoperative result with improvement of cup-ear deformity and reconstruction of inferior aspect of ear.

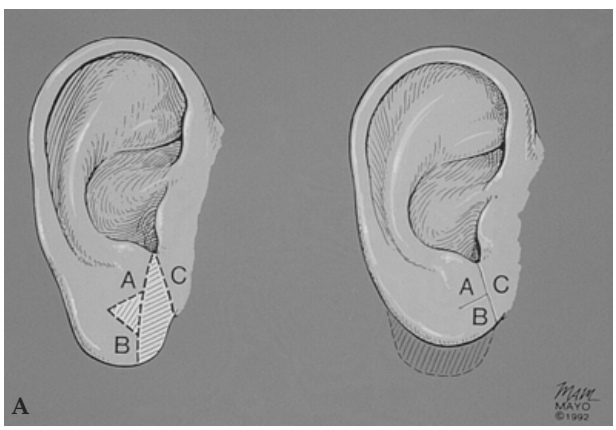


Figure 50–10 **(A)** Reduction of the aging elongated earlobe via two triangular excisions. **(B)** Excisions marked intraoperatively on patient. **(C)** Completion of earlobe reduction. Note correction of pendulous earlobe. This procedure is routinely performed in conjunction with aging-face surgery.

DEFECTS INVOLVING PERIAURICULAR TISSUES

Significant tissue loss in the periauricular region can usually be reconstructed with recruitment and mobilization of cervical facial skin to resurface the defect (Fig. 50–11). When the defect involves the preauricular temporal hair tuft, reconstruction can be performed using a hair-bearing scalp flap recruited from the postauricular region to recreate the preauricular temporal tuft. The postauricular donor region is closed with local advancement flaps (Fig. 50–12).

Figure 50–11 **(A)** Preauricular defect following Mohs' excision for basal cell carcinoma. **(B)** Reconstruction with cervical facial advancement flap.

Figure 50–12 **(A)** Preauricular defect following excision for skin malignancy. Note that superior aspect of defect extends to the temporal hair-bearing region of the scalp. Reconstruction of this area involves resurfacing of the lower aspect of the defect, as well as bringing in hair-bearing skin to reconstruct the temporal tuft. **(B)** Postauricular skin recruited to reconstruct preauricular defect using superiorly based occipital hair-bearing scalp to reconstruct the temporal tuft and inferiorly based mastoid skin flap to reconstruct the inferior aspect of the defect. **(C)** Closure of postauricular scalp and mastoid donor sites. *(continues on next page)*

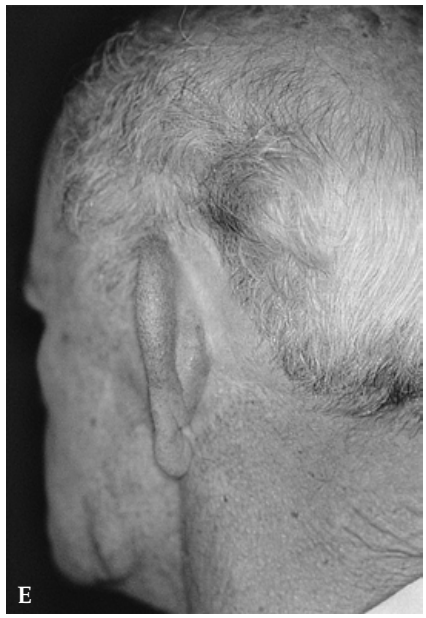


Figure 50–12 *(continued)* **(D)** Final appearance. Note satisfactory reconstruction of preauricular temporal hair-bearing tuft. **(E)** Final appearance, postauricular view. Note satisfactory camouflage of donor site scars and recreation of natural occipital hairline.

LARGE DEFECTS INVOLVING BOTH THE CENTRAL AND PERIPHERAL PORTIONS OF THE EAR

Large defects of the ear present the greatest challenge for the reconstructive surgeon. A number of reconstructive options exist in these circumstances. The patient's wishes are critical in this decision-making process. Not all patients want to have their defects reconstructed. For some, the primary concern is retaining the helical root and superior helical rim portion of the ear, which will allow them to wear their glasses securely. In those instances, simple closure of the remainder of the defect would suffice to meet the patient's desires (Fig. 50–13). Other patients may not be candidates for total auricular reconstruction. For patients in whom neglect was a significant factor in the initial disease process, as well as patients in whom secondary tumor surveillance is critical, reconstruction should be deferred until a more appropriate time. In that circumstance, simply resurfacing the region and subsequent camouflage with a wig would fulfill the patient's oncologic requirements (Fig. 50–14).

For patients with total auricular loss who desire reconstruction but for whom continued tumor surveillance is required, the use of an auricular prosthesis is a viable option. The prosthesis is anchored by clips to titanium

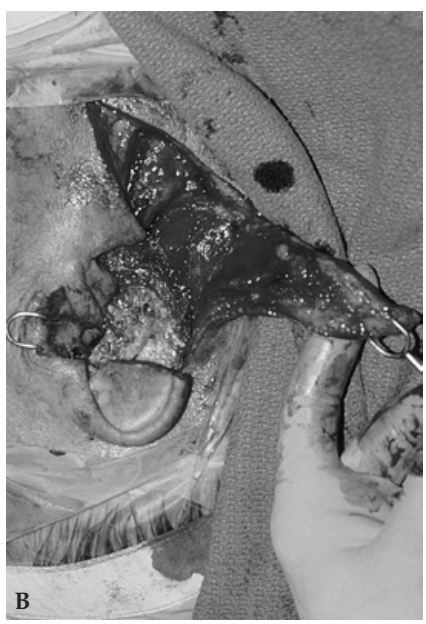


Figure 50–13 **(A)** Auricular mastoid defect following removal for malignancy. Patient is only interested in having the superiormost portion of his ear intact to allow him to wear eyeglasses. He was not interested in further extensive reconstruction. **(B)** Myocutaneous flap elevated for reconstruction of exposed bony defect, as well as recreation of ear contour. *(continues on next page)*

Figure 50–13 *(continued)* **(C)** Flap swung into position and all raw surfaces satisfactorily covered. Note that no attempt was made at reconstructing the auricular defect other than simple closure of edge of excision. **(D)** Long-term follow-up showing satisfactory healing with superior auricular portion intact to allow patient to wear eyeglasses.

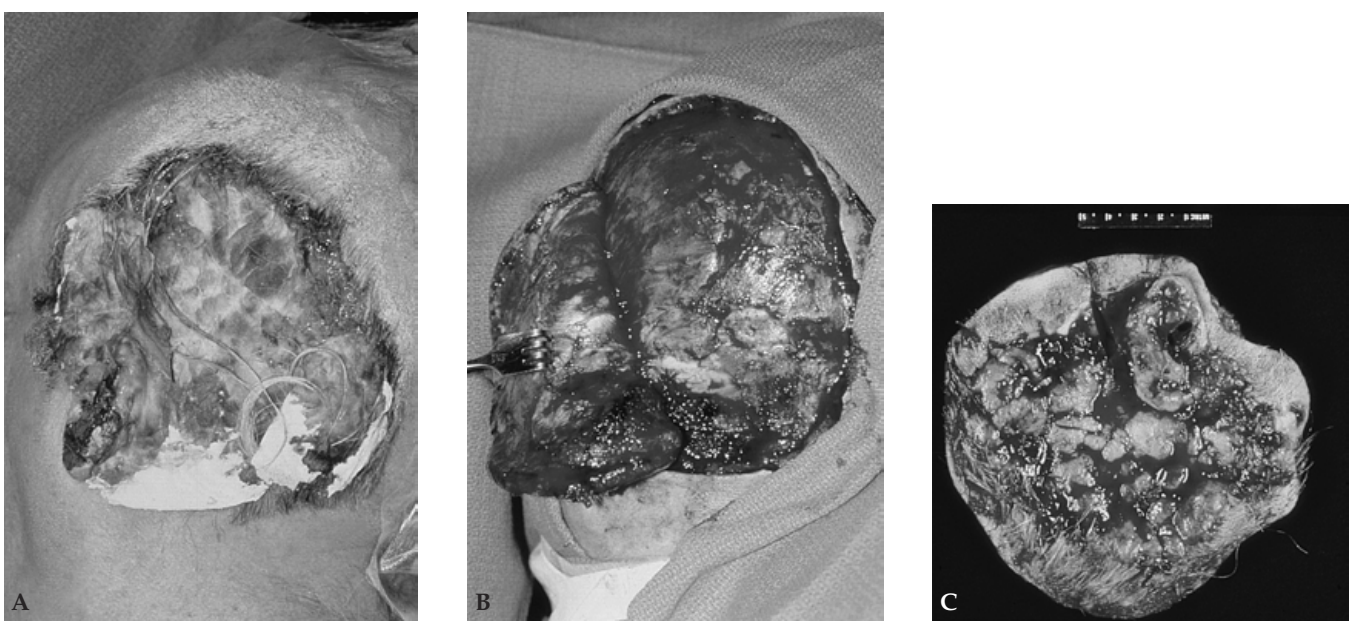


Figure 50–14 **(A)** Giant neglected basal cell carcinoma involving the ear, mastoid, and temporal region. Patient has been ignoring this lesion for years and has been dressing it with tissue paper. **(B)** Intraoperative excision of tumor down to temporalis muscle and mastoid bone. **(C)** Specimen with complete auriculectomy. *(continues on next page)*

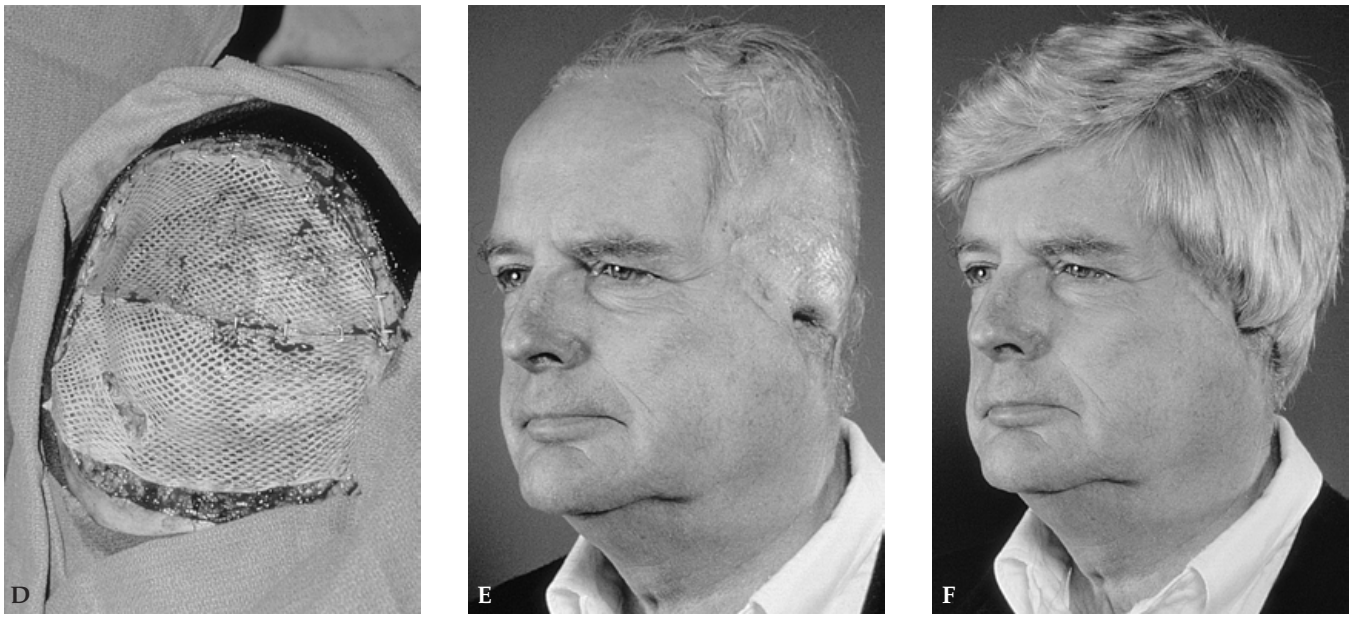


Figure 50–14 *(continued)* **(D)** Due to the need for ongoing tumor surveillance and the history of patient's neglect, a full-thickness skin graft was used to resurface the entire region. **(E)** Final postoperative appearance. **(F)** Patient camouflages the temporal and auricular defect with wig.

osteointegrated implants placed in the mastoid bone. Placement of these implants involves a simple outpatient procedure that is done in two stages. The anaplastologist fabricates the prosthesis, which is based on a mirror image of the patient's normal ear. These reconstructions recreate an excellent fascimile of an ear while allowing simultaneous tumor surveillance (Fig. 50–15).

In cases where the patient desires autogenous tissue reconstruction of large auricular defects, the principle used in microtia reconstruction is incorporated. This involves

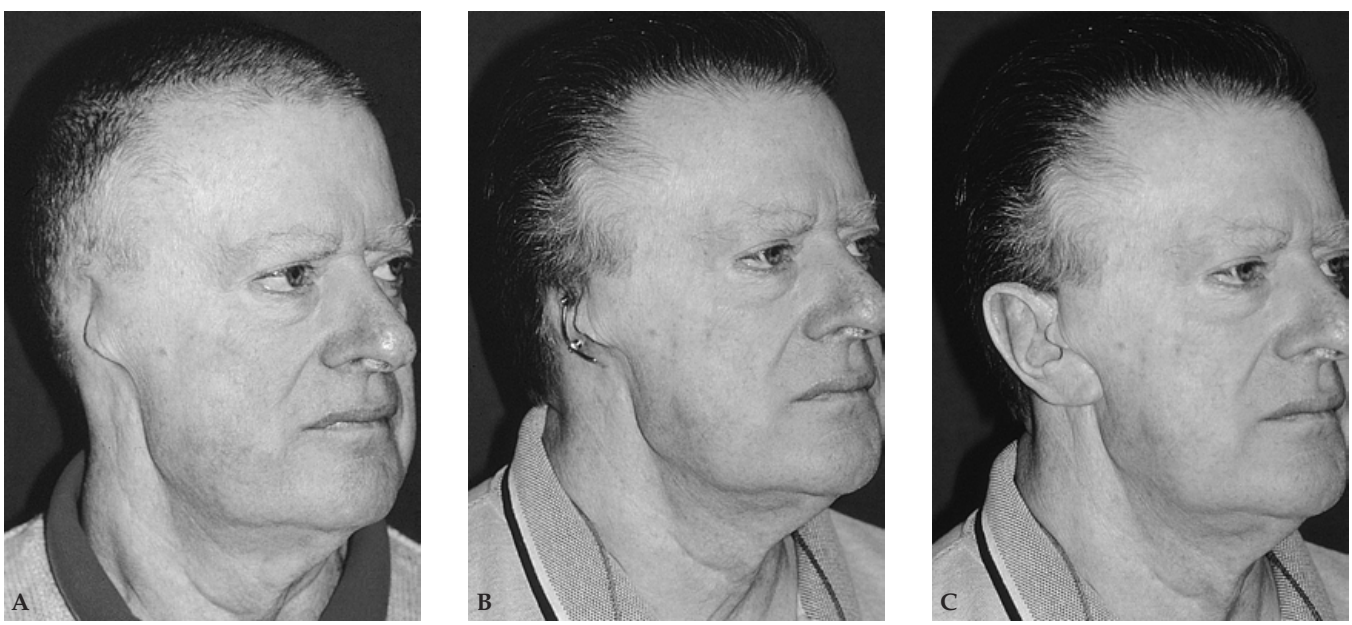


Figure 50–15 **(A)** Patient status post total auriculectomy for recurrent malignant melanoma. **(B)** Patient with titanium osteointegrated implant in place with abutment attached to wire. **(C)** Prosthetic ear is easily attached to the wire framework.

the creation of a freestanding costal cartilage sculptural framework that is implanted in vascularized tissue (Fig. 50–16). This process is done in a staged fashion to recreate a freestanding auricular contour. When additional vascularity is required, the temporoparietofascial flap (Fig. 50–17) has been used in conjunction with autogenous costal cartilage framework and primary skin grafting to recreate the appropriate auricular contour (Fig. 50–18). The advantage of this technique lies in the fact that complete reconstruction can take place essentially in a one-stage setting, allowing very satisfactory reconstruction of large defects of the ear (Fig. 50–19).

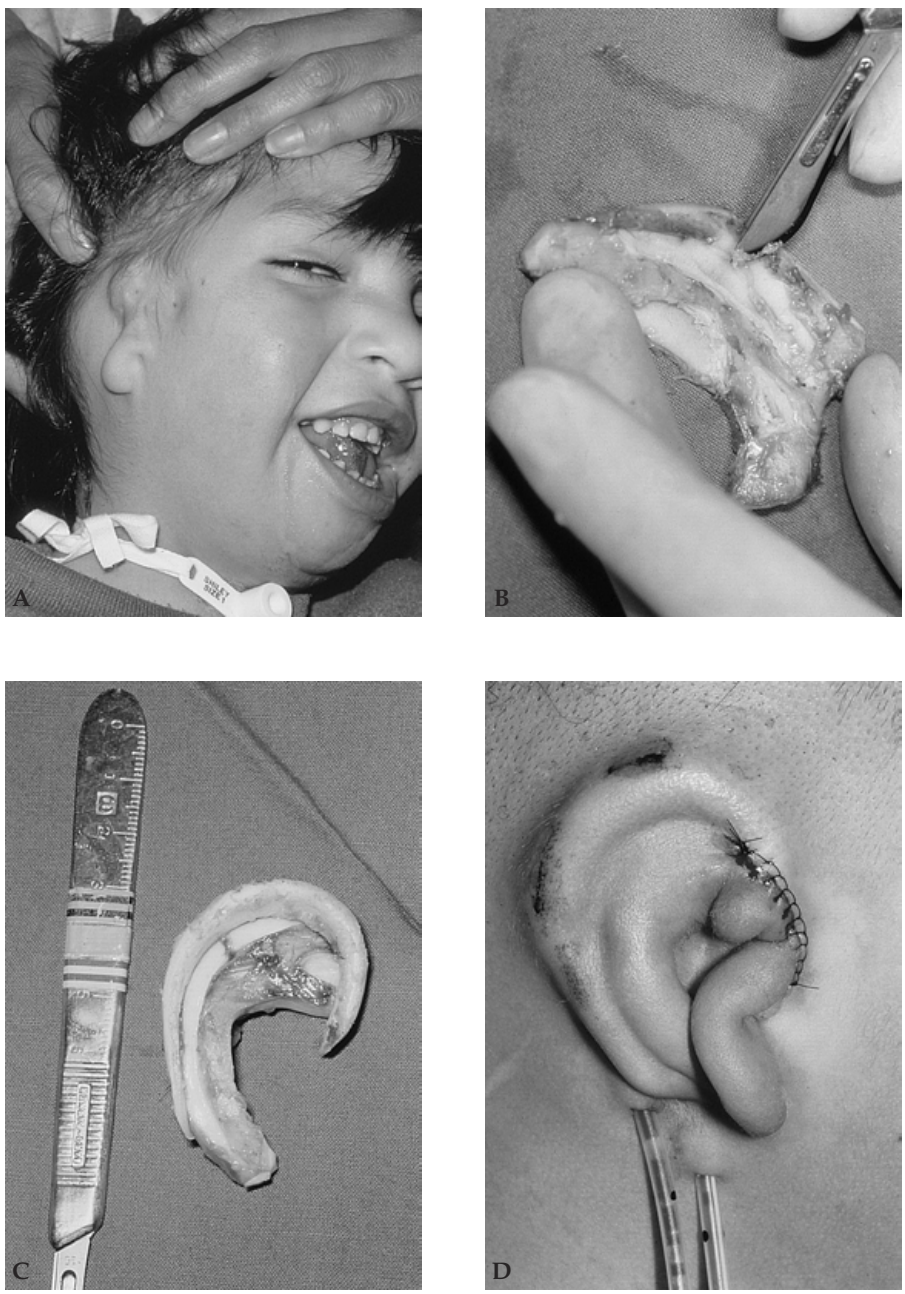


Figure 50–16 **(A)** Patient with unilateral microtia deformity. **(B)** Autogenous costal cartilage harvested for reconstruction. The costal cartilage is carved in framework of an ear intraoperatively patterned on the contralateral normal ear. **(C)** Completed ear cartilage framework. **(D)** Ear cartilage framework implanted under skin pocket to create auricular sillhouette. *(continues on next page)*

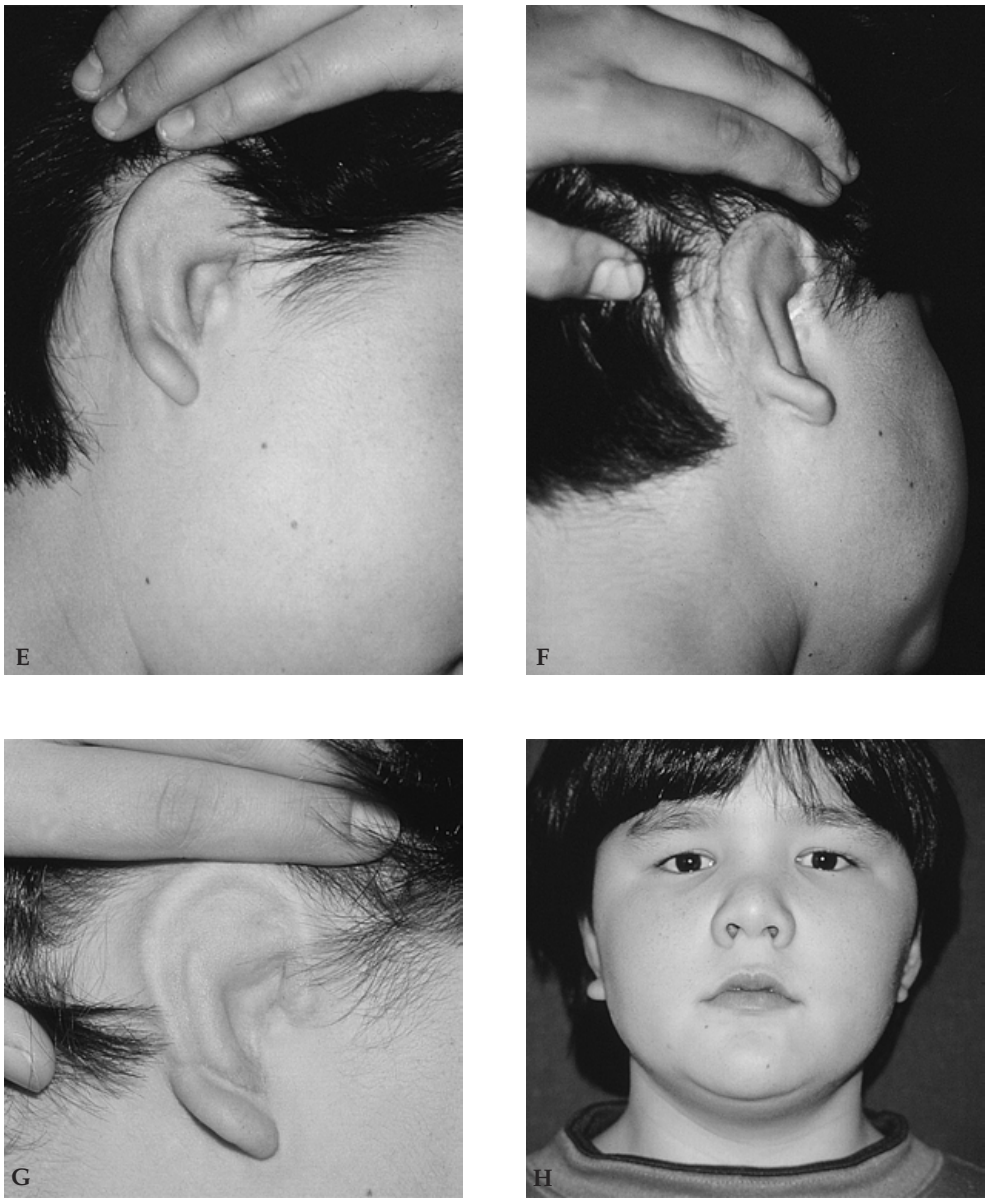


Figure 50–16 *(continued)* **(E)** Auricular silhouette following lobule transposition. **(F)** Ear cartilage framework elevated from side of head with creation of postauricular sulcus. **(G)** Final appearance of reconstructed ear, including tragus. **(H)** Final reconstructive result, frontal view.

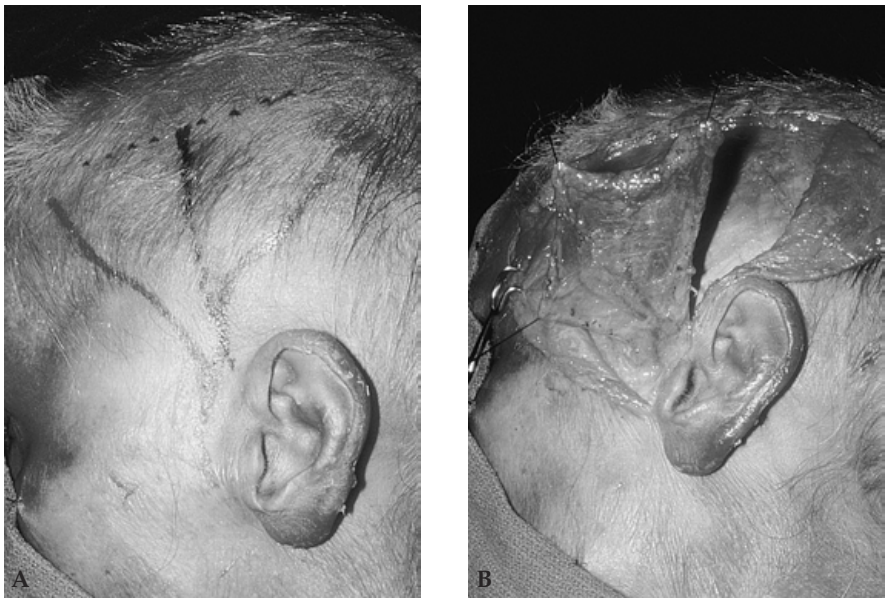
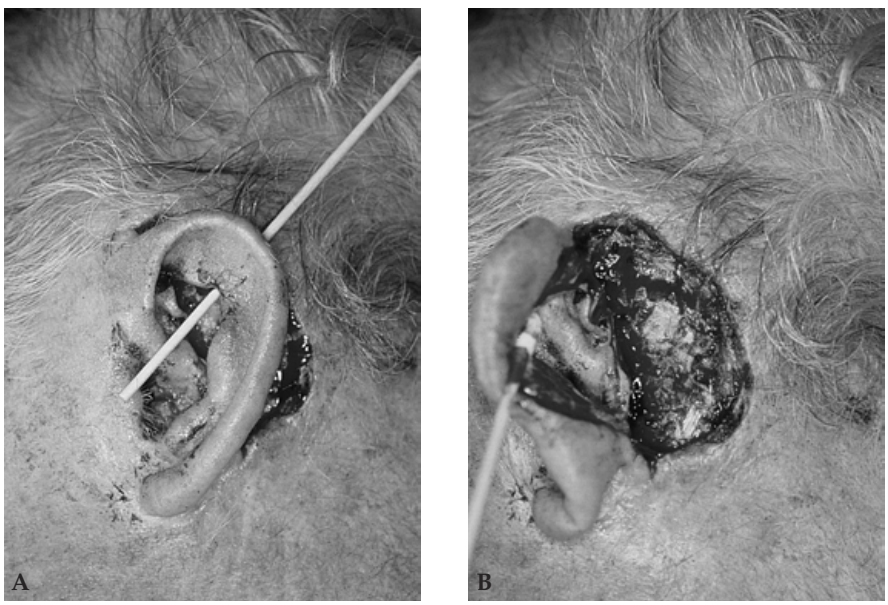


Figure 50–17 **(A)** "T" incision used to harvest temporoparietofascial flap. Anterior and posterior superficial temporal vessels are also marked. **(B)** Anatomy of temporoparietofascial flap elevated based on superficial temporal vessels. Note the dense white conjoint temporal fascia found deep to the superficial temporoparietal fascia.



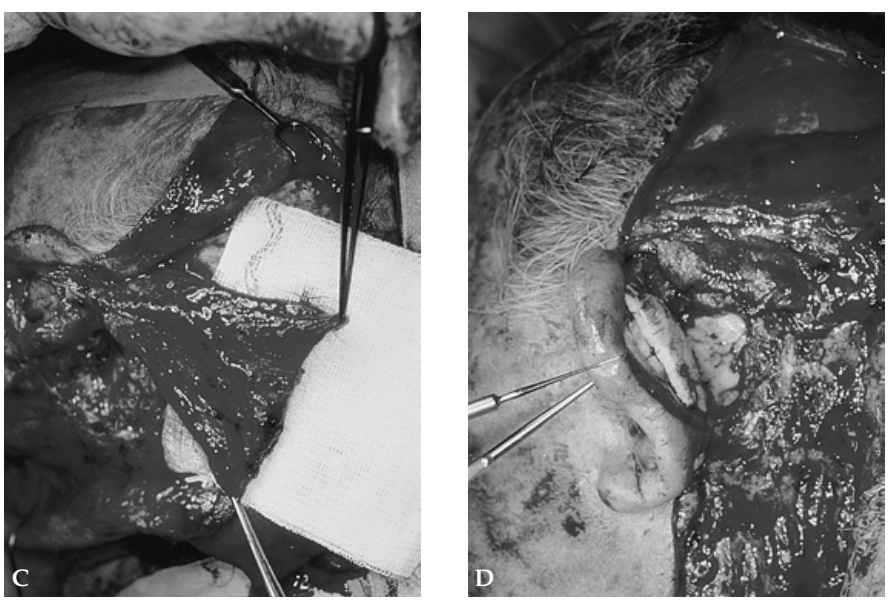


Figure 50–18 **(A)** Large auricular defect involving full-thickness loss of mid portion of ear following cancer excision. **(B)** Ear reflected forward to reveal the full-thickness loss, as well as postauricular defect down to mastoid bone. **(C)** Well-vascularized temporoparietofascial flap harvested to provide vascularity. **(D)** Autogenous costal cartilage shaped to recreate cartilaginous portion of defect and provide auricular structural framework. This will be wrapped with the vascular temporoparietofascial flap and covered with skin graft for reconstruction.
(continues on next page)

Figure 50–18 *(continued)* **(E)** Completion of initial reconstruction. **(F)** Postauricular view of completed reconstruction. **(G)** Long-term follow-up with excellent maintenance of auricular contour and satisfactory healing of temporoparietal donor site.

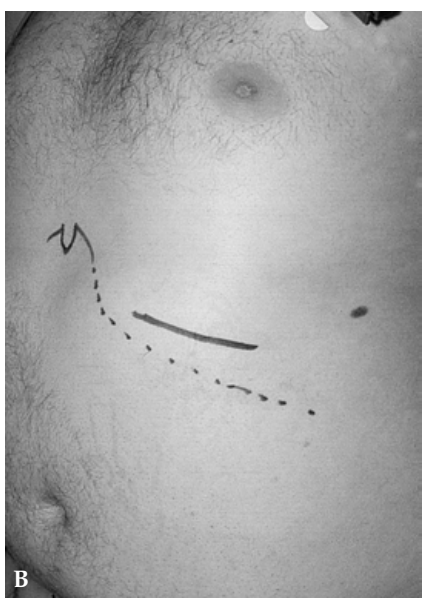


Figure 50–19 **(A)** Large full-thickness defect of right ear following cancer excision. **(B)** Marking for harvest of autogenous costochondral cartilage. **(C)** Costochondral cartilage harvested and ready for sculpturing. **(D)** Temporoparietofascial flap raised to provide vascular lining. *(continues on next page)*

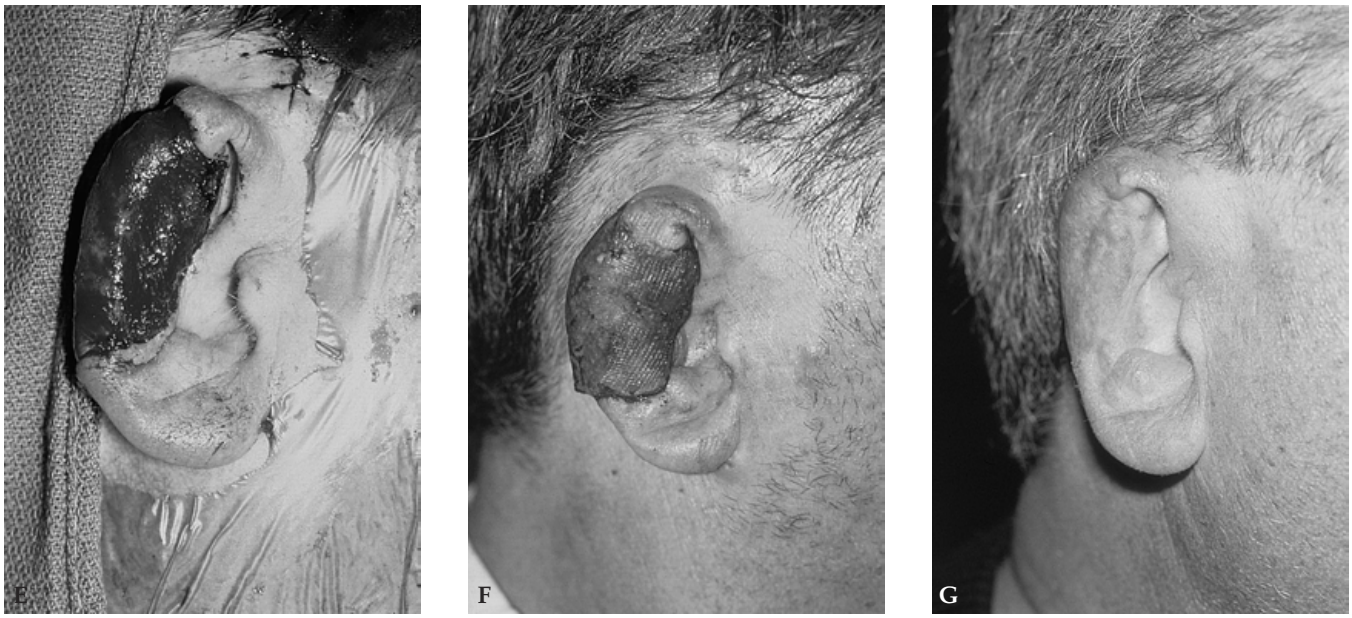


Figure 50–19 *(continued)* **(E)** Cartilage framework and temporoparietofascial flap sewn into position to reconstruct the defect. **(F)** Appearance at 1 month following reconstruction. **(G)** Four-year postoperative result demonstrating satisfactory recreation of auricular contour.

SUMMARY

Auricular reconstruction can present myriad challenges for the reconstructive surgeon. As in reconstruction elsewhere in the head and neck, it is useful to approach defects in the ear from the standpoint of aesthetic subunits that will help guide the reconstructive effort. Appropriate reproduction of the missing anatomic region conforming to the appropriate subunit principle will yield a satisfactory reconstructive outcome.

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Chapter 51

Lip Reconstruction

Edwin F. Williams III and Christopher Hove

HISTORICAL PERSPECTIVE

Lip reconstruction for large defects of the lower and upper lip continues to be a formidable challenge. The first written description of lip reconstruction was by Susruta in 1000 BC, but an ancient Hindu description of facial, lip, and nasal reconstruction with a forehead flap is reported as early as 3000 BC.[1] Sabatini first described lip reconstruction using a cross-lip flap in 1837,[2] but a subsequent modification of this technique by Abbe and Estlander resulted in their names being ascribed to this method of reconstruction. Bernard and Burow later described a method of lip reconstruction for total and subtotal defects using bilateral full-thickness advancement flaps to the cheeks that were brought to the midline to fashion a new lip.[3,4] Full-thickness triangles were excised in the location of the nasal alar fold to alleviate puckering that resulted from tissue excess in that location. In the 1920s, Gillies described a classic fan flap using a full-thickness pedicle that allows redistribution of the remaining lip during the reconstructive effort and emphasized the use of similar or like tissue.[5] This concept was further modified by Karapandzic in 1974, who made incisions through the skin and mucosa at a distance equal to the depth of the defect, but with primary emphasis on preservation of the underlying musculature and neurovascular structures.[6] More contemporary refinements for reconstruction of large lip defects by Burget and Menick include the importance of the subunit principle as it applies to the upper lip for an optimal aesthetic result.[7]

Evaluation of the patient in need of lip reconstruction requires a clear understanding of the lip anatomy, aesthetics, and function. In this chapter, a systematic approach will be emphasized based on the anticipated or presenting size and location of the lip defect for a given patient.

ANATOMICAL CONSIDERATIONS

The primary objective of a reconstructive effort is an aesthetic result that approaches a normal appearance. Functional considerations, including oral competence, articulation, speech, and the role of the lips in mastication, must be kept in mind during reconstruction of large lip defects.

Anatomically, the lips extend vertically from the subnasale to the chin and horizontally from oral commissure to oral commissure. Both upper and lower lips consist of a separate red lip and white lip component separated by a vermilion border.

The upper lip is a curved "M"-shaped structure with the highest points of the vermilion border just located at the philtral ridges. The philtral ridge extends bilaterally from the highest point of the vermilion border to the base of the columella, and between the lines is a central depression in the upper lip. The complexity of the surface topography, its lines and shadows, results in two medial and lateral subunits of the upper lip, first described by Ulloa-Gonzales and subsequently emphasized by Burget and Menick as illustrated in Fig. 51–1. A reconstructive effort of the upper lip in which the surgical defect is simply filled without regard to the subunit principle is perceived by the observer as a patch. Aesthetically, for the lip to look normal, the observer's eye should perceive it as normal. The perception of normal is more accurately described as the absence of abnormal because the "mind's eye" of the observer ignores the defect it would see and focuses on the absence of aberrance. During lip reconstruction, one should

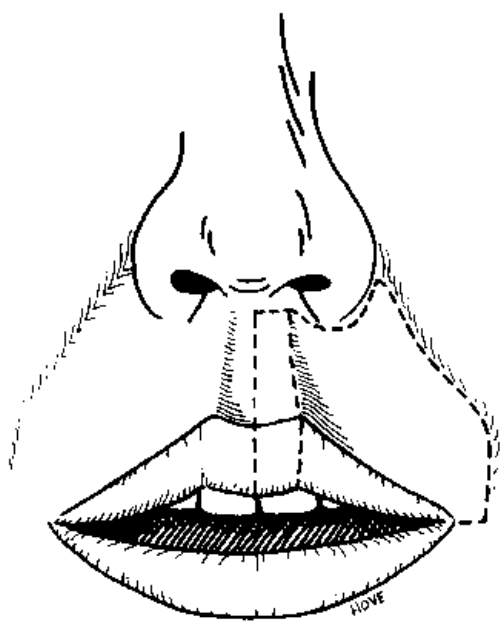

Figure 51–1 Medial and lateral upper lip subunit.

Figure 51–2 Periorbital musculature and muscular modiolas.

attempt to duplicate appropriate height, projection, and the relationship of white to red lip. In addition, because regional or distant tissue is a different color, the use of local tissue with local flaps generally provides a superior result. The lower lip anatomy is considerably less complex and more forgiving of a reconstructive effort. However, the same general principles apply for an optimal aesthetic result.

Functionally the lips act as a sphincter to assist phonation, mastication, and speech. Anatomical structures that are important to the function of the lips and oral sphincter include the perioral facial musculature, the neurovascular anatomy, and the muscular modiolus, all of which are located between the mucosal surface and the cutaneous surface of the lips. The muscular modiolus is a fibrous structure located at the oral commissure bilaterally and is a site of insertion of the oral sphincter musculature as illustrated in Fig. 51–2. The most successful functional reconstruction will address not only the integrity of the muscular oral sphincter but the importance of the orientation, position, and function of the muscular modiolus within the oral sphincter.

TECHNIQUES OF RECONSTRUCTION

Although traumatic defects were relatively common during times of war, the most common defect challenging the facial plastic surgeon is a result of an oncologic excision. Squamous cell carcinomas (SCCs) are the most common malignant neoplasm of the red lip (95%). Furthermore, lower lip SCCs outnumber upper lip SCCs (90% versus 10%), probably related to a more direct sun exposure encountered by the lower lip. However, in the author's experience, most basal cell carcinomas of the upper lip arise from the cutaneous white upper lip.

Reconstructive procedures can be classified as:

1. **Minor reconstruction**
   A. Vermilion defects
   B. Small full-thickness defects (less than 30% horizontal lip)
      1. Lower lip
      2. Upper lip
   C. Combination of previous
2. **Major reconstruction**
   A. Medium-size defects (30–60% horizontal lip)
      1. Upper lip
      2. Lower lip
3. **Subtotal/total lip reconstruction**
   A. Large defects (greater than 60% horizontal lip)
      1. Lower lip
      2. Upper Lip

Minor Reconstruction

Vermilionectomy

Vermilionectomy is indicated in the patient with chronic actinic cheilitis or microinvasive SCC. Actinic cheilitis is almost exclusively seen on the lower lips and can persist for several months or years before it progresses to SCC. A positive diagnosis is considered an indication for surgical treatment because of the long-term risk for invasive carcinoma. In the compliant patient where there is no concern about appropriate follow-up, the author advocates an ablation procedure with the CO_2 laser. Local anesthetic is infiltrated, and a laser-resurfacing mode is used at the same parameters one would utilize to treat eyelid skin. Two or three passes are performed, and the appropriate short- and long-term follow-up recommended. In the authors' experience with a compliant patient, this approach is very successful, and it is more cosmetically acceptable than a traditional vermilionectomy and lip–advancement procedure.

Technique A vermilionectomy procedure is the time-honored and traditional procedure for actinic cheilitis or carcinoma in situ, especially in the patient for whom reliable follow-up might be a concern. A surgical marking pen is used to delineate the vermilion border from oral commissure to oral commissure. A fusiform-type excision of the vermilion is planned and a posterior incision is placed parallel to the anterior vermilion border incision. The lip is infiltrated with the appropriate amount of lidocaine with 1:100,000 epinephrine. Incisions are performed and the vermilion is excised in a submucosal plane as illustrated in Figure 51–3. A submucosal dissection is carried from the posterior incision toward the gingival–buccal sulcus approximately two times the width of the fusiform excision from anterior to posterior. Posterior red lip is advanced in a meticulous repair that is performed along the vermilion with a 5-0 chromic suture. Two back-cuts from each oral commissure toward the sulcus may be necessary to facilitate advancement. It is important that the vermilion border be repaired without tension on the incision line.

Wedge Excision and Primary Repair

A wedge or full-thickness excision is indicated with invasive SCC of the lower lip. A full-thickness wedge excision and repair can be utilized for surgical defects measuring

up to one third the size of the horizontal lip. The length of the lower lip generally measures 7 to 7.5 cm, allowing a surgical defect of approximately 2.5 cm. However, one should exercise judgment in the patient at the upper limit of an acceptable excision for primary repair. In a patient with less tissue elasticity or one in whom repair will result in a significant and noticeable discrepancy of the upper and lower lip, it may be advisable to reconstruct using a cross-lip flap.

Technique A surgical marking pen is used to plan for the reconstruction. It is generally recommended that the vermilion border be marked adjacent to the line of resection as local anesthetic, edema, and the blanching effect of epinephrine often make a precise repair at the vermilion border difficult. The line of resection through the red lip should be perpendicular to the long axis of the red lip and allowed to converge beginning on the white lip as illustrated in Figure 51–4. Incorporation of an M-plasty in the repair is advised for larger wedge resections as it prevents the incision from crossing the lip–chin junction and assists in irregularizing a longer incision. The repair is begun by placing a 6-0 nonabsorbable, monofilament suture at the vermilion border (Prolene, nylon). Two or three interrupted sutures should then be placed in the obicularis muscle with a longer lasting absorbable monofilament polyglycolic suture (4–0 PDS, macron). A 4-0 chromic is used for the intraoral red lip, and the author prefers a 5-0 chromic for the exposed red lip repair. The skin should be closed with a 6-0 nonabsorbing monofilament (Prolene, nylon).

Combined Defects

Occasionally, a patient presents with a discrete lower–lip lesion amenable to excision with a full-thickness repair. How-

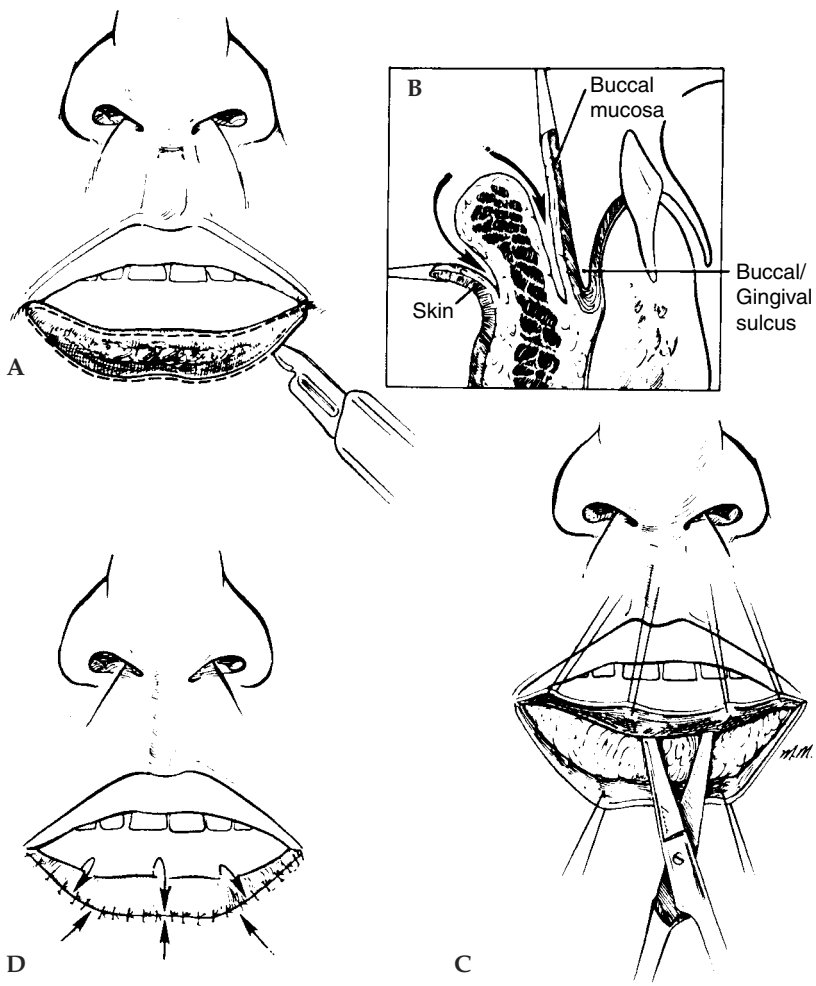

Figure 51–3 Vermilionectomy technique.

ever, on inspection the remaining red lip has the clinical appearance of a severe actinic cheilitis, placing the patient at high risk for subsequent carcinoma of the lip. In this patient population, a full-thickness incision and repair should be performed in conjunction with vermilionectomy and lip advancement for the remaining red lip.

Major Reconstruction

Medium Sized Defects: Cross-Lip Flap

Surgical defects measuring between 30 and 60% of the horizontal lip are best reconstructed with a staged cross-lip flap, as first described by Sabatini and further modified by Abbe and Estlander. In general, this corresponds to a surgical defect between 2.5 and 4.5 cm. The cross-flap reconstruction has the benefit of reconstructing a relatively large full-thickness lip defect with tissue of similar texture, complexion, thickness, and muscular activity. Electromyography studies at one year following reconstruction have confirmed the ability of the transferred obicularis muscle to reinnervate successfully and function as an animated segment.[7] In addition, the cross-lip reconstruction successfully redistributes the remaining upper and lower lip discrepancy to the deficient lip with a minimal effect on the muscular modulus in orientation of the remaining musculature of the oral sphincter. Because of the complexity of the upper lip anatomy as compared with the lower lip anatomy, the primary consideration of a cross-lip flap reconstruction is generally the effect the reconstruction will have on the upper lip anatomy.

Lower Lip

The approach to lower lip defects of 30 to 60% with a cross-lip flap is fairly straightforward, with primary emphasis placed on how taking the upper lip donor flap will affect the upper lip aesthetically.

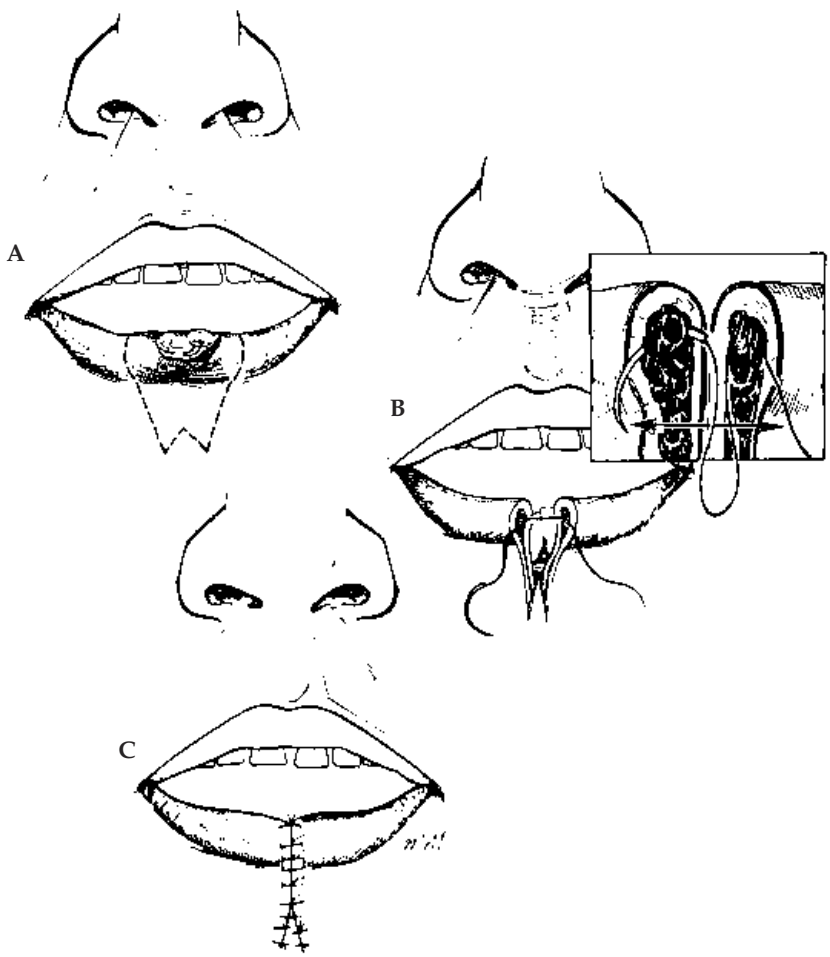

Figure 51–4 Wedge excision and primary full-thickness repair.

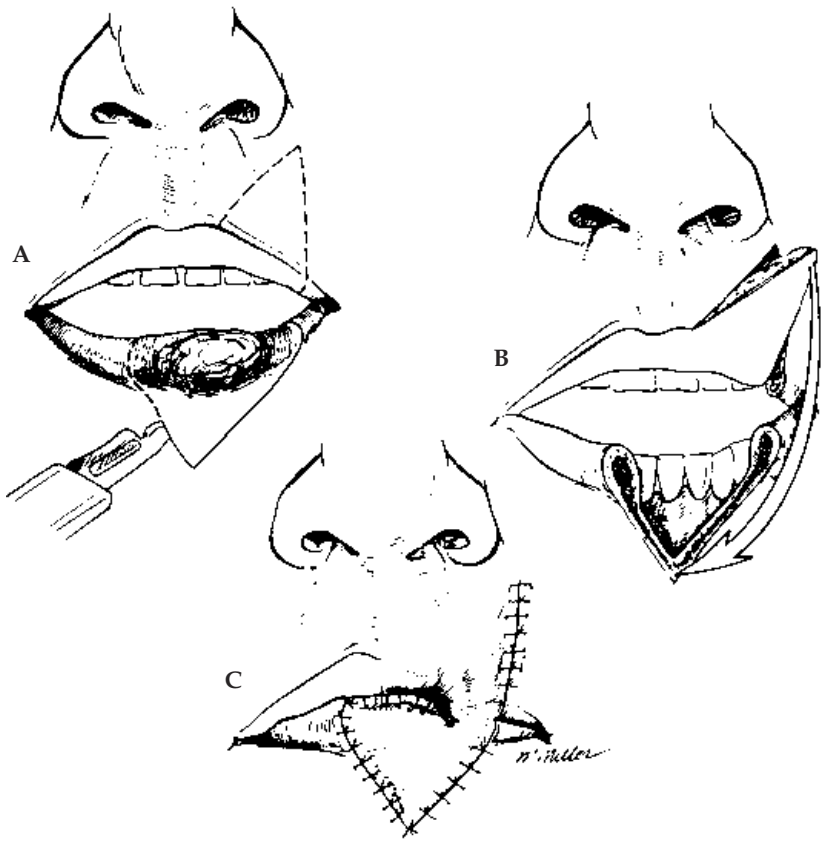

Figure 51–5 Cross-lip flap technique.

Technique After a wedge resection of the lower lip has been performed, a triangular full-thickness flap is designed on the upper lip. Traditionally, a cross-lip flap is designed at a width of one half to two thirds of the horizontal lip surgical defect, as illustrated in Figure 51–5. A full-thickness incision is carried approximately 2 to 3 mm to the vermilion border, and a meticulous dissection through the orbicularis muscle allows preservation of the labial artery. Burget emphasizes the importance of the blood supply provided by the vermilion mucosa and stresses the importance of preserving approximately 5 mm of mucosa in addition to the labial artery, which is included in the pedicle. Division and inset of the flap should occur at 14 to 21 days, and no attempt is made to test the flap with a tourniquet as suggested by some authors.

In the fastidious patient with a larger defect (60 to 70% lower lip), one should consider bilateral cross-lip flaps to fill the lower lip defect as shown in Figure 51–6. This approach not only keeps the incision lines at the junction of the aesthetic subunits of the upper lip, but it also distributes the loss between the upper lip lateral subunits rather than recruiting all tissue from one side and causing a noticeable upper lip asymmetry.

Upper Lip

Upper lip defects pose a greater challenge for an optimal reconstruction because of the surface topography, complexity of the anatomy, and potential for distorting the upper lip subunits, thus creating a noticeable asymmetry.

Technique In defects that result in more than 50% loss of the subunit, the reconstructive surgeon should excise the remaining normal tissue and replace the entire subunit from the lower lip, as shown in Figure 51–7. The template from the contralateral normal subunit is outlined on the upper lip, and a similar technique is used for developing, transposing, and resecting the cross-lip flap. The contralateral normal lip is utilized for developing a template because the presence of local anesthetic, tumor, and edema will result in a less accurate template if one uses the involved lip and subunit.

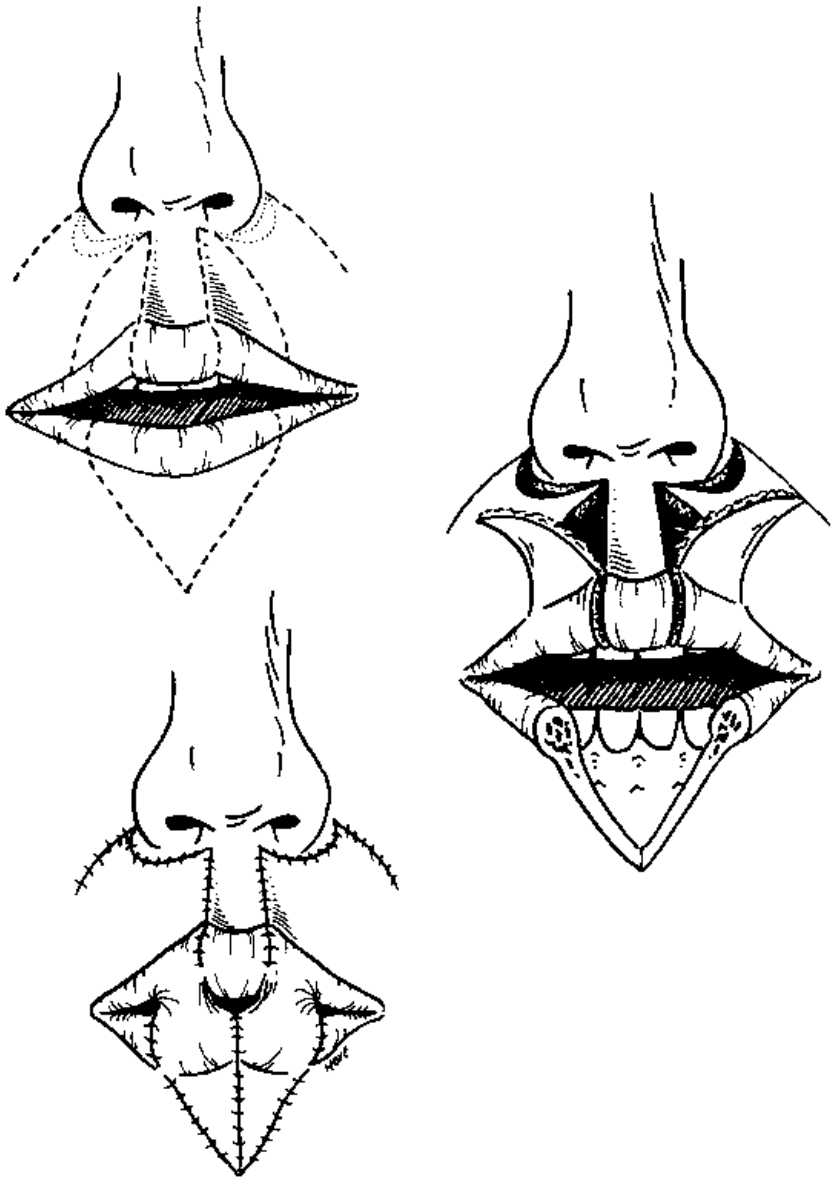

Figure 51–6 Modified bilateral cross-lip flap for the lower lip.

Subtotal/Total Lip Reconstruction

Surgical defects measuring greater then 70 to 80% of the lip continue to be a formidable challenge. In the 1920s, Gillies first described the classic fan flap using a full-thickness pedicle that allows redistribution of the remaining lip as illustrated in Figure 51–8. Karapandzic further modified this concept with an incision through both the skin and mucosa, with emphasis placed on preservation of the underlying musculature, as shown in Figure 51–9. Both techniques are important for historical purposes but have shortcomings with regard to an optimal aesthetic and functional reconstruction as previously discussed. In a more recent report, Kroll described a similarly staged procedure that uses the Bernard-Burow modification of the Karapandzic fan flap (Fig. 51–10) followed by a cross-lip flap at a different operative setting.[8–10] In principle, this accomplishes the same goal of reconstructing the missing lip with like tissue. This approach addresses the problem of lip tissue discrepancy between the lip that is reconstructed and the remaining lip by redistributing lip tissue in an area where it is needed. Williams et al further described the simultaneous use of a modified Bernard-Burow cheek advancement flap and a cross-lip flap for total lower or upper lip defects.[11] We believe that the modified cheek flap

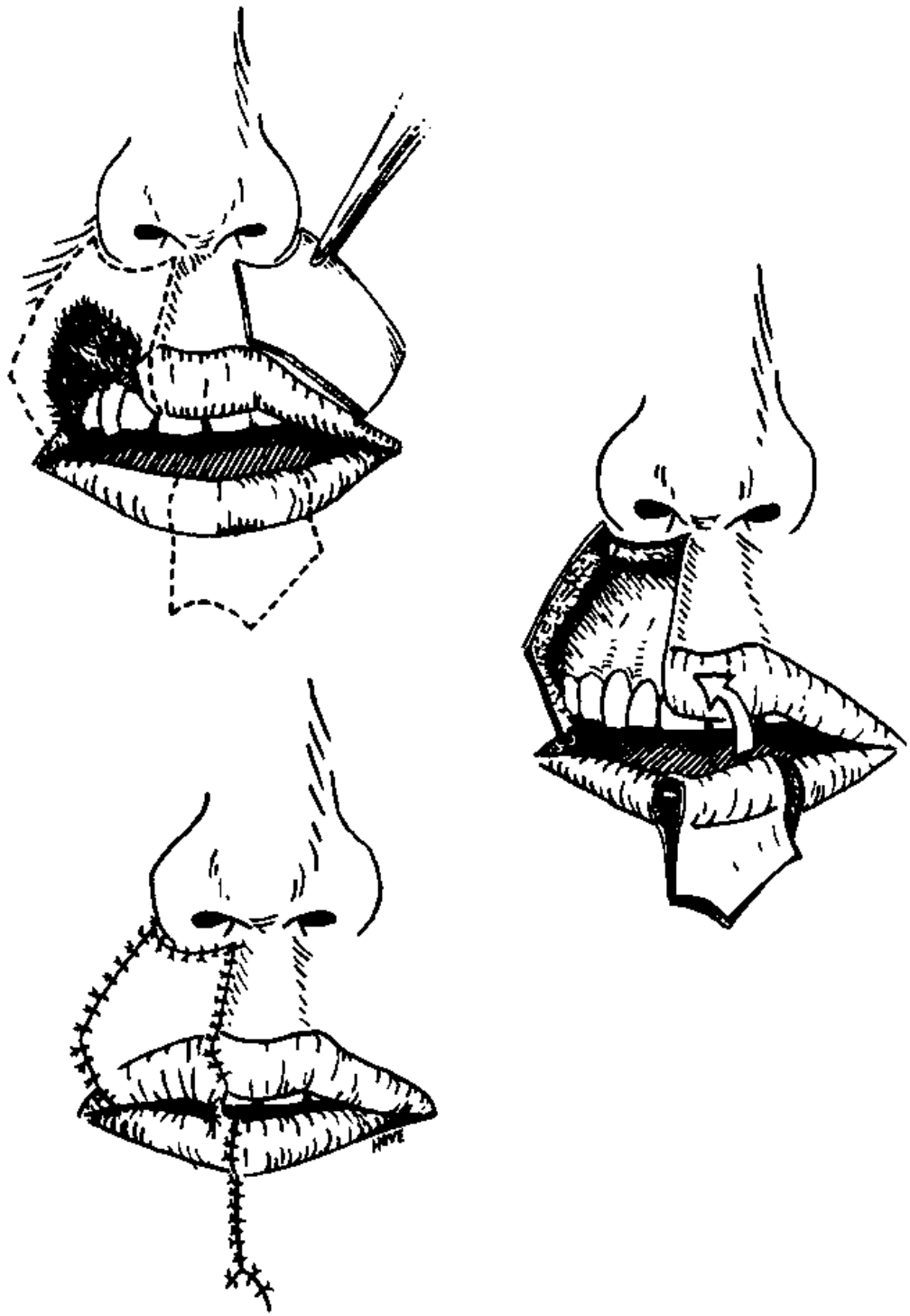

Figure 51–7 Modified cross-lip flap for the upper lip with emphasis on the subunit principle.

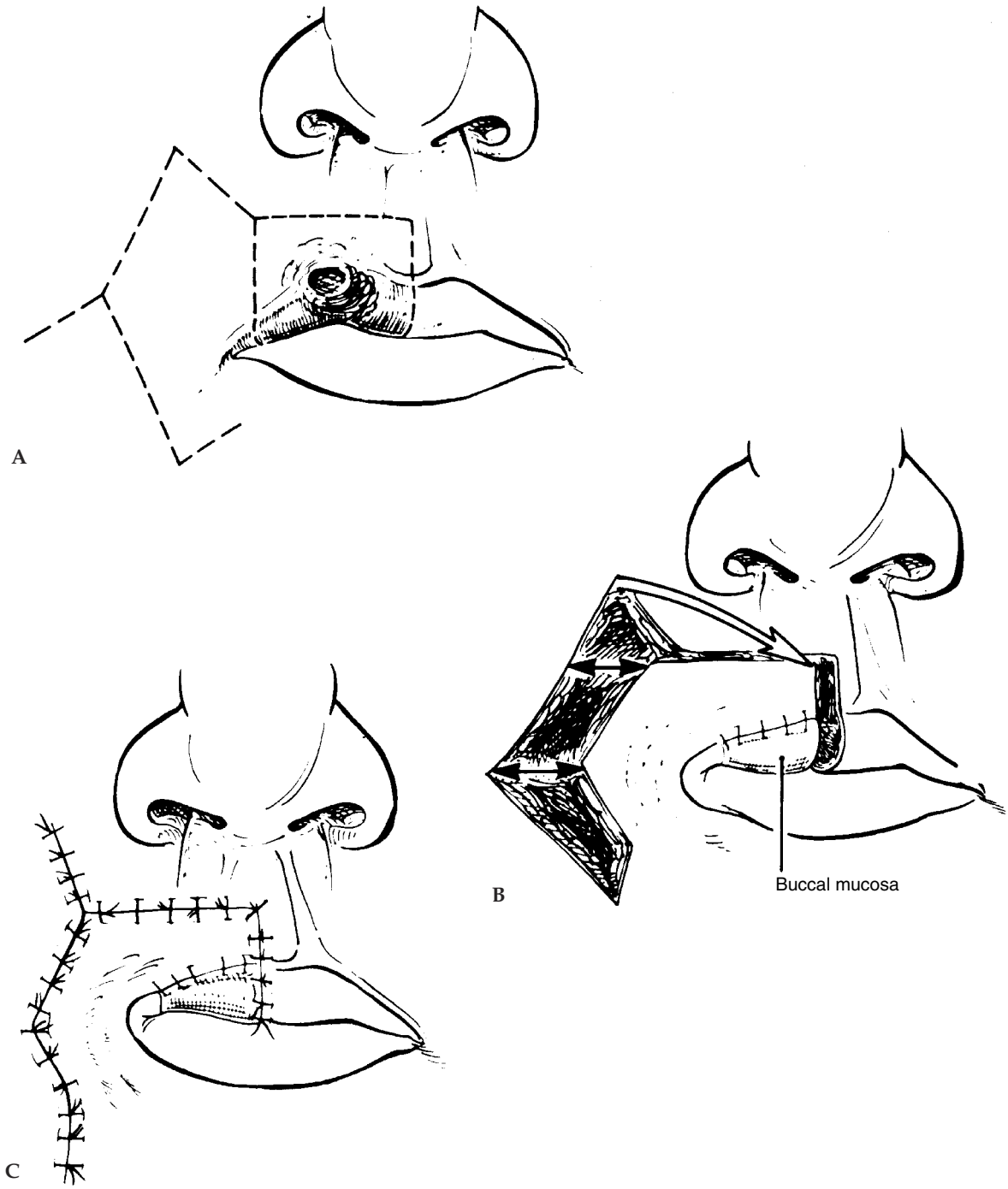

Figure 51–8 Gillies fan flap technique.

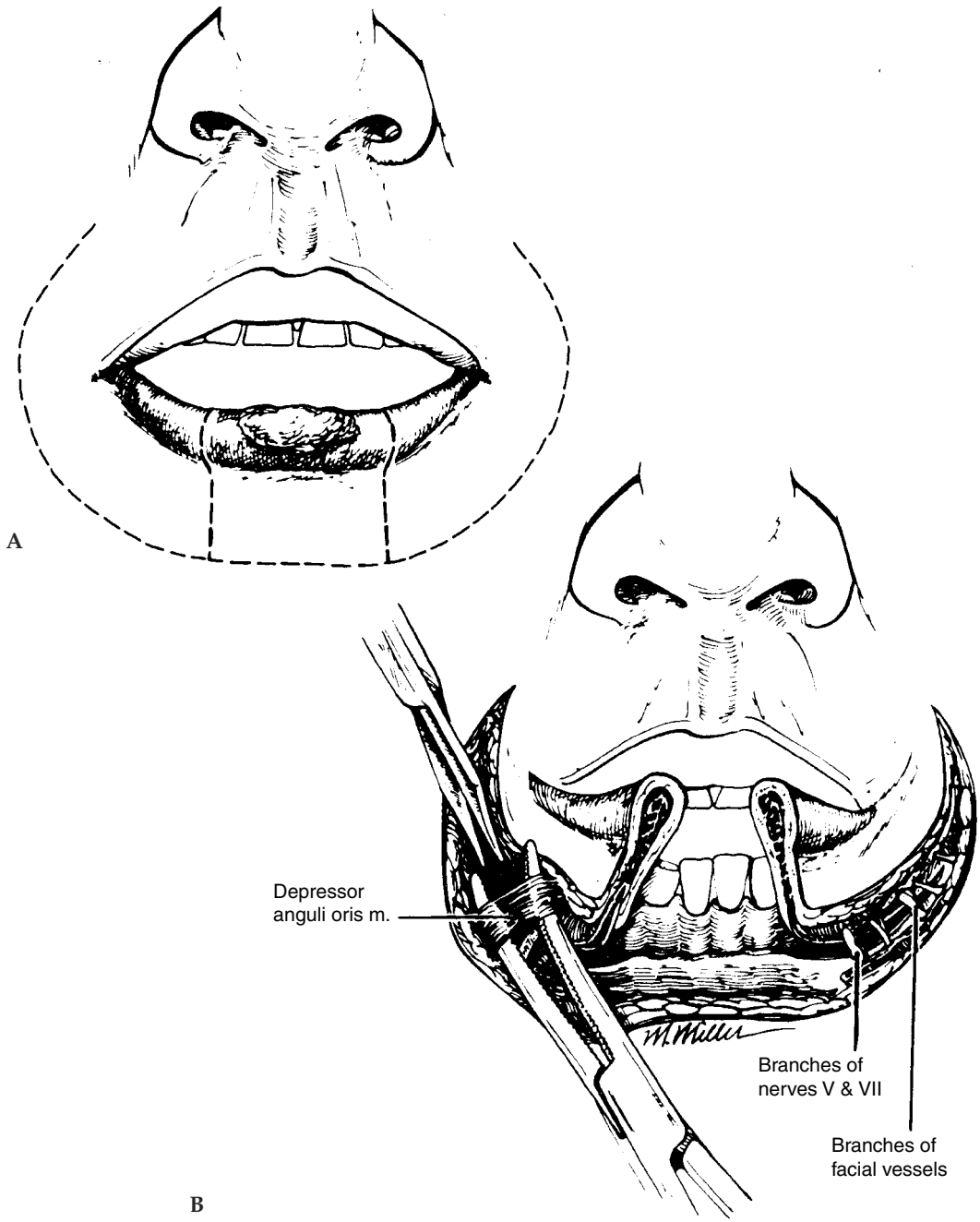

Figure 51–9 Karapandzic flap technique.

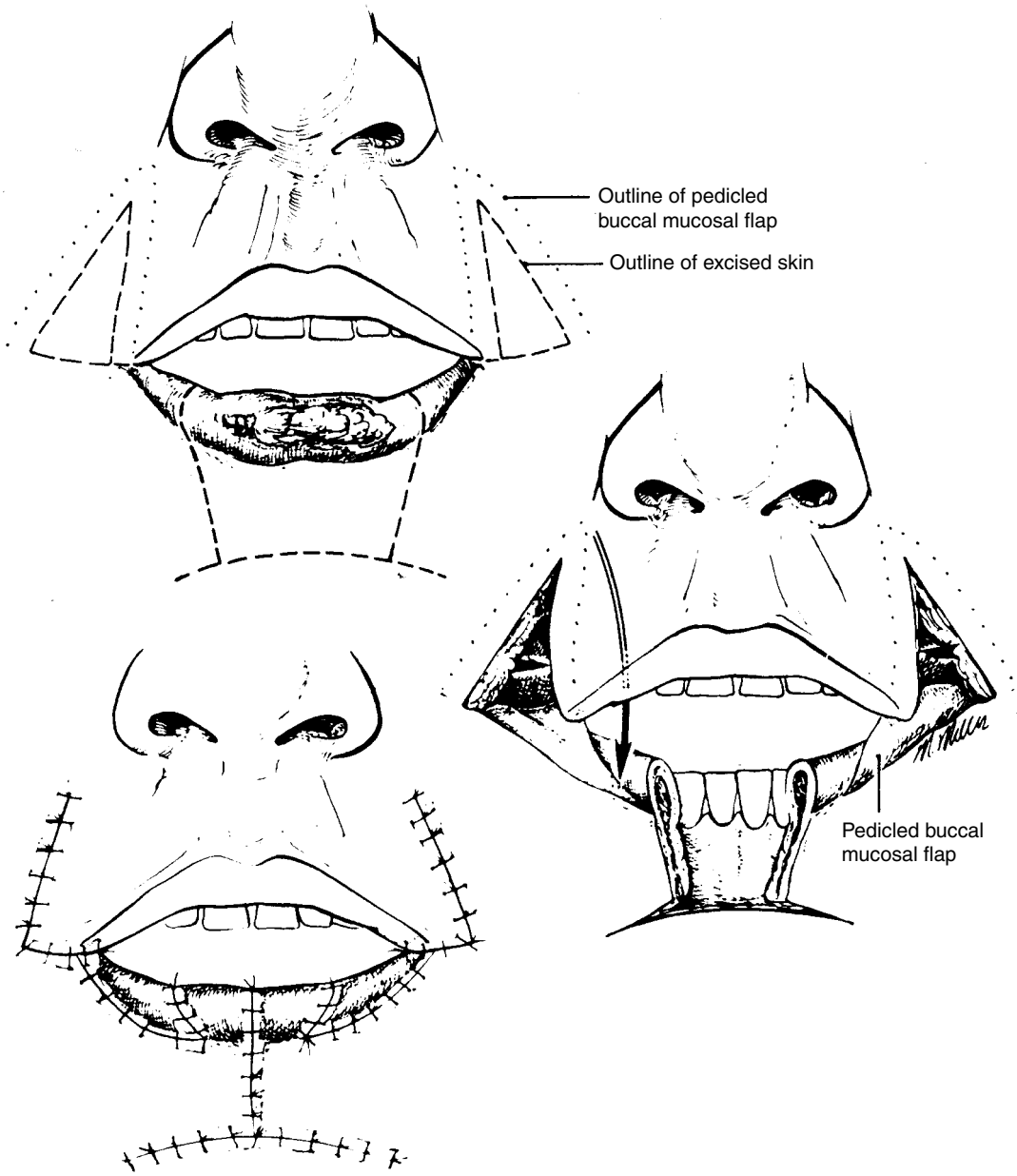

Figure 51–10 Bernard-Burow flap technique.

offers several advantages over sequential reconstruction described by Kroll. The extended intraoral incisions described allow for considerable advancement of the cheek into the surgical defect while preserving the neurovascular structures of the remaining lip. Furthermore, the procedure offers a theoretical advantage of less postoperative microstomia because it recruits new lip tissue into the periorbital area rather then rearranging or sharing the remaining lip.

Large Defects

Subtotal/Total Lower Lip Defects

Technique Total lower defects are full-thickness defects that extend from oral commissure to oral commissure or past the oral commissure to include a portion of the cheek, as detailed in Figure 51–11. During the first stage of reconstruction, the lateral aspect of the lip is reconstructed using a modification of the Bernard-Burow flap. Incisions only through the mucosa are created in the gingival buccal sulcus from the surgical defect posterior to the angle of the mandible. Next, a horizontally oriented parallel incision is made through the mucosa only from the oral commissure posteriorly so that it is at least 1 cm from the opening of Stenson's duct. An inferiorly based mucosal flap is created at the anterior aspect of this incision to be used for creation of the lateral oral commissure in red lip. Finally, a Burow's triangle full-thickness skin is excised from the most lateral aspect, allowing advancement.

These surgical maneuvers allow mobilization of the cheek to be recruited in the lower lip reconstruction. At this time, a midline cross-flap is developed and rotated into the central aspect of this large central defect. A three-layered, full-thickness defect closure is now performed between the laterally advanced lower lip and the transposed central cross-lip flap. A new oral commissure is created by rotation and inset of the mucosal flap. At 2 weeks, a delayed section of the cross-lip flap is performed (Fig. 51–12).

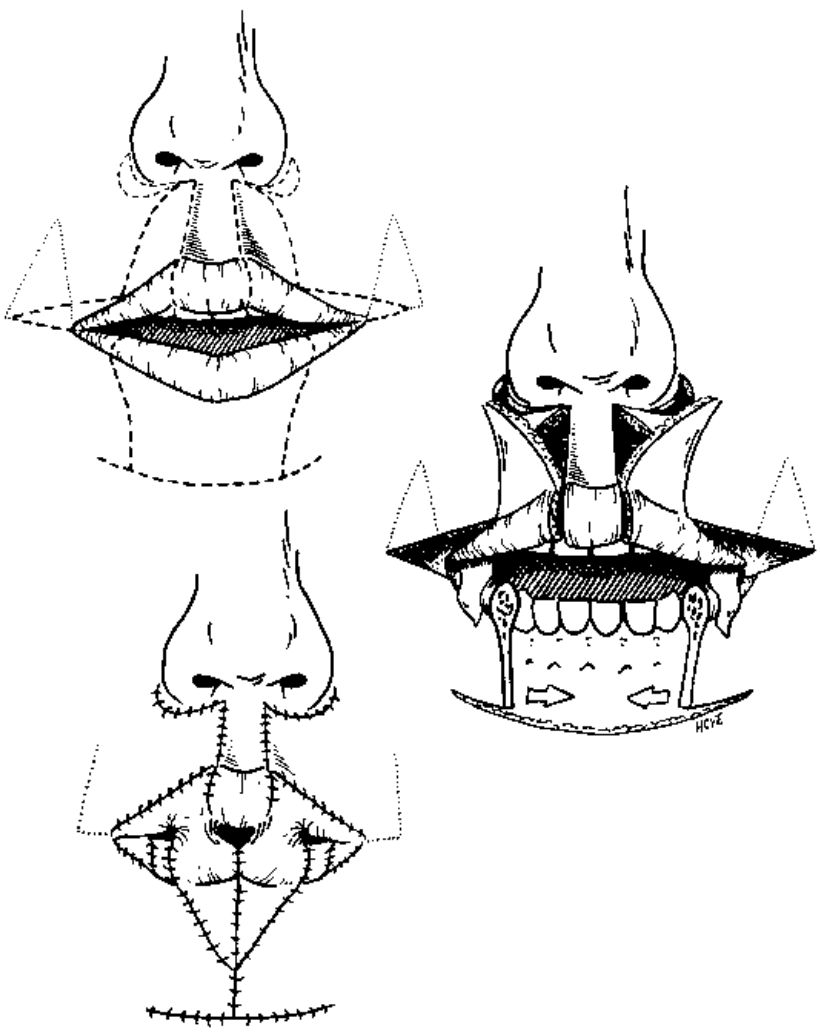

Figure 51–11 Modified Bernard-Burow cheek advancement with simultaneous cross-lip flap.

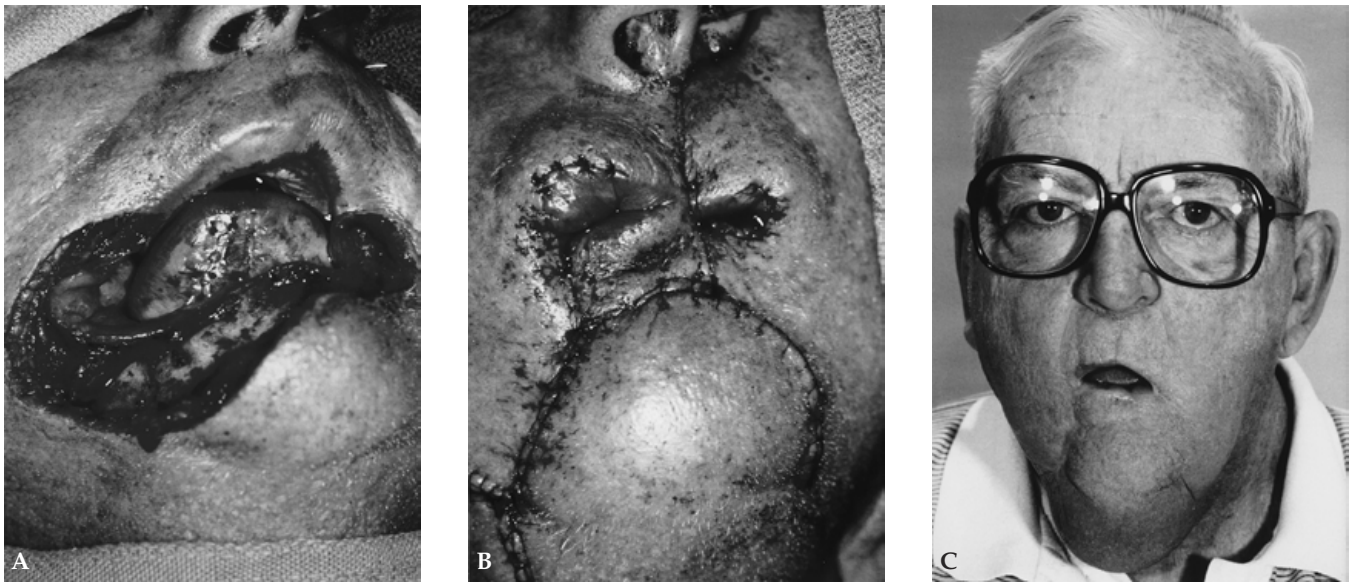

Figure 51–12 Intraoperative **(A)**, immediate postoperative **(B)** and 1-year **(C)** result of a surgical defect extending from left and commissure to include entire lower lip right oral commissure and right cheek repaired with a modified Bernard-Burow cheek advancement with a simultaneous cross-lip flap.

Subtotal/Upper Lip Defects

Technique For upper lip defects, the modified Bernard-Burow cheek advancement is performed in a similar fashion. In addition, it may be necessary to excise a perialar crescent of skin bilaterally. When used in conjunction with bilateral cheek advancement, the suture lines will be placed where the eye expects to see a shadow and will thus look more normal. In contrast to reconstruction of the lower lip, it is more important to emphasize and employ the subunit priniciple as previously described.

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Chapter 52

Periocular Reconstruction

Sara A. Kaltreider

Reconstruction of the periocular area is unique because of the specialized protective function of the periocular tissues in preserving vision. Specific functions of the eyelids include protection of the ocular surface from trauma, preservation of the tear film (which is crucial for clarity of vision), and tear excretion (which is dependent on the pumping action of the lids and the presence of an intact tear excretory apparatus). The principles of surgical reconstruction in the periocular area are generally the same whether the defect arises from excision of tumor, trauma, previous surgical procedures, or a pathologic cicatrizing process.

The foremost goal of reconstruction is restoration of the three-dimensional anatomy of the eyelid as close to normal as possible. Attention to the microscopic anatomy and meticulous surgical technique are crucial to the success of the reconstruction. The details of the surgical anatomy are described and illustrated in other sources.[1–3] Areas deserving special attention during soft tissue reconstruction are the retractors of the eyelids, the lateral canthal tendon, the medial canthal tendon, the canalicular system, and the lacrimal sac. In addition to the complex microanatomy, the concavity of the medial canthal area presents particular challenges. Attention to postoperative care and splinting of the medial canthus after reconstruction will impact the outcome. As with reconstruction of any type, there is a potential need for secondary surgical revision.

Apposition of the eyelid conjunctiva to the ocular surface is important for a normal tear film and corneal clarity. If cicatricial forces disturb the delicate balance of the eyelid margin, then keratinized tissue and cilia may destroy the corneal epithelium and cause loss of vision. Therefore, reconstructive procedures must replace the anterior lamella of the eyelid with skin and the posterior lamella with mucous membrane while maintaining horizontal muscle tone, preserving the tear excretory microanatomy, and allowing the lids to open and close completely. The soft tissue reconstructive techniques described herein depend on the location, depth and extent of the defect, and the potential sources for any tissue that may be missing or insufficient. Salient references are important for those who plan to become adept at eyelid reconstruction as details of each and every technique cannot be reproduced in a single chapter.

ANTERIOR LAMELLAR DEFECTS

Anterior lamellar defects involving skin or skin and the underlying orbicularis oculi muscle may be repaired using a number of techniques. Small defects may be left to granulate spontaneously, but judgment and experience must dictate those defects at risk for distorting the eyelid position or causing lagophthalmos.[4] Even large defects (greater than 15 mm) in the medial canthal area may be allowed to heal by secondary intention as seen in Figure 52–1. The advantages of healing by secondary intention are preservation of tissue relationships and expediency for patients who may not wish to have additional surgery to cover the defect. Disadvantages are the presence of an open wound with serosanguinous discharge and crusting until epithelialization occurs, and the potential for ectropion and tearing if scarring distracts the eyelid margin from the ocular surface.

Alternatively, direct closure or local flaps such as an O- to Z-plasty, rotational flap, transpositional flap, rectangular advancement flap, V to Y advancement flap, Y to V advancement flap, or rhomboid flap may be used.[5,6] Figure 52–2 demonstrates a nodular basal cell carcinoma that was removed and the defect closed using an O- to Z-plasty. The Z-plasty flaps are mobilized from the lateral and medial direction to avoid webbing in the medial canthus. Likewise, closure of defects in the upper or lower eyelid must be carefully planned to avoid vertical shortening of the eyelids and consequent lagophthalmos.

Myocutaneous flaps consisting of skin and orbicularis muscle may be transposed from the upper eyelid, where an excess of skin may be found in some patients, to a lower eyelid anterior lamellar defect. The lower incision of the flap is placed in the eyelid crease, and the upper incision is placed 10 to 12 mm below the brow cilia. The flap is carefully dissected to avoid damage to the underlying levator aponeurosis. The base of the pedicle is left intact medially or laterally. This procedure may produce some asymmetry of the upper lid fold with less redundancy on the side of the reconstruction, but it provides skin of matching color and texture. Figure 52–3 shows a patient whose defect was repaired with a transpositional flap from the upper eyelid to the lower eyelid.

Multiple noncontiguous defects closed with a variety of flaps. Often the bridging tissue is useful in forming one of the flaps, as in the patients shown in Figures 52–4 and 52–5. The patient in Figure 52–4 has basal cell nevus syndrome and underwent Mohs' excision of three defects in the temple area.

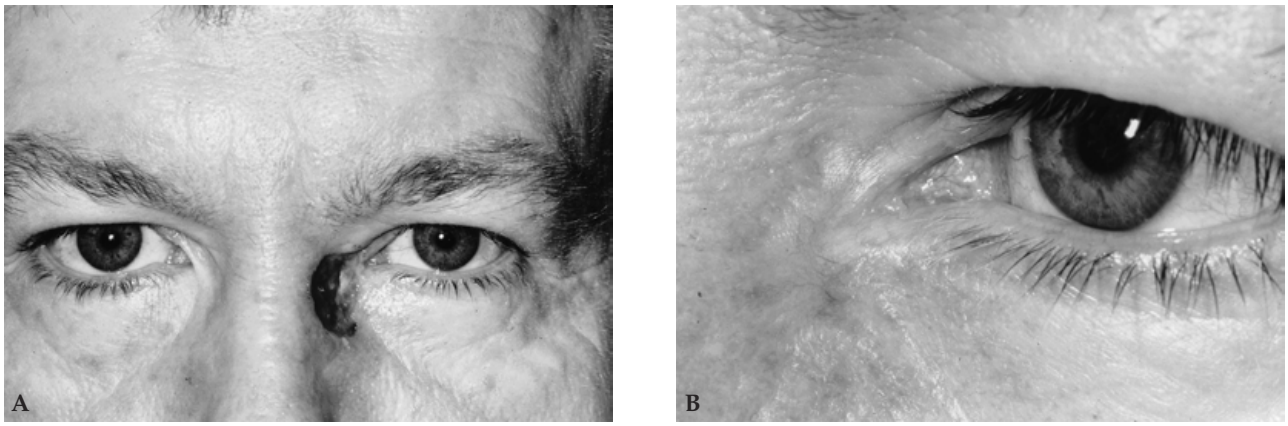


Figure 52–1 This patient underwent Mohs' excision of a basal cell carcinoma of the left medial canthus. The defect did not involve the canalicular system and was centered over the medial canthal area **(A)**. Two months after excision and healing by granulation, the area is well covered, with no distraction of the eyelids from the ocular surface **(B)**.

Figure 52–2 This patient underwent excision of a basal cell carcinoma of the medial canthal area **(A)**. The defect was reconstructed using an O- to Z-plasty, with mobilization of the flaps from the horizontal direction **(B)**. No distortion of the medial canthal angle or web formation occurred **(C)**.

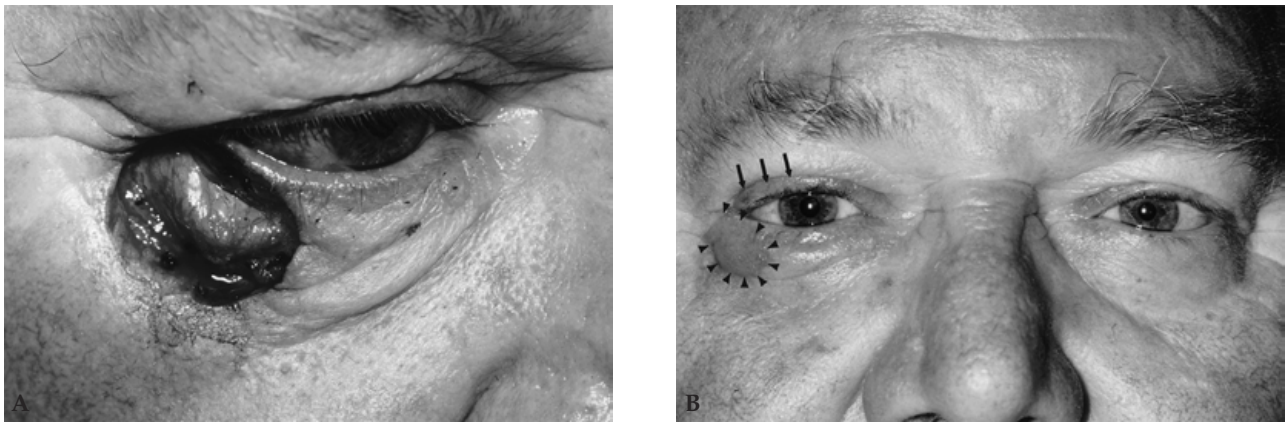


Figure 52–3 This patient underwent Mohs' excision of a basal cell carcinoma in the lateral canthal area and lower eyelid **(A)**. Reconstruction consisted of transposing a myocutaneous flap from the upper eyelid to the defect **(B)**. The lower edge of the flap was placed in the eyelid crease, and the upper incision was placed 10 to 12 mm below the brow cilia. The flap was transposed, sutured into position, and splinted with a dressing. A postoperative photograph at 1 month shows good eyelid contour and symmetry **(B)**. The arrowheads show the extent of the transposition flap, and the arrows show the closed donor site well hidden in the eyelid crease.

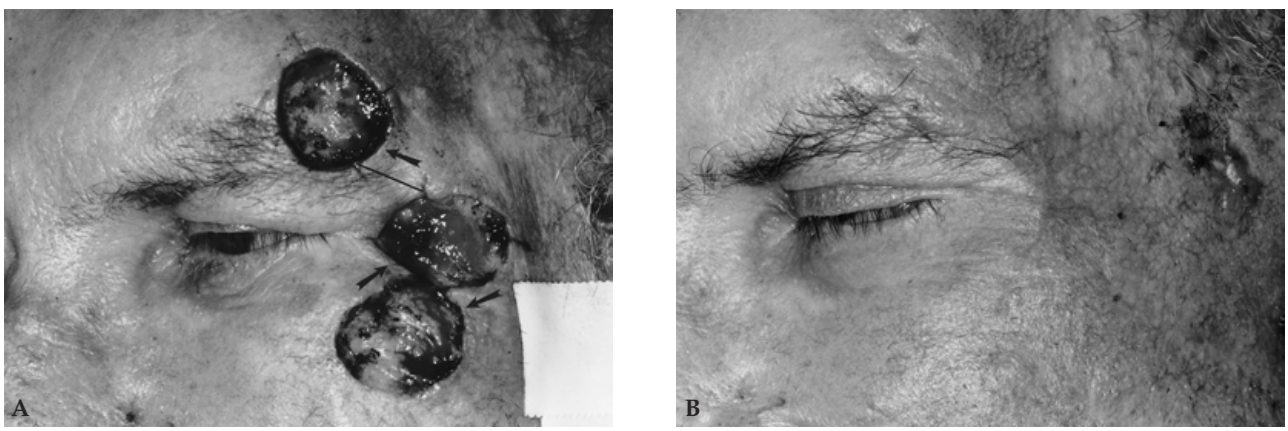


Figure 52–4 This patient with basal cell nevus syndrome had a bridge of tissue between the upper and middle skin defects that was severed (*line*) and mobilized (*arrows*) into the upper defect **(A)**. The lower skin defects were repaired by undermining and advancing the adjacent tissue (*arrows*). Two months postoperatively, the area is well healed **(B)**.

The bridge of tissue between the upper two defects was severed just above the brow cilia, and the tissue was advanced and lifted upward into the defect above the brow. The projection of tissue adjacent to the lower eyelid was lifted upward and laterally, and the cheek tissue was mobilized by pulling the skin edges together from the horizontal direction to create a vertical closure.

The patient in Figure 52–5 has two defects: one on the nose and one in the left medial canthus. The bridge of tissue was severed laterally and rotated clockwise into the lower defect. The longest line of closure was deliberately placed along the side of the nose rather than on the dorsum. The remaining defect in the medial canthus was covered with a small flap from the redundant upper eyelid skin.

Large anterior lamellar defects may require repair with full-thickness skin grafts from the retroauricular area. Skin grafts from the neck and below have a sallow appearance when grafted to the eyelids, whereas retroauricular skin has a pink hue matching that of the eyelids.[7] Although split-thickness grafts may also be used, rarely does

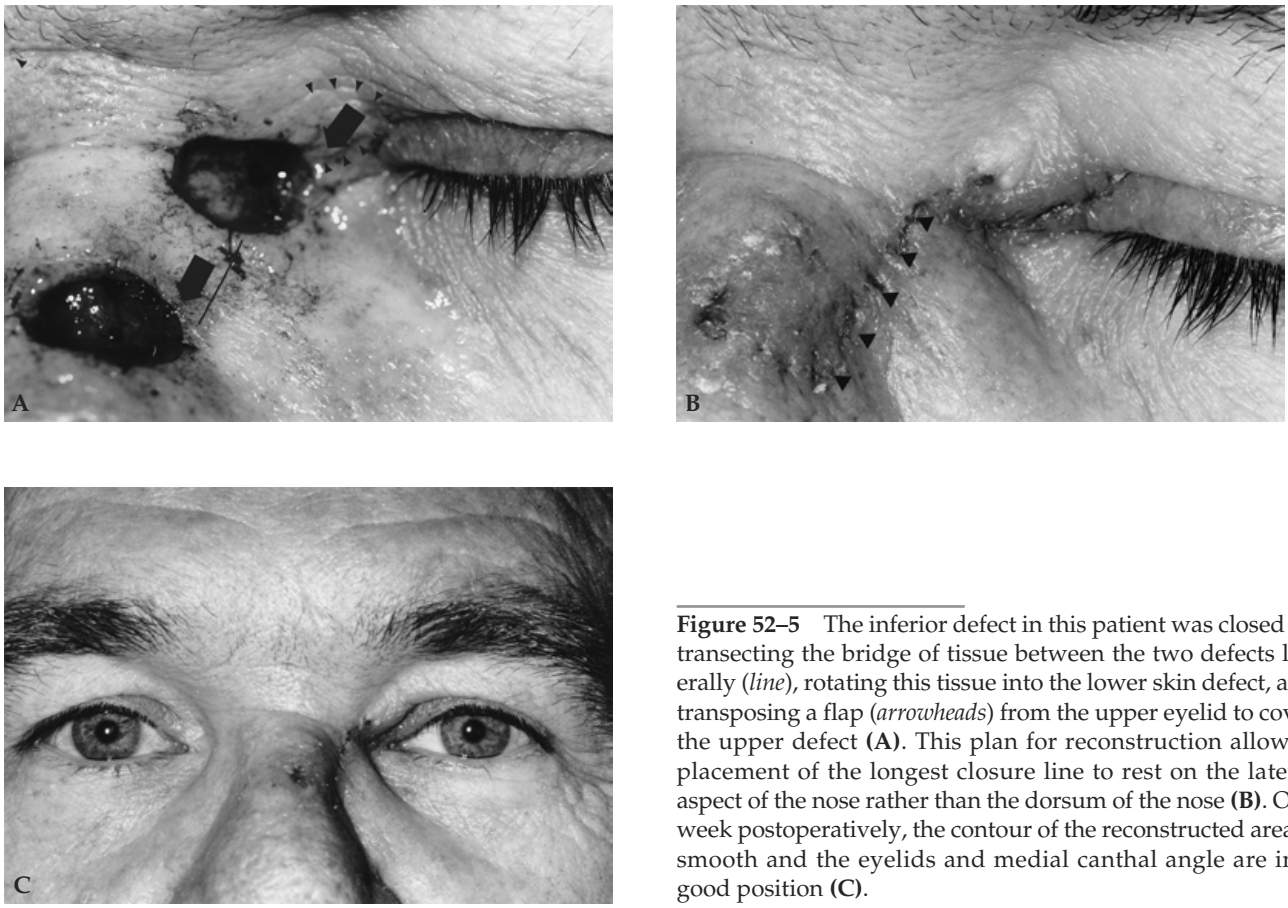


Figure 52–5 The inferior defect in this patient was closed by transecting the bridge of tissue between the two defects laterally (*line*), rotating this tissue into the lower skin defect, and transposing a flap (*arrowheads*) from the upper eyelid to cover the upper defect **(A)**. This plan for reconstruction allowed placement of the longest closure line to rest on the lateral aspect of the nose rather than the dorsum of the nose **(B)**. One week postoperatively, the contour of the reconstructed area is smooth and the eyelids and medial canthal angle are in a good position **(C)**.

the deficiency of eyelid skin require a large enough surface area to warrant split-thickness grafting. Figure 52–6 shows a defect too large to be repaired with local flaps alone. The area above the medial canthal tendon was covered with a flap from the upper eyelid, and the large defect in the lower eyelid and medial canthus was covered with a full-thickness skin graft from the retroauricular area. The component of the defect over the bridge of the nose was closed with adjacent skin, undermined, and closed in a horizontal fashion.

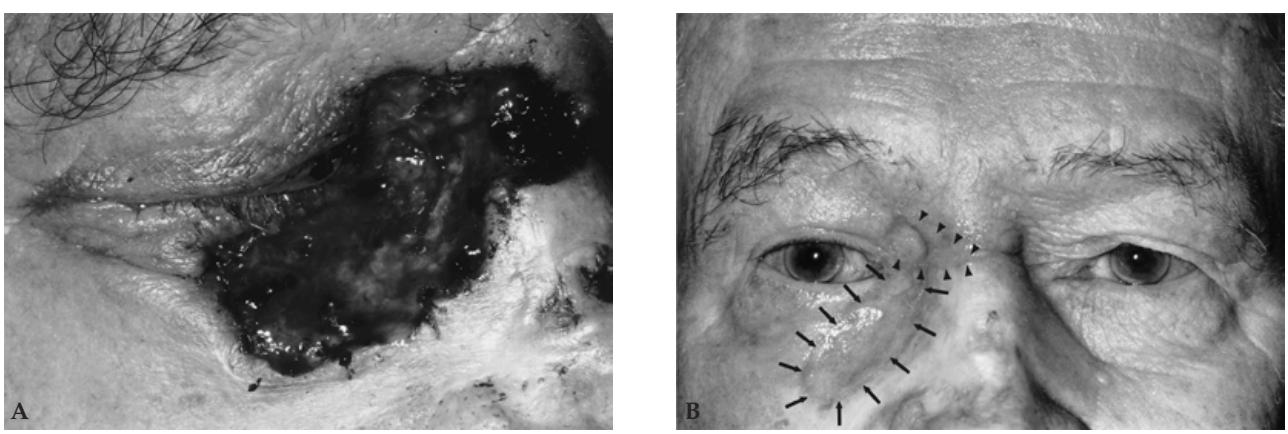


Figure 52–6 This defect **(A)**, too large to be covered by flaps alone, was reconstructed using a transposition flap from the upper eyelid to the upper part of the defect (*arrowheads*, **B**) and a full-thickness skin graft from the retroauricular area to the lower eyelid defect (*arrows*). Postoperatively, the eyelids are in an excellent position, and the skin graft matches the color of the lower eyelid nicely.

POSTERIOR LAMELLAR DEFECTS

Posterior lamellar defects are usually accompanied by anterior lamellar defects unless a cicatrizing conjunctival process is present. Those defects that are purely posterior in nature and extensive require mucous membrane grafting from the buccal mucosa, lip mucosa, tarsoconjunctival graft, or hard palate.[7–10] Cicatricial entropion, which is caused by deficiency or scarring of the conjunctiva, may be repaired by the Wies procedure or a variation of an eyelid-splitting procedure. The Wies procedure is a transverse blepharotomy and rotation of the eyelid margin outward.[11] A bipedicle tarsoconjunctival flap, with or without mucous membrane grafting, is another means of rotating the eyelid margin outward.[12] The latter procedure is particularly useful in anophthalmic patients and when combined with a mucous membrane graft addresses the issue of the eyelid margin position and the deficiency of surface area of the socket.

FULL-THICKNESS DEFECTS

Some full-thickness defects may be closed primarily depending on the size, age of patient, and degree of horizontal laxity of the eyelid. Precise three-dimensional alignment of the lid margin is crucial to the health of the eye. Silk sutures (5-0) are placed in the gray line and lash line and then draped away from the ocular surface (Fig. 52–7). A third silk suture may be placed in the mucocutaneous junction if needed. The lid margin tissue is everted with a vertical mattress suture in the gray line, so that as healing takes place the eyelid margin will become smooth and flat rather than contracting into a notched contour. The eyelid margin sutures should be left in place for 10 to 14 days because earlier removal may lead to dehiscence, eyelid notching, and trichiasis.[13] Absorbable sutures (polyglactin, 6-0) are placed in the tarsus and orbicularis. The skin is approximated with absorbable or nonabsorbable sutures.

Larger defects may require canthotomy, cantholysis, and a semicircular flap as described by Tenzel and Stewart.[14] The canthotomy is a straight, horizontal incision that splits the lateral canthal tendon down to the level of the periosteal insertion at Whitnall's tubercle. The cantholysis is performed across the lower crus of the tendon behind the skin. If a semicircular flap is anticipated, the skin incision is located entirely above the level of the lateral canthal angle, and includes skin and orbicularis. This flap is rotated medially to form the new eyelid margin. The lateral edge of the conjunctiva may be sutured to the edge of the semicircular flap with 6-0 plain running suture. The remaining healthy eyelid margin, now mobilized, may be sutured to the medial eyelid as described previously if the medial edge is lateral to the punctum and residual tarsus is present medially. If the medial edge of the remaining eyelid tissue is medial to the punctum, the closure is accomplished with subcutaneous 5-0 absorbable (polyglactin) skin sutures. In the latter case, the canaliculus may be preserved if it is in close proximity to the tear film. Silicone intubation is also a consideration. A common complication of the Tenzel semicircular flap is retraction of the reconstructed lateral eyelid margin, as seen in the patient in Figure 52–8.

Composite grafts may also be used to fill moderate-sized defects that are too large to be reconstructed by direct closure or the Tenzel procedure.[15,16] A full-thickness block of tissue is taken from the opposite eyelid; the orbicularis and skin are removed up to the subciliary area and sutured to the defect (Fig. 52–9). Minimal cautery is used, so that damage to the lash follicles is avoided and a healthy vascular supply to the grafted eyelid is maintained. Lash survival is often disappointing, but an excellent lid contour may be achieved in a one-stage procedure. Double composite grafts, and a combined composite graft and temporal semicircular flap are other possibilities for the treatment of large defects.[17,18]

A variety of techniques may be used for reconstruction of large or total full-thickness defects. Procedures are lid sharing

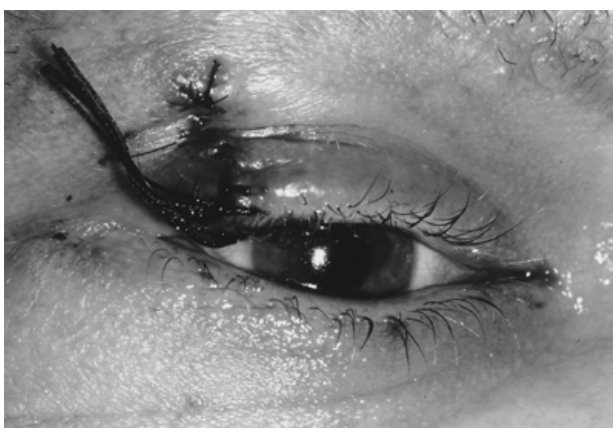


Figure 52–7 This figure shows a lid margin closure with silk sutures in the lid margin. Eversion of the eyelid margin is enhanced by a vertical mattress suture in the gray line.

Figure 52–8 This patient has had resection of multiple skin carcinomas of the left face, left ear, and left medial lower eyelid. He also has a history of radiation to the left temple and ear. Therefore, a vascularized rotational flap was used for reconstruction of the medial defect (Tenzel semicircular flap). One can see the abnormal contour and the retraction of the lateral left lower lid. Despite these residual eyelid abnormalities, the patient's eyelids are functional and he has no lagophthalmos.

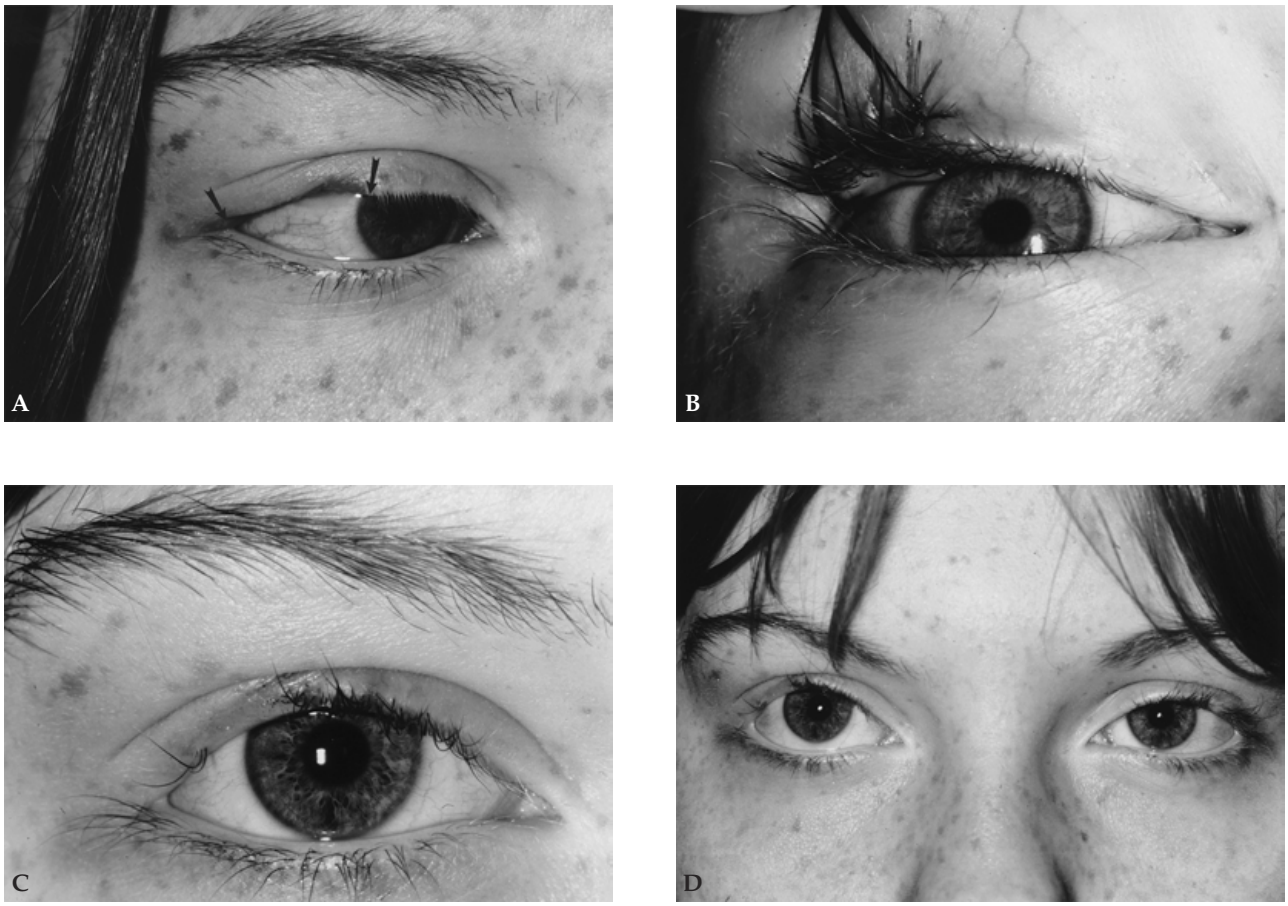


Figure 52–9 This young patient lost the lateral half of the right upper eyelid margin in an automobile accident (**A**, arrows show extent of eyelid margin defect). A full-thickness composite graft was retrieved from the left upper eyelid and placed in the defect in the right upper eyelid **(B)**. No cautery was used intraoperatively, and a flap of vascularized orbicularis was placed over the composite graft near the level of the lash follicles. The contour of the eyelid margin is restored, but only a few of the lashes within the composite graft survived **(C, D)**.

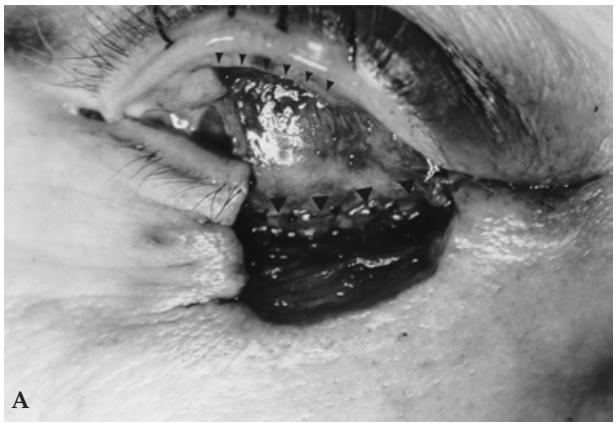
or non–lid sharing, one-stage or two-stage. Visual function should be taken into account when selecting the technique. For example, a one-stage procedure (which does not require closure of the eyelids for an extended period) should be used for reconstruction of an eyelid in a monocular or amblyopic patient (if the reconstruction is ipsilateral to the good eye).

The Hughes procedure is a superb two-stage reconstructive technique for treatment of total full-thickness lower eyelid defects and consists of a tarsoconjunctival flap with an overlying full-thickness skin graft or myocutaneous flap (Fig. 52–10).[19] The second stage takes place 3 to 6 weeks later to allow contraction to run its course, thereby minimizing the retraction of the newly constructed eyelid. Intraoperatively, the lower eyelid level is adjusted approximately 1 mm higher than the desired height to allow for additional contraction. This technique, carefully performed, is less likely than some other techniques to produce lagophthalmos or retraction, and may be used for reconstruction of the upper or the lower eyelid. Complications include ptosis, retraction of the donor eyelid, lagophthalmos and retraction of the reconstructed eyelid, eyelid margin instability, necrosis of the donor eyelid, eyelid notching, and medial or lateral canthal deformity.[20]

A one-stage technique described by Leone and Van Gemert allows replacement of lower eyelid anterior and posterior lamellae with a pedicle tarsoconjunctival flap covered by a myocutaneous flap.[21] Both transposition flaps are based laterally.

A technique for total upper eyelid reconstruction analogous to the Hughes procedure for the lower eyelid is the Leone procedure.[22] This is a two-stage, lid sharing technique in which a tarsoconjunctival flap is mobilized from the lower eyelid into the upper eyelid defect. The lower edge of the tarsus will be the new upper eyelid margin once the flap is severed. A full-thickness skin graft is placed over the tarsoconjunctival flap, and the flap is separated after 4 weeks.

The Cutler–Beard technique is an eyelid sharing procedure in which a full-thickness flap from the lower eyelid is inserted into the upper eyelid defect.[23] A transverse horizontal



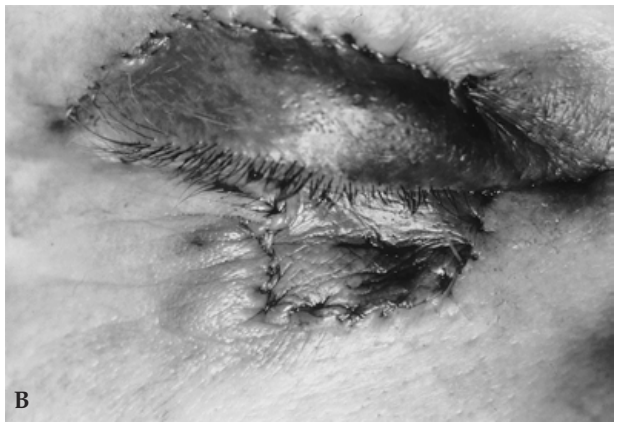


Figure 52–10 Total or near-total eyelid defects may require a two-stage procedure, such as a Hughes procedure. A tarsoconjunctival flap is sutured to the remaining conjunctiva in the inferior fornix (*large arrowheads*) and the residual tarsus, tendon, or periosteum medially and laterally **(A)**. The *small arrowheads* define the initial incision in the tarsus, 2 to 3 mm above the eyelid margin on the posterior surface of the eyelid. A myocutaneous flap or full-thickness skin graft from the retroauricular area or upper eyelid is sutured over the tarsoconjunctival flap **(B)**. Three to six weeks later, the flap is detached from the posterior aspect of the upper eyelid. The upper and lower eyelids are adjusted intraoperatively to achieve good lid levels, contour, and symmetry, as seen in the patient in **(C)** who underwent left lower eyelid reconstruction. The reconstructed eyelid extends from the arrowheads medially to the lateral canthus.

blepharotomy incision is made several millimeters below the eyelid margin, and a full-thickness flap is brought upward behind the bridge of lower eyelid margin and sutured to the defect in the upper lid. The flap is severed 3 or more weeks later. Complications include necrosis of the lower eyelid margin, retraction of the lower eyelid, retraction or ptosis of the upper eyelid, and decreased mobility of the upper eyelid.

MEDIAL CANTHAL DEFECTS

Specific anatomic considerations in the medial canthus are the lacrimal excretory apparatus, the complexity of the medial canthal tendon, soft tissue webbing, and deep defects requiring vascularized flaps. Certain techniques applicable to reconstruction involve the lacrimal excretory apparatus and the medial canthal tendon.

Careful examination of the defect will reveal whether or not the canalicular system is involved. If sufficient canalicular tissue remains, then microsurgical repair with silicone intubation is indicated (Fig. 52–11).[24,25] The silicone stent should remain in place for approximately 6 weeks. However, if only a tiny remnant of canaliculus remains, then the remaining tissue cannot be restored to a functional passageway from the tear film to the sac.

If both canalicular systems are absent, then a conjunctival dacryocystorhinostomy (DCR) with placement of a Jones tube is indicated, as seen in the patient in Figure 52–12.[26] This glass tube serves as a permanent prosthetic device to drain tears from the medial canthal angle into the nasal cavity.

If the anterior crus of the medial canthal tendon is disrupted, it should be reattached to its normal location along the anterior lacrimal crest. If both anterior and posterior projections of the medial canthal tendon are disrupted, as in nasoethmoidal fractures, then unilateral or transnasal wiring is indicated.[27,28] The patient shown in Figure 52–13 has traumatic telecanthus and epiphora following a gunshot injury directly over the nasal bridge. Bilateral DCR and transnasal wiring were performed. The transnasal wiring was done through the DCR incisions using an awl to pass the 28-gauge wire between the canthi. Unilateral wiring may be performed using a microdrill to create an attachment site just behind the anterior lacrimal crest.

Telecanthus and epiblepharon are effectively treated with Z-plasties, Y to V-plasties, or Mustarde flaps.[29] The Mus-

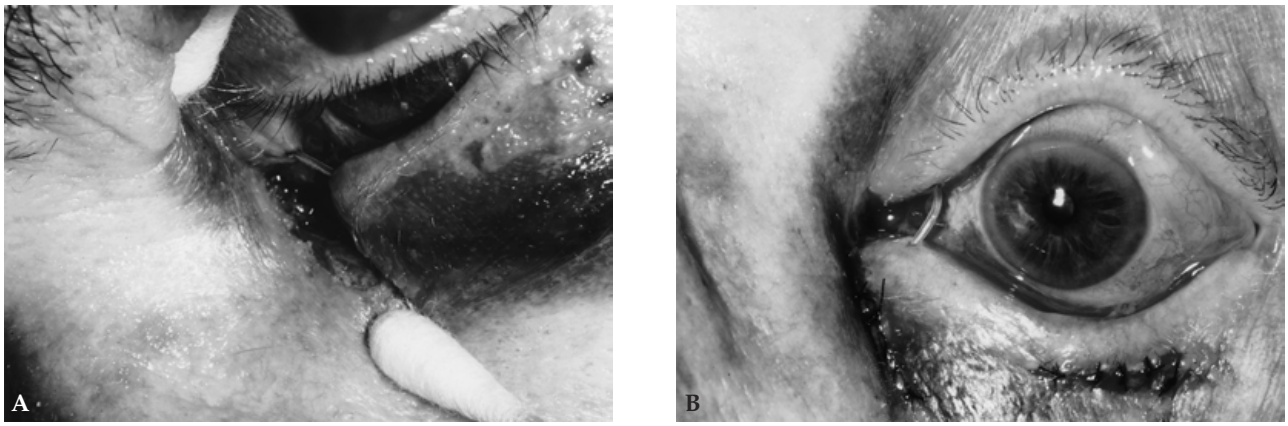


Figure 52–11 Canalicular defects require silicone intubation of the lacrimal passageway and microsurgical repair of the canalicular epithelium and medial canthal tendon. The silicone tube is passed through the upper and lower canalicular systems, the lacrimal sac and duct **(A, B)**. The canalicular epithelium, the medial canthal tendon, orbicularis, and skin are sutured. The silicone tube is removed after 6 weeks **(C)**. The patient has no epiphora.

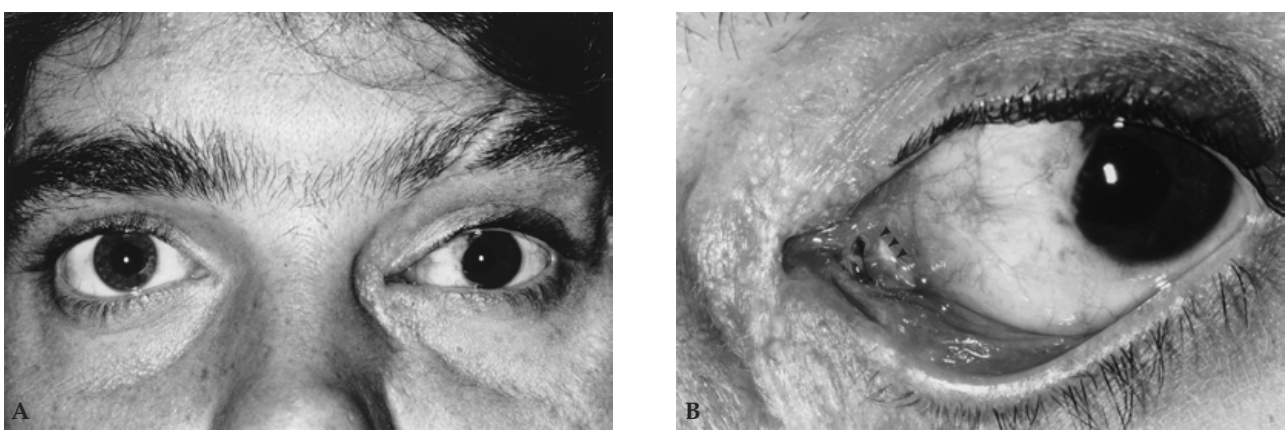


Figure 52–12 The Jones tube, a Pyrex tube connecting the medial canthal angle to the nasal cavity, can be seen in this patient who sustained severe bicanalicular lacerations and ocular trauma **(A, B)**. The arrowheads in B show the posterior edge of the flange of the tube.

tarde flap consists of two Z-plasties and a Y to V-plasty. The patient in Figure 52–14 is a Caucasian female with congenital epiblepharon repaired with Mustarde flaps.

Alternatives for deep and extensive soft tissue defects in the medial canthal area include the glabellar flap and the midline forehead flap (Fig. 52–15).[30] These defects require thicker tissue with a vascular supply that is provided by the supratrochlear and supraorbital vascular supply. Complications include thickened flap, rounded medial canthal angle, and necrosis of the tip of the flap.

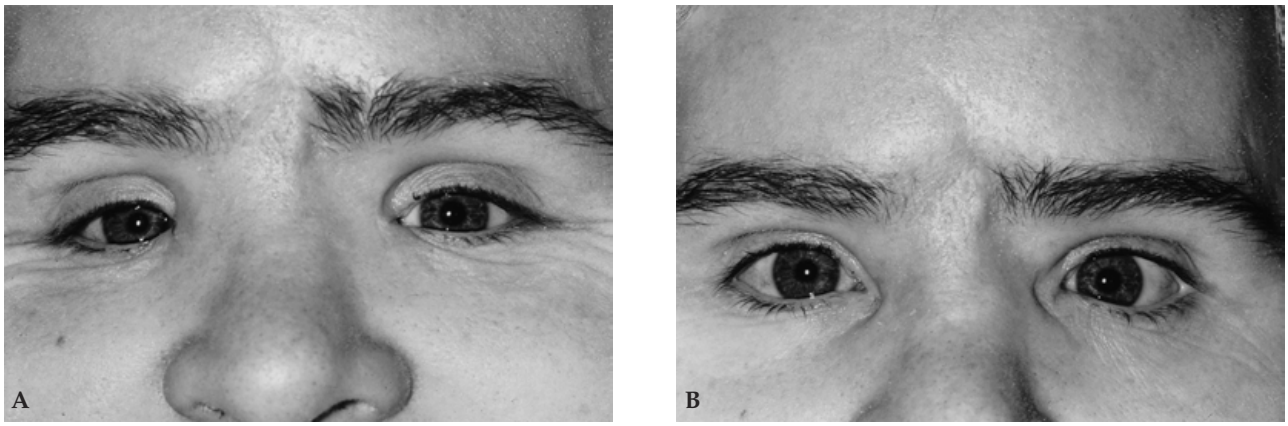


Figure 52–13 Preoperative **(A)** and postoperative **(B)** photographs of a patient who underwent bilateral dacryocystorhinostomy and transnasal wiring following a gunshot wound. The intercanthal distance is diminished, and the patient's epiphora was resolved.

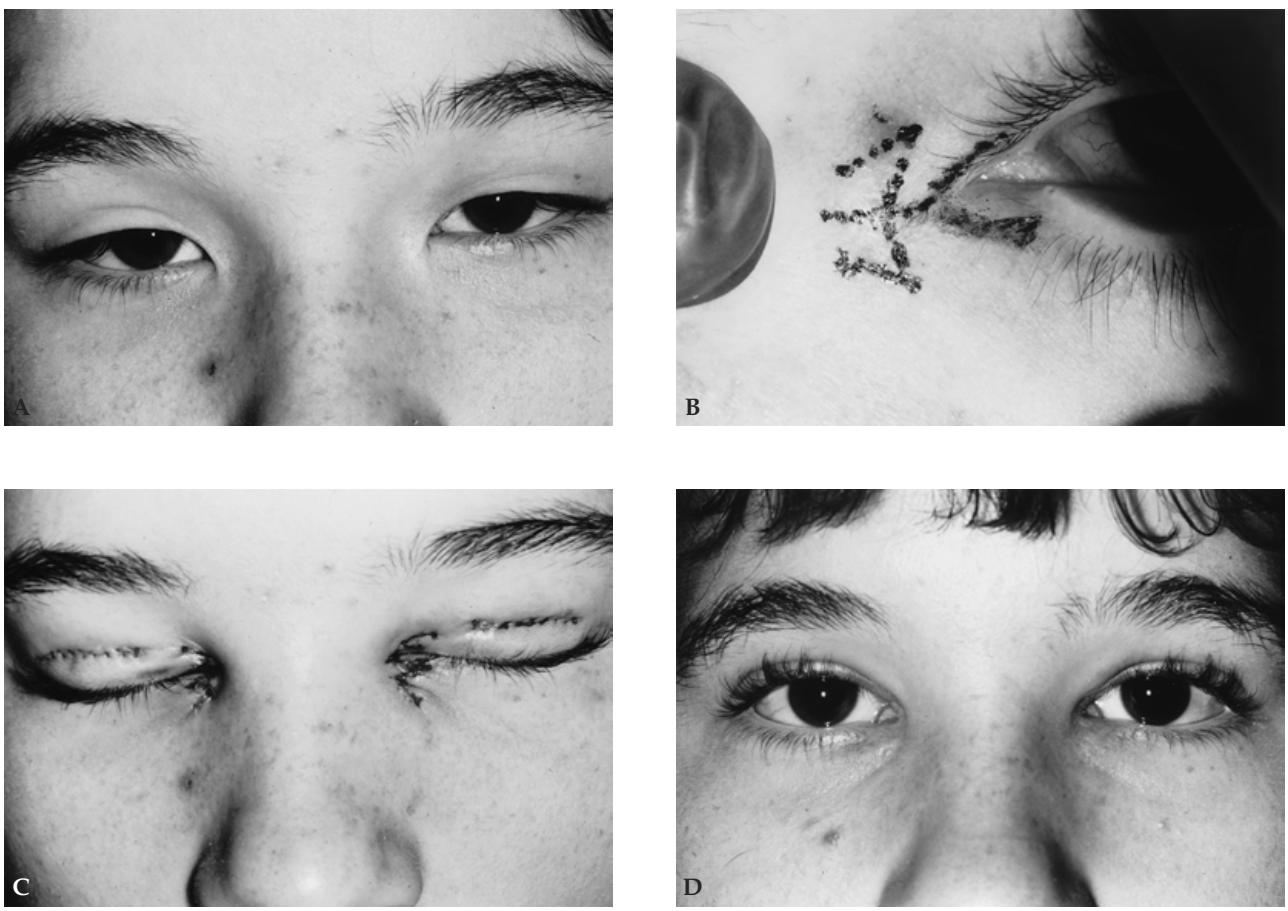


Figure 52–14 This patient with congenital epiblepharon **(A)** underwent a Mustarde medial canthoplasty. Note the components of the canthoplasty include a Z-plasty in the upper and the lower eyelids, and a Y to V-plasty to mobilize the medial canthal angle toward the nose **(B)**. Fixation of an eyelid crease was performed by suturing the skin and orbicularis to the levator aponeurosis (intraoperative photograph, **C**). Postoperative appearance is seen in **(D)**.

Figure 52–15 This patient had an extensive and very deep defect following excision of a recurrent basal cell carcinoma **(A)**. The defect involved the medial canthus, lacrimal excretory apparatus, medial half of the upper eyelid, and medial half of the lower eyelid. A sliding tarsoconjunctival flap and an overlying midline forehead flap were used to reconstruct the missing tissue **(B, C)**. A Jones tube was placed beneath the medial canthal angle to drain the tears into the nose. Six months after the procedure, the patient has good eyelid function and no tearing **(D)**.

LATERAL CANTHAL DEFECTS

Anterior lamellar defects in the lateral canthal area are reconstructed with sliding, O to Z, rotation, transposition, or rhomboid flaps. Generally, redundancy of skin in this area and the lack of fixation of the tissues to the orbital rim allow mobilization of skin to cover small and moderate defects. The lateral canthal tendon attaches to Whitnall's tubercle, and this structure should be restored to its normal location if it has become disrupted. A periosteal strip or a tarsal strip may be used for reconstruction if the tendon is absent.[31,32] Eyelid shortening often prevents the complication of ectropion following reconstruction of the anterior lamella of the lower eyelid. A wedge of the eyelid margin and tarsus may be removed following canthotomy and cantholysis. The remaining tarsus may be sutured to the periosteum at Whitnall's tubercle using 5-0 polyglactin in the upper and lower tarsus to provide stability of the eyelid position. Alternatively, a periosteal or tarsal strip may be used following shortening of the eyelid.

EYELID RETRACTORS

The eyelid retractors, the levator in the upper eyelid and the capsulopalpebral fascia in the lower eyelid, must be restored to normal position at the time of reconstruction. The levator muscle inserts on the lower two thirds of the anterior surface of the tarsus. Absorbable or nonabsorbable sutures may be used for reattachment. Careful attention to eyelid contour, level, and symmetry will prevent complications postoperatively. Likewise, the capsulopalpebral fascia in the lower eyelid attaches to the inferior border of the tarsus, and this anatomy should be maintained for stability of the eyelid

margin position. Inadvertent plication of the septum in the upper or the lower eyelid will cause retraction, tethering of the eyelid, and lagophthalmos. Therefore, one should avoid closure or tethering of this structure during reconstruction of the eyelids.

ANOPHTHALMIC DEFECTS

The initial stage of reconstruction in anophthalmic patients begins at the time of enucleation and placement of the intraconal implant. Enophthalmos and superior sulcus deformity are the hallmarks of poor volume replacement and poor volume distribution in the socket. Adequate replacement of volume by the intraconal implant placed in the posterior compartment of the socket avoids enophthalmos and superior sulcus deformity in most cases.[33] Orbital bony asymmetry and socket contraction are factors that might limit optimal volume replacement. The balance of the volume deficit after enucleation and intraconal implant placement is provided by the prosthesis. The prosthesis is custom-fitted after the socket heals in approximately 4 to 6 weeks. Meticulous surgical technique at the time of enucleation provides a foundation for successful prosthetic fitting by the ocularist.

Enophthalmos and superior sulcus deformity are common findings in anophthalmic patients, and may be addressed by removing the intraconal implant and replacing it with a larger intraconal implant, or inserting a subperiosteal orbital floor implant. The former approach is extremely difficult if the primary implant is porous with fibrovascular ingrowth. Removal of porous implants risks damage to the extraocular muscles and their innervation. Subperiosteal implants for augmentation of volume should be placed far enough posteriorly that they effectively replace volume and at the same time do not cause shortening of the inferior fornix.[34–37] The anterior edge of the implant should rest behind the orbital rim. The patient in Figure 52–16 underwent subperiosteal implant placement by a transconjunctival approach.

Procedures that attempt to place material in the upper eyelid to fill the superior sulcus should be avoided because of risk of tethering the levator muscle and impairing upper eyelid function. A more conservative approach to achieve improved symmetry of the superior sulcus area is a blepharoplasty on the contralateral side.

Adequate surface area and good eyelid tone must be present for normal retention of the prosthesis and complete closure of the eyelids over the prosthesis. Lack of adequate surface area is generally manifested by cicatricial entropion, an early sign of socket contraction. Severe contraction precludes retention of the prosthesis in the anterior socket. Additional surface area is provided by mucous membrane grafting from the lip, buccal mucosa, or hard palate mucosa (Fig. 52–17).[38] One or both fornices may require reconstruction.

Dermal fat grafts provide both volume and surface area in selected cases, although control of volume replacement and motility is not as precise as other methods of volume replacement.[39] Keratinized epithelium should not be used as grafting material in the socket because of the presence of skin appendages that produce a malodorous discharge.

Optimal motility may be provided by porous implants, which may be integrated with the prosthesis if desired. Porous polyethylene and hydroxyapatite implants are available for patients whose priority is motility.[40,41] Implant exposure is a challenging problem associated with the porous implants, and results from anterior malposition of the implant, infection, or insufficiency of vascularized tissue over the anterior surface of the implant.[42] The advantages of these implants are a decreased risk of extrusion and migration, and the ability to integrate the implant and the prosthesis by way of a peg (Fig. 52–18).

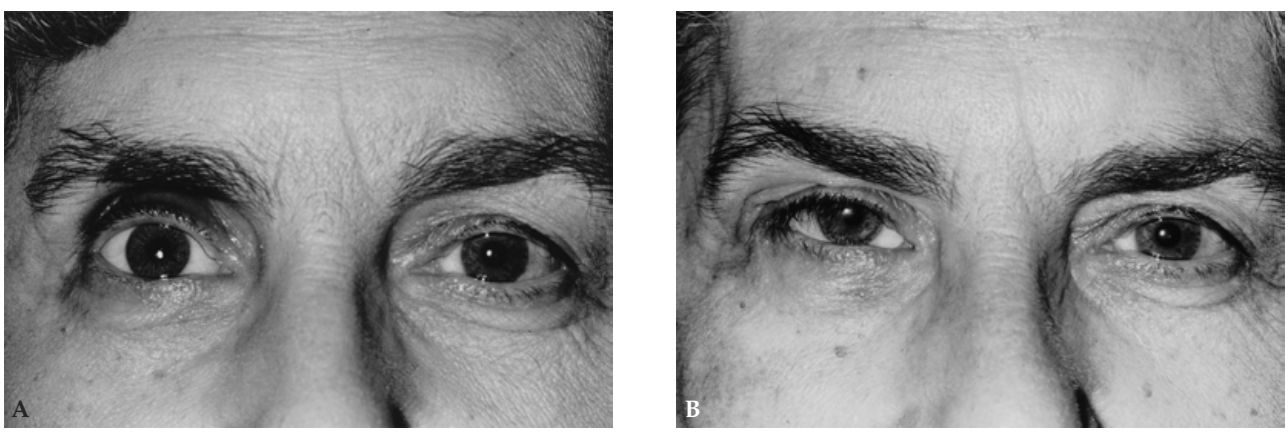


Figure 52–16 This patient has severe enophthalmos and superior sulcus deformity **(A)**. The superior sulcus deformity resolved following placement of a subperiosteal orbital floor implant through a transconjunctival approach **(B)**.

Figure 52–17 Socket contraction is treated with mucous membrane grafting (buccal mucous membrane or hard palate mucosa) in one or both fornices. Entropion and lagophthalmos generally resolve after augmenting the surface area of the socket.

Anophthalmic patients may develop entropion, ectropion, ptosis, and lid retraction. These problems are generally addressed in the same fashion as in ophthalmic patients, except for ptosis repair. Ptosis repair by a conjunctival approach should be avoided because of the risk of losing surface area and instigating socket contraction. An anterior approach to the levator should be used; a frontalis sling will suffice when no levator function exists.

Cosmetic optics provide noninvasive means of disguising the stigmata of anophthalmos.[43] Plus lenses augment and minus lenses minimize the image of the prosthesis. Plus cylinder lenses augment the image in the direction 90 degrees from the axis of the lens. Tint in the upper lens hides the superior sulcus deformity. Most importantly, all anophthalmic patient's should wear protective glasses at all times while awake to protect the functioning eye. Anophthalmic patients should be examined thoroughly by an ophthalmologist at least once a year.

The optimal prosthesis is made by the modified-impression technique.[44] An alginate cast of the patient's socket is made with an impression tray. The prosthesis is made of polymethylmethacrylate in a reverse mold of the alginate cast.

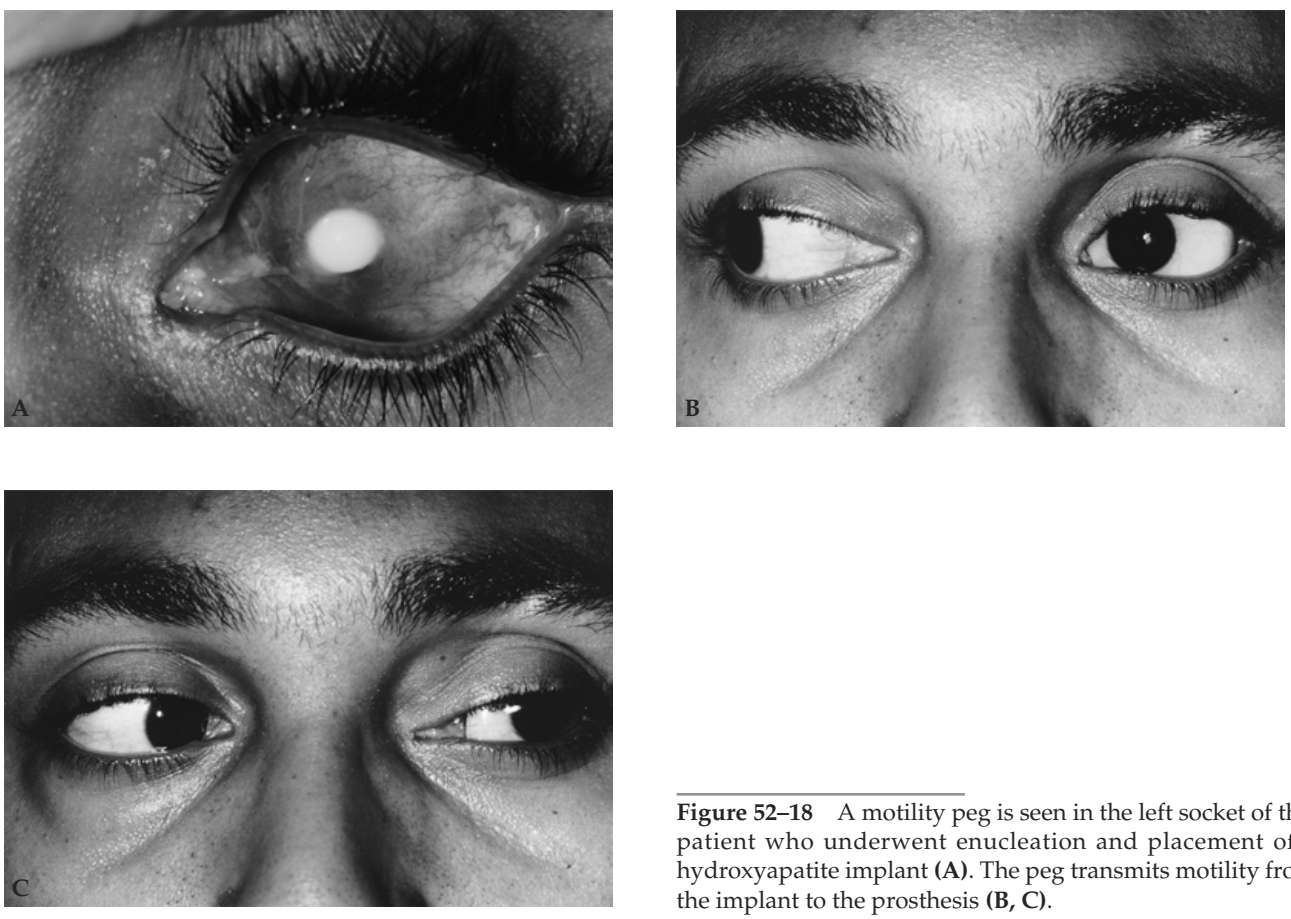


Figure 52–18 A motility peg is seen in the left socket of this patient who underwent enucleation and placement of a hydroxyapatite implant **(A)**. The peg transmits motility from the implant to the prosthesis **(B, C)**.

An iris disk custom-painted by the ocularist to match the appearance of the normal eye is embedded in the plastic. The prosthesis is modified as necessary to alter the position of the eyelids and to augment volume. Maintenance by cleaning and buffing at 6- to 12-month intervals is important for the health of the eye socket. The patient may leave the prosthesis in place for months unless mucous buildup occurs, whereupon more frequent removal and periodic cleaning may be necessary. Many patients experience giant papillary conjunctivitis related to prosthetic wear. Treatment with a mast cell inhibitor ophthalmic solution and an ophthalmic steroid ointment usually eliminates the symptoms of chronic discharge and irritation.[45] Patients often require ophthalmic lubricant drops and ointment on a long-term basis for comfort.

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Chapter 53

Management and Reanimation of the Paralyzed Face

J. Madison Clark and William W. Shockley

Facial paralysis is a potentially catastrophic condition. Unfortunately, the facial nerve is the most commonly paralyzed nerve in the human body.[1] This impairment imposes a devastating effect on the cosmetic, functional, social, psychological, and economic aspects of a person's life. The facial nerve is responsible for emotional and voluntary facial expression, protection of the eye, lacrimation, oral competence, salivation, taste, and sensation. Even in cases where the actual disability is not severe, the accompanying disfigurement may result in a sense of isolation and alienation from one's community. Not surprisingly, depression is a common sequela of facial paralysis.

In addition to the role of facial movement in physical appearance and beauty, an intact facial motor system is essential for effective human communication, both spoken and unspoken. Facial movements provide a supplement to speech and help control the flow of dynamics in conversation. The constancy of facial expression during conversation is cross-cultural. The expressions of happiness, sadness, interest, disinterest, surprise, anger, and fear are universally understood. As originally proposed by Darwin in 1872, human facial expressions of emotion have evolved, are innate, and therefore are universal.[2]

Any distortion or disfigurement of an individual's facial features may have major social and psychological consequences. The sequelae of facial disfigurement, specifically facial paralysis, are complex and unpredictable. Clinical observation demonstrates that some patients with mild facial paresis display severe maladjustment whereas others with complete facial paralysis demonstrate only mild negative reactions. The facial plastic surgeon must understand and anticipate a continuum of psychosocial adjustment in patients with facial paralysis. As with facial aesthetic surgery, reanimation surgery requires extensive preoperative counseling with regard to realistic expectations.

Facial paralysis not only impacts on appearance, self-image, and nonverbal communication, but also results in predictable functional sequelae. These include ophthalmologic disturbances, difficulty with speaking, nasal obstruction from valve collapse, as well as oral incompetence and the inability to maintain effacement of the gingivobuccal sulcus, leading to problems with mastication.

Of greatest concern to the facial plastic surgeon are the potentially devastating ophthalmologic consequences, such as exposure keratitis and corneal ulceration, leading to decreasing visual acuity and potentially to blindness. The fundamental deficits are loss of the blink response and incomplete eye closure. The primary goal in ocular rehabilitation is to protect the cornea from these sight-threatening complications. A staged approach to the management of the eye in facial surgery has been developed and will be discussed later.[3]

Paralysis of the orbicularis oris muscle leads to oral incompetence, which manifests as ipsilateral spillage of food and liquids and difficulty with pronunciation of words that require pursing of the lips. Loss of tone in the buccinator muscle leads to masticatory problems due to difficulty with clearance of food from the ipsilateral gingival buccal sulcus.

Nasal obstruction occurs due to loss of tone in the dilator nasi and nasalis muscles with subsequent valve collapse. This may be compounded by midface skin laxity. The resulting nasal symptoms may be an independent problem or may exacerbate a previously subclinical septal deformity or inferior turbinate hypertrophy.

The overall effect of facial paralysis on static and dynamic facial appearance, verbal and nonverbal communication, functional issues such as ocular dryness and epiphora, oral incompetence, nasal obstruction, and the resultant impairment in the patient's self-image results in significant global disability. Many patients withdraw from their normal lives. They may cease to interact socially, change to jobs that require minimal person-to-person contact, and avoid sexual relationships.[4,5] Not surprisingly, depression is a common emotional response to facial paralysis. It is incumbent on the facial plastic surgeon to recognize these psychosocial manifestations and be prepared to discuss them with the patient. If clinically significant maladjustment to the facial deformity is recognized, then professional referral may be necessary, preferably to a psychologist or psychiatrist with experience in treating patients with facial paralysis.

ETIOLOGIC FACTORS

The most complete differential diagnosis of facial palsy in literature was compiled by May and Klein[6] (Table 53–1). These authors classified the etiologic factors as follows: birth, trauma, neurologic, infection, metabolic, neoplastic, toxic, iatrogenic, and idiopathic. The four most common causes—trauma, Bell's palsy, iatrogenic, and idiopathic—merit further discussion. These are more commonly associated with permanent deficits and therefore frequently require facial reanimation.

TABLE 53–1 Causes of Facial Palsy Identified in a Review of Medical Literature (1900–1990)

Birth
- Molding
- Forceps delivery
- Dystrophia myotonica
- Möbius' syndrome (facial diplegia associated with other cranial nerve deficits)

Trauma
- Basal skull fractures
- Facial injuries
- Penetrating injury to middle ear
- Altitude paralysis (barotrauma)
- Scuba diving (barotrauma)
- Lightning

Neurologic
- Opercular syndrome (cortical lesion in facial motor area)
- Millard-Gubler syndrome (abducens palsy with contralateral hemiplegia caused by lesion in base of pons involving corticospinal tract)

Infection
- External otitis
- Otitis media
- Mastoiditis
- Chickenpox
- Herpes zoster oticus (Ramsay Hunt syndrome)
- Encephalitis
- Poliomyelitis (type 1)
- Mumps
- Mononucleosis
- Leprosy
- Influenza
- Coxsackie Virus
- Malaria
- Syphilis
- Scleroma
- Tuberculosis
- Botulism
- Acute hemorrhagic conjunctivitis (enterovirus 70)
- Gnathostomiasis
- Mucormycosis
- Lyme disease
- Cat scratch
- AIDS

Metabolic
- Diabetes mellitus
- Hyperthyroidism
- Pregnancy
- Hypertension
- Acute porphyria
- Vitamin A deficiency

Neoplastic
- Benign lesions of parotid
- Cholesteatoma
- Seventh-nerve tumor
- Glomus jugulare tumor
- Leukemia
- Meningioma
- Hemangioblastoma
- Sarcoma
- Carcinoma (invading or metastatic)
- Anomalous sigmoid sinus
- Carotid artery aneurysm
- Hemangioma of tympanum
- Hydradenoma (external canal)
- Facial nerve tumor (cylindroma)
- Schwannoma
- Teratoma
- Hand-Schüller-Christian disease
- Fibrous dysplasia
- Neurofibromatosis type 2

Toxic
- Thalidomide (Miehlke's syndrome, cranial nerves VI and VII with congenital malformed external ears and deafness)
- Ethylene glycol
- Alcoholism
- Arsenic intoxication
- Tetanus
- Diphtheria
- Carbon monoxide

Iatrogenic
- Mandibular block anesthesia
- Antitetanus serum
- Vaccine treatment for rabies
- Postimmunization
- Parotid surgery
- Mastoid surgery
- Posttonsillectomy and adenoidectomy
- Iontophoresis (local anesthesia)
- Embolization
- Dental

Idiopathic
- Bell's, familial
- Melkersson-Rosenthal syndrome (recurrent alternating facial palsy, furrowed tongue, fasciolabial edema)

Hereditary hypertrophic neuropathy (Charcot-Marie-Tooth disease, Déjérine-Sottas disease)
- Autoimmune syndrome
- Amyloidosis
- Temporal arteritis
- Thrombotic thrombocytopenic purpura
- Periarteritis nodosa
- Guillain-Barré syndrome (ascending paralysis)
- Multiple sclerosis
- Myasthenia gravis
- Sarcoidosis (Heerfordt syndrome–uveoparotid fever)
- Osteopetrosis

Adapted from May M, Klein S. Differential diagnosis of facial nerve palsy. *Otolaryngol Clin North Am* 1991;24:613–644.

In adults, blunt head injury is the most common cause of traumatic facial nerve injury. Approximately 7 to 10% of temporal bone fractures are associated with facial nerve dysfunction.[7]

Overall in children, trauma is second to Bell's palsy as a cause of facial palsy.[8] The more lateral position of the stylomastoid foramen and facial nerve renders it a higher risk factor in neonates and children. In neonates, the most common cause is birth trauma. A complete return of facial nerve function without sequelae was found in more than 90% of neonatal cases.[9] Facial paralysis in neonates with congenital malformations, such as Möbius' syndrome, has a poor prognosis for recovery.

Iatrogenic facial paralysis following middle ear and mastoid surgery ranges in incidence from 0.2 to 1.4%.[10,11] The most common segment of the nerve to be iatrogenically injured is the tympanic segment.

Controversy remains regarding the difference between Bell's palsy and idiopathic facial palsy. However, formerly regarded as synonymous terms, most experts currently believe that Bell's palsy is caused by a herpes simplex virus (HSV) infection.[12–14] Statistically significant improvement in facial nerve function with acyclovir in a double-blind, prospective, randomized trial[15] is also suggestive of HSV causality. Despite the improved outcomes reported with treatment with antiviral agents and steroids, a small percentage of patients with Bell's palsy have a poor outcome, with incomplete return of facial movement.[12]

EVALUATION AND WORKUP

As with any disease or injury, a detailed history and physical examination precedes therapeutic intervention. The history and physical exam are directed to identification of the cause and topographic location of the injury, the degree of injury, and the optimal choice of neural repair or reanimation techniques.

After a complete history, physical examination, electrodiagnostic studies, and imaging studies have been obtained, the facial plastic surgeon is faced with the decision of when and how to proceed with facial reanimation. The complex decision making involved in facial reanimation is not unlike that faced by the head and neck surgical oncologist. The decision must include consideration of both disease-specific factors and patient-specific factors. Disease-specific factors include prognosis for recovery (such as from resection of tumors involving the brain stem or cerebellopontine angle, or from parotid gland malignancies) and likelihood of recurrence or progression of disease (such as in neurofibromatosis). Patient-specific factors include age, medical status, skin type, motivation for rehabilitation, and likelihood of appropriate follow-up.

State-of-the-art rehabilitation of persons with facial paralysis involves a comprehensive program that includes medical management, physiotherapy, and psychosocial support, in addition to the myriad of surgical procedures available for reanimation.

Radiographic Testing

Radiographic studies are occasionally necessary in patients with facial paralysis. Generally, the extratemporal facial nerve is usually made visible with fine-cut computed tomography (CT) scanning, whereas the intratemporal and intracranial portions are best seen with MRI.

MRI has contributed significantly to improved imaging of the facial nerve. Gadolinium-enhanced MRI allows detection of inflammation and edema of the facial nerve, as well as differentiation of facial nerve tumors or hemangiomas from Bell's palsy.[16] Gadolinium enhancement centered at the geniculate ganglion on the side of the paralysis is often seen in patients with Bell's palsy. In addition, MRI findings may also carry prognostic significance in these patients. Murphy reported that patients with Bell's palsy who had enhancement extending to the mastoid segment of the facial nerve had more severe inflammation and, consequently, a poorer chance for recovery.[16] Some authors have recommended gadolinium-enhanced MRI prior to any reanimation procedure for facial nerve paralysis.

Radiographic testing should also be considered in the following clinical scenarios: (1) a patient with facial paralysis with a palpable mass in the parotid gland; (2) a patient with a suspected lesion in the internal auditory canal (IAC) or cerebellopontine angle; and (3) a patient with atypical idiopathic facial paralysis or Bell's palsy.

Electrodiagnostic Testing

Electrodiagnostic testing is a method of evaluating the degree of injury to the facial nerve and the integrity of the facial musculature. This battery of tests adds valuable information to the history and physical examination with regard to choice of method of facial reanimation. Electrical testing of the facial nerve is unique in the following ways: (1) as most causes of facial nerve injury occur proximal to the stylomastoid foramen, the electrical stimulation point is distal to the site of injury; (2) as the nerve distal to the lesion responds normally to stimulation as long as the axon is intact, the nerve will continue to respond to stimulation even in the presence of paralysis; and (3) with axonal disruption or complete transection, the ability to transmit and impulse is gradually lost over a period of 3 days, corresponding to the timing of Wallerian degeneration.

Electrodiagnostic testing is particularly helpful in differentiating a Sunderland first- or second-degree neural injury from more severe injury.[17] Compression of nerve trunks tends to block the larger fibers first because the smaller ones are more resistant to compression.[18] Initially, compression slows conduction through the area of injury, but conduction proximal and distal to the area of injury remains normal. Further compression will cause a complete block of transmission, first in the less resistant larger fibers and then in the smaller ones. As long as axonal flow remains intact, the nerve responds to stimulation distal to the area of compression. When axonal flow is completely blocked (axonotmesis, or Sunderland second degree), response to stimulation distal to the lesion decreases.

A variety of electrical tests are available, but the most commonly used tests are the maximum stimulation test (MST), the nerve excitability test (NET), electroneuronography (ENOG), and electromyography (EMG).

Maximum Stimulation Test

The MST is an excellent test for facial nerve degeneration soon after onset of injury. The test is not useful during the first 3 days after injury because the nerve with complete proximal transection will continue to conduct impulses distally for up to 3 days. The test is performed using the Hilger

nerve stimulator and involves subjective observation of the facial musculature in response to electrical stimulation. The technique for performing the MST is described in detail by Blumenthal and May.[18] The parameter of significance for the interpretation of the results of the MST is the amount of muscle twitch in response to supramaximal stimulation with the nerve stimulator. The response on the paretic side is compared with that on the normal side.

Because the test is uncomfortable for the patient, and because patients with incomplete paralysis have a favorable prognosis, the test should not be performed unless there is complete (House-Brackmann grade 6) paralysis. May found that when the MST was absent within 10 days of injury, the test was 100% reliable in predicting an incomplete return of facial function. When the response was markedly decreased, 73% of patients had an incomplete return of facial function.[19]

Nerve Excitability Test

The NET is based on the same principle as the MST, except that the NET measures the current (in amperage) required to obtain a minimal visible response at a standard square-wave pulse duration. Like the MST, the test is not useful during the first 3 days after injury because the distal segment of the nerve, even with complete proximal transection, will continue to conduct impulses distally for up to 3 days. The test is also performed using the Hilger nerve stimulator, which measures the difference in the amperage required to produce a barely visible twitch on the paretic side compared with that required on the normal side. A side-to-side difference of greater than 3.5 mA indicates a poor prognosis.[18]

Electromyography

EMG is the study of depolarization potentials of muscle fibers and groups of fibers that make up motor units. EMG measures the response to needle insertion and electrical activity of the muscle/motor unit at rest. As the needle is inserted in the muscle, a short burst of electrical activity normally occurs. Insertion activity is decreased when muscle has atrophied. With denervation, activity is usually increased and positive sharp waves are often present.

After insertion of the stimulating electrode, the muscle is measured at rest. Normal resting muscle exhibits no spontaneous electrical activity. With denervation, spontaneous fibrillation potentials and positive sharp waves are present. The presence of fibrillation potentials is the strongest electromyographic evidence that denervation has occurred.[18] Fibrillation potentials are not present immediately after injury, however. It may take up to 2 or 3 weeks for fibrillation potentials to be detected by EMG. The farther the recording electrode is placed from the site of the lesion, the longer it takes for the fibrillations to appear.[20]

Polyphasic action potentials (PAPs) refer to simultaneous discharge of a group of nerve fibers in the motor unit in the field of the stimulating electrode. PAPs are the best indication that regeneration is occurring.

EMG is most useful when significant nerve degeneration has occurred and the responses to the MST and ENOG have been lost. EMG can demonstrate the presence or absence of viable facial muscle tissue, as well as the gross functional integrity between nerve and muscle.

Electroneuronography

ENOG evaluates the integrity of the nerve and muscle together. ENOG is similar to the MST and the NET, except that instead of relying on observation of the response, the response to a supramaximal stimulation is recorded by the distal recording electrodes in ENOG. Fisch used ENOG to determine which facial nerve disorders would be best treated by facial nerve decompression.[21]

Using surface electrodes, a stimulating electrode is placed over the main trunk of the facial nerve on the skin at the stylomastoid foramen and a recording electrode is placed over the distal facial musculature. If intact axons are present over the branch of the nerve being tested, then an action potential will be generated and recorded. If axonal degeneration or transection has occurred, then the ability to transmit an impulse will be lost after about 3 days. As in the MST and the NET, ENOG compares the response on the paretic side of the face with that on the normal side; however, ENOG is more sensitive.[22] The results are expressed as a percentage of the amplitude of the action potentials on the abnormal side as opposed to the normal side. This is believed to correlate with the percentage of nerve degeneration.[23]

ENOG results are most commonly used to stratify patients into surgical decompression versus observation following nerve injury. A 90% degeneration of the nerve is considered to be the threshold for consideration of surgical decompression.

MEDICAL MANAGEMENT

Protection of the Eye

The primary goal of medical management in patients with facial paralysis is to protect the cornea from sight-threatening complications. As such, it should begin immediately following facial nerve injury. Correction of eyelid malpositions, reduction of epiphora, and improvement of cosmesis are therefore secondary goals, although they are of great importance to the patient.[4,24] It is vitally important for the facial plastic surgeon to emphasize the serious nature of eye protection when discussing the reconstructive possibilities because the patient may be more concerned with aesthetic aspects.

Corneal protection begins with patient education about the eyelids and their function. Eyelids provide a physical barrier to trauma and desiccation, and they inhibit adherence of organisms to the ocular surface. The tear film contains antimicrobial substances, such as immunoglobulin A, and provides mechanical lubrication to wash away organisms. If eyelid closure is defective, as with facial palsy, then the tear film may not provide adequate coverage and the epithelium may become susceptible to desiccation. This reduction in mechanical protection and tear production is especially dangerous in patients with concurrent ipsilateral corneal hypesthesia.

After adequate evaluation of the eye, treatment of the paralytic eye begins with a regimen of regular ocular lubrication. At a minimum, the regimen should include the use of artificial tears or the equivalent 5 to 10 times per day, with ophthalmic ointment at night. About one third of patients require lubrication only, and such patients do not require ophthalmic referral.[3]

Other adjunctive measures include the use of a moisture chamber and taping. A moisture chamber is used *in addition to drops and ointment* and has been found to be most useful

whenever the patient is outdoors (to prevent mechanical trauma). Taping must be atraumatic, as corneal injury may result from poor taping technique. The nonallergenic tape should be applied from superomedial to inferolateral and should not contact the cornea or invert the eyelids. Again, taping is used *in addition to drops and ointment.*

Our recommendations regarding ophthalmologic referral are to refer (1) any patient with symptoms or signs of ocular irritation, (2) any patient with concurrent ipsilateral corneal hypesthesia, and (3) any patient being considered for surgical intervention.

Physical Therapy

Physical therapy is an underutilized modality in the comprehensive treatment of patients with facial nerve paralysis. Many patients with Bell's palsy are told, "Relax, it will get better on its own." Indeed, the natural history of Bell's palsy is that most patients recover fully, without any intervention. As previously alluded to, the goal in the management of patients with Bell's palsy is identifying those patients *early* who will not achieve full recovery. Those patients predicted to have adverse sequelae should have intervention designed to maximize their functional outcome. Several investigators have shown that outcomes may be improved with the use of physical therapy.[25–27] Additional research suggests that physical therapy also improves outcomes in patients who have undergone neural procedures or reanimation surgery for facial paralysis.[25,28–34]

Methods of rehabilitation for facial paralysis have included massage, electrical stimulation, and repetition of common facial expressions. This "generic" form of therapy has been found to be of little benefit.[35,36] In fact, some authors have suggested that certain nonspecific interventions may affect recovery adversely, perhaps by disrupting reinnervation patterns and leading to greater synkinesis and mass movement of the facial muscles.[28,36–38]

The most promising physical therapy treatment technique for patients with facial paralysis appears to be facial neuromuscular reeducation using surface electromyography (sEMG) or mirror biofeedback. Randomized clinical trials have demonstrated that qualitative and quantitative improvements in facial movement occurred after this method of treatment. Facial neuromuscular reeducation is a process of relearning facial movement using specific and accurate feedback to (1) enhance facial muscle activity in functional patterns of facial movement and meaningful expression and (2) suppress abnormal muscle activity and synkinesis interfering with normal facial function.[36] The program is highly individualized and has been validated, based on classification of patients according to one of four treatment-based categories.[36]

Comprehensive management of patients with facial paralysis should include the vital involvement of a physical therapist on the multidisciplinary team. The therapist should be involved early in the evaluation, as physical therapy techniques, like most surgical procedures, are most effective when implemented early in the course of the disease.

Botulinum Toxin

Botulinum toxin (botox) is a relatively new treatment in the medical armamentarium for the management of facial paralysis. In patients with facial neuromuscular disorders, botox was initially introduced to treat patients with hemifacial spasm and hyperkinetic blepharospasm following Bell's palsy.[25] The use of botox in facial paralysis patients now includes selective medical neurolysis, treatment of hyperlacrimation after Bell's palsy, and treatment of synkinesia.[39–41]

Aberrant regeneration of fibers after facial nerve injury leads to several untoward effects, as previously mentioned, such as involuntary synkinesia between the orbicularis oculi and orbicularis oris muscles, or increased lacrimation of the affected eye. Botulinum toxin blocks the presynaptic release of acetylcholine and causes a functional denervation of neuromuscular end plates. Collateral sprouting reestablishes the pathologic state after 3 to 5 months.[39]

Local injection of botox into the orbicularis oculi muscle has been found by many researchers to be an effective means of controlling facial synkinesis.[40,42,43]

The toxin affects the neuromuscular junction as well as the autonomic cholinergic transmission, as in the lacrimation pathway. Secremotor fibers of the facial nerve innervate the lacrimal gland through greater superficial petrosal nerve via the nervus intermedius. After a facial nerve injury or Bell's palsy, aberrant fibers originally destined for the submandibular and sublingual glands may develop and travel to the lacrimal gland, causing a hyperlacrimation syndrome whenever the patient salivates (crocodile tears, or Bogorad's syndrome). Because the fibers to the lacrimal gland utilize acetylcholine as a neurotransmitter, local injections of botox into the gland can remedy hyperlacrimation.

In fact, Boroojerdi et al have reported nearly total resolution of hyperlacrimation in a cohort of patients using this technique.[39] The authors found successful response in most patients with subcutaneous injection in the superolateral part of the orbicularis oculi muscle, and when this was suboptimal, injection into the lacrimal gland was more effective.

Corrective Makeup Techniques

Makeup application is not simply a technique for covering the face with color. It is also a cognitive interactive technique that can change a person's appearance and create different impressions using optical illusion.[44] Wright et al reported improvements on the depression and psychasthenia scales of the Minnesota Multiphasic Personality Inventory (MMPI) administered to young women with facial blemishes who were given beauty instruction involving basic skin care and makeup.[45] Makeup techniques have been applied to clinical situations and have demonstrated efficacy in patients with depression, schizophrenia, and senile dementia.[46,47]

Recently, Kanzaki et al reported the use of makeup techniques to improve the appearance in two women with incomplete facial paralysis (House-Brackmann grade III) following surgical resection of posterior fossa lesions. An expert beautician instructed the women in the application of makeup to correct their facial imbalance. In both cases, results of personality assessments administered before and after instruction demonstrated positive changes, including reduction in depression and feelings of inferiority. The authors stressed the simplicity, low cost, and lack of any risk of their use of makeup as an adjunct to reanimation procedures or during recovery from facial nerve paralysis.[48]

SURGICAL REANIMATION PROCEDURES

Eye

Medical treatment of the paralytic eye has been discussed previously. From a surgical perspective, the primary goal is to continue medical protection of the eye against sight-threatening complications. When considering the surgical options for improvement in cosmesis of the eye, this primary goal must not be compromised.

A multitude of surgical procedures have been described to correct paralytic lagophthalmos and ectropion, the main surgically correctable ocular features in patients with facial paralysis. Techniques include tarsorrhaphy as well as use of Silastic or wire-spring implants, gold weights, magnets, ear cartilage grafts, and various muscle-tendon slings or grafts.[49–53] Reanimation may require surgery on the upper eyelid alone or on the lower lid as well. The method of "dual reanimation," or addressing the eye and the mouth with independent surgical procedures, provides the best functional and cosmetic results.[54]

Before any reanimation procedures are attempted, it is necessary to ascertain the baseline function of the eye and its supporting structures. A complete eye examination should include assessment of visual acuity, assessment of presence or absence of a Bell's phenomenon, assessment of tear production with a Shirmer's test, evaluation of the lacrimal excretory system with a Jones test, and measurement of the margin gap (the distance between the borders of the upper and lower eyelids on closure).[52]

Lower Eyelid Procedures

Although much attention has been directed to rehabilitation of upper lid lagophthalmos, assessment and treatment of the paralyzed lower eyelid has largely been neglected. The amount of lower lid laxity is best assessed by the snap test. The decision whether or not to address the lower medial canthus as part of the ectropion correction depends on the position and function of the inferior punctum. Medial lower lid laxity, or medial ectropion, causes the punctum to evert. With the inferior punctum no longer against the globe, drainage of the lacrimal system is interrupted, resulting in pooling of tears at the inferior lid margin.[52]

Correction of medial lower lid laxity requires that the inferior punctum be moved back into its native position against the globe to avoid collection of tears in the inferior cul-de-sac. This may be accomplished by the use of a Gore-Tex sling procedure[52] or a medial canthoplasty.[55]

Most doctors prefer to use the medial canthoplasty technique,[55] thereby avoiding the use of foreign material. Normally, the procedure is performed under local anesthesia with intravenous sedation. The cornea is topically anesthetized with tetracaine, lubricated, and a corneal protector applied. The incision is marked prior to injection of local anethesia (Fig. 53–1). After the flaps have been raised, the tarsal components of the superior and inferior canthal tendons are dissected. The lateral portion of the inferior canthal tendon is plicated to the medial portion of the superior canthal tendon. Excess skin is excised prior to skin closure.

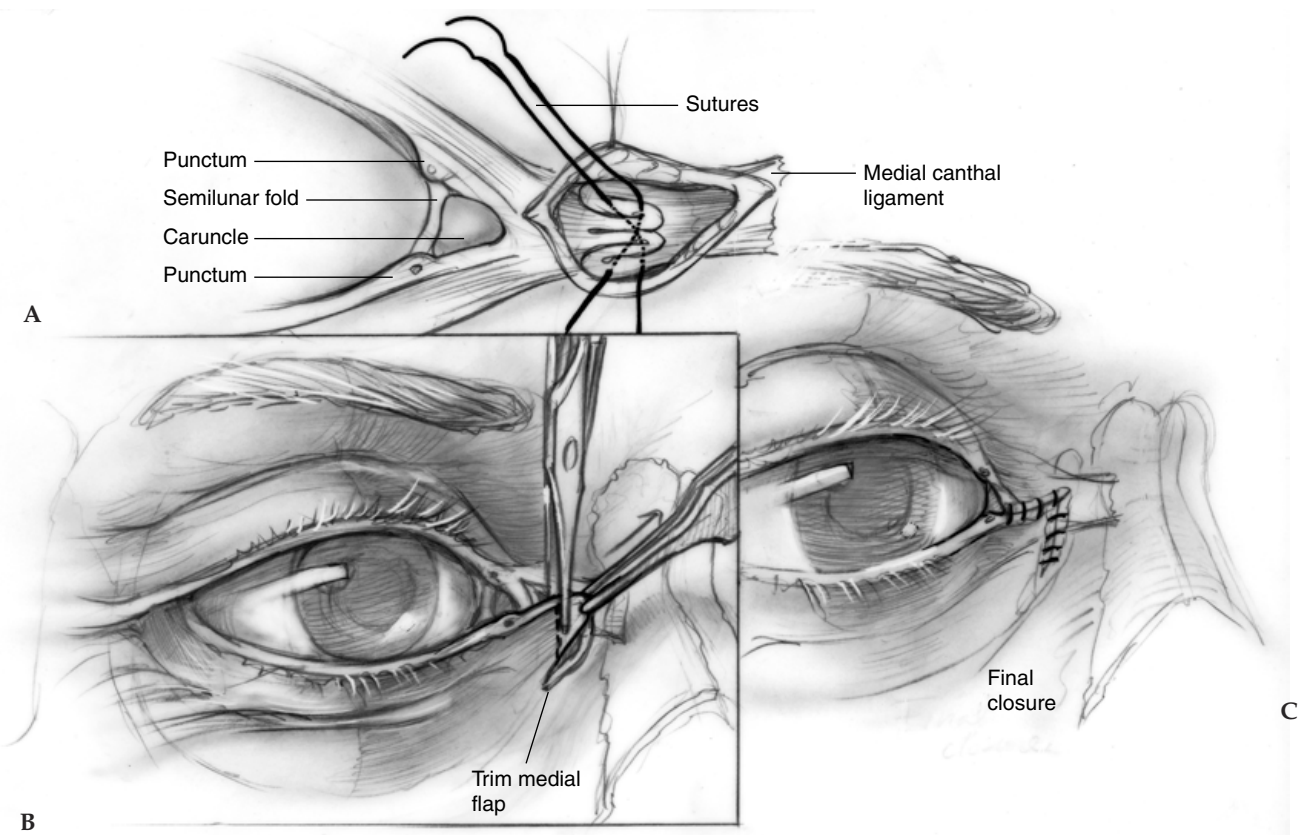

Figure 53–1 Medial canthoplasty. **(A)** Placement of sutures to tighten medial canthal ligaments. **(B)** Trimming of medial skin flap. **(C)** Final skin closure.

Laterally, the extent of laxity ranges from scleral show, defined as greater than 1 mm distance between the margin of the lower lid and the inferior limbus, to ectropion. When lateral lower eyelid laxity is excessive, a horizontal lid-shortening procedure is indicated. This procedure usually uses some variation on the classic tarsal strip technique.[52] A lateral canthotomy and inferior cantholysis are performed, preserving the insertions supplied from the upper lid. The anterior lamella of skin and muscle is separated from the posterior lamella, and the skin and conjunctiva are removed. The lateral canthal ligament is then trimmed appropriately and resuspended from periosteum from the medial surface of the lateral orbital rim superior to Whitnall's tubercle (Fig. 53–2).

Upper Eyelid Procedures (Gold Weight)

Of the upper eyelid procedures, the gold weight implantation is currently the most popular. Originally conceived by Sheehan,[56] lid loading was later refined by Jobe,[57] who also introduced gold as the material of choice. The primary advantage of lid loading over other upper eyelid techniques is the superior success rates and low complication rates.[49,55,58] The advantages of gold are its low reactivity, high density, and good color match with skin. The gold weights are easily selected for proper placement and are reversible. This relatively simple procedure is usually performed under local anesthesia. The disadvantages are threefold: (1) Gold is a foreign body and could possibly extrude; however, extrusion rates are extremely low. (2) Lid loading is gravity-dependent, so when the patient is supine, it can be counterproductive. However, most of our patients do not require lubrication while sleeping after placement of gold weights. (3) The gold weight leaves a visible bump on the upper eyelid when it is closed. A thinner, lower profile gold weight design is reported to improve the cosmetic result.[49]

The technique begins with a small amount of local anesthetic injected in the supratarsal fold and over the tarsal plate (Fig. 53–3). The incision is slightly longer than the implant and is centered over the junction between the medial and middle thirds of the upper eyelid. The skin is elevated to the superior edge of the tarsal plate. The orbicularis is sharply incised, and a pocket is formed over the tarsal plate to within 2 mm of the lash line. The weight is placed in the pocket so that the side with two fenestrations faces cephalad. The implant is sutured to the levator aponeurosis over the tarsal plate, using the fenestrations (Fig. 53–4).

Neural Procedures

Regardless of the cause of facial paralysis, the most successful outcomes for reanimation were brought about by procedures intended to restore neural input to a functionally intact neu-

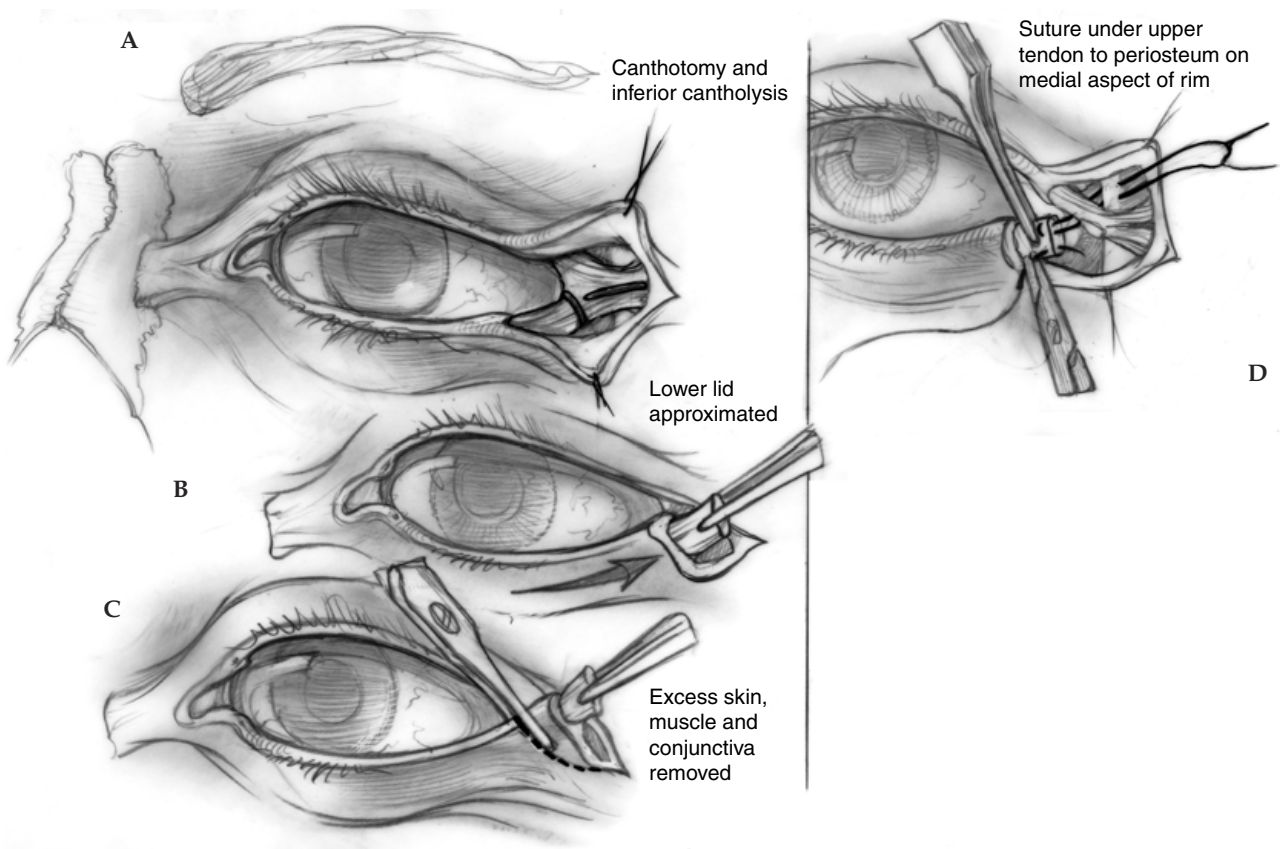

Figure 53–2 Lateral tarsal strip. **(A)** Exposure and division of inferior lateral canthal tendon. **(B)** Lateral retraction of tendon to correct lid malpositioning. **(C)** Skin, muscle, and conjunctiva stripped from tendon as necessary. **(D)** Resuspension of tendon to medial aspect of lateral orbital rim.

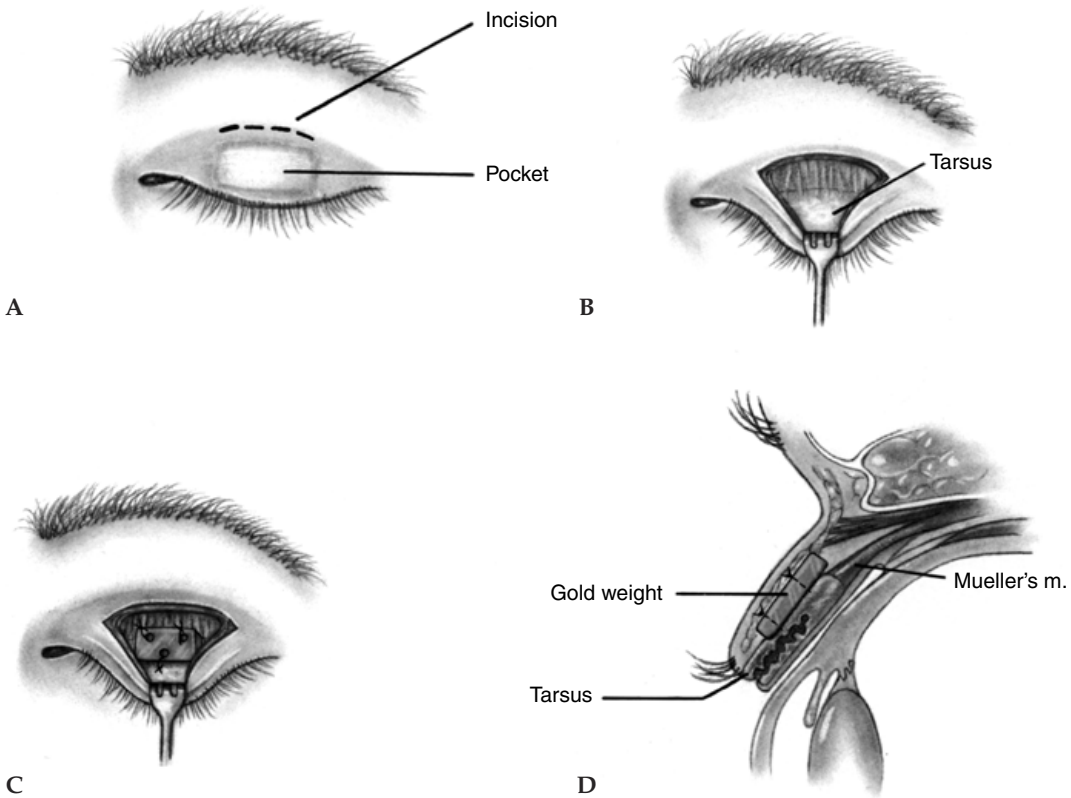

Figure 53–3 Gold weight implantation. Twenty-four-carat polished gold weights are available in weights ranging from 0.6 to 1.4 g (Med Dev Corp., Los Altos, CA). With the patient sitting, these are taped to the upper lid 2mm above the lash line over the tarsal plate. The patient is asked to close the eyelid and blink, and the lightest weight that provides closure is selected. Weights of 1.0 or 1.2 g are most frequently used. Thinner gold implants that are less visible after implantation have recently become available. **(A)** The surgical approach is similar to that of upper lid blepharoplasty. Although most prefer the pocket in the midline, some place the implant more medially at the junction between the medial and middle third of the upper lid. Following infiltration of local anesthetic into the upper lid, an incision is made in the supratarsal fold. **(B)** The incision is extended through the skin and orbicularis oculi muscle to the levator aponeurosis overlying the tarsal plate. The pocket is enlarged in this plane. **(C, D)** The gold weight is placed in the pocket and secured with 6–0 fast-absorbing gut suture through the three holes in the implant 2 mm above the lash line. The wound is closed in a single layer using a running 6–0 fast-absorbing gut suture. Magnification with loupes is recommended for this procedure. (From Burgess LPA, Goode RL. *Reanimation of the Paralyzed Face*. New York: Thieme Medical Publishers; 1994:53. With permission.)

romuscular junction. Restoring impulses from the ipsilateral facial nerve is the first choice.[59–64] This could occur in the setting of facial nerve preservation/exploration for tumor removal, facial nerve decompression after trauma or Bell's palsy, neurorrhaphy with or without rerouting, and cable grafting. Nerve crossover procedures are a secondary consideration, with variations of XII–VII most commonly in use today. Cross-facial nerve grafting is another consideration, but this technique without free-muscle transplantation has largely been abandoned due to poor results.

Extratemporal Neurorrhaphy

It is currently accepted that the optimal timing of primary neurorrhaphy is immediately following injury to permit coaptation of the nerve ends before scarring and retraction require more extensive mobilization and grafting. Some authors have advocated waiting until 21 days after injury based on the belief that the greatest degree of axonal regeneration occurs at 21 days. Barrs reviewed the literature pertaining to this question, concluding that the best functional

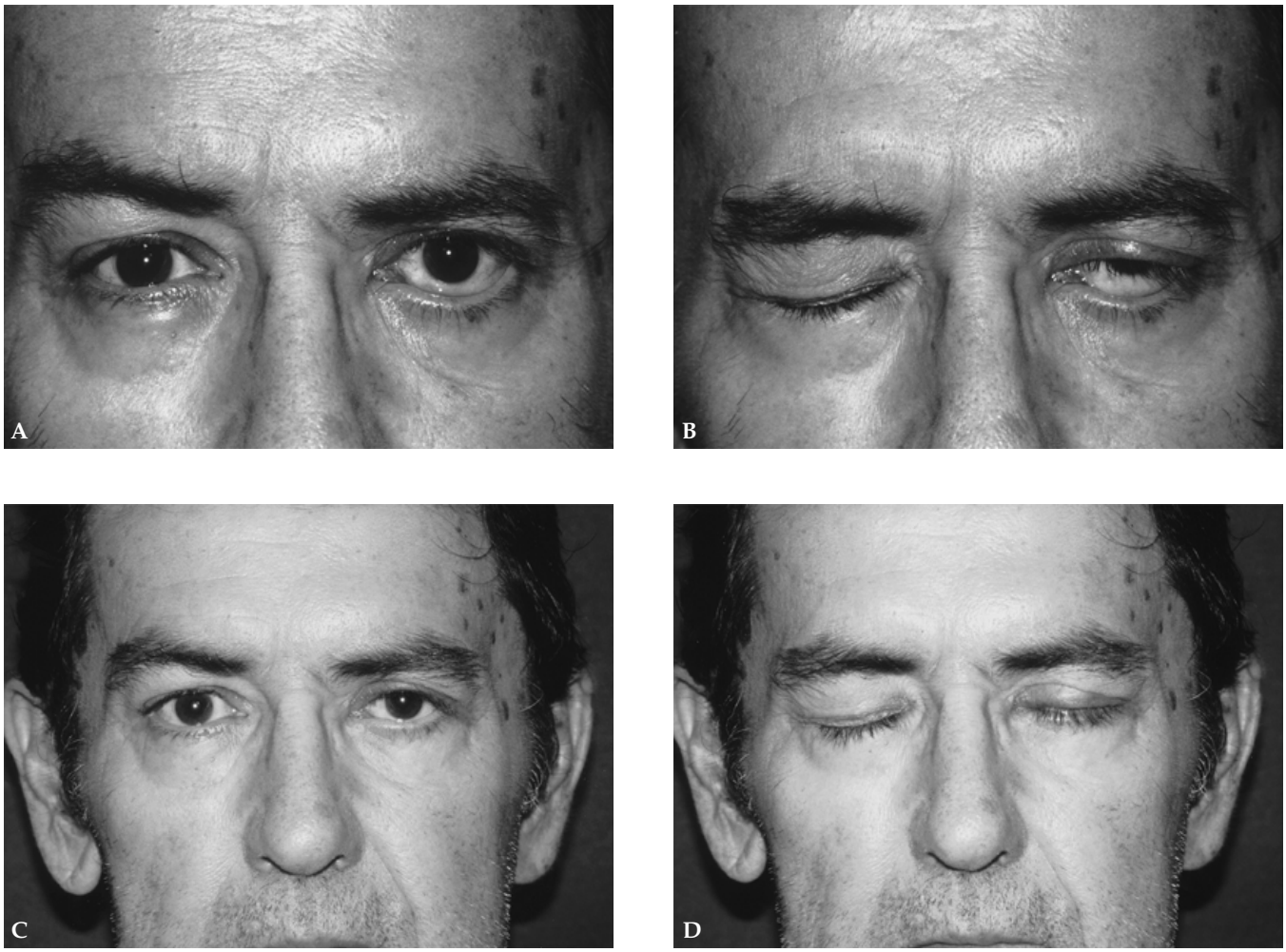

Figure 53–4 A 52-year-old patient with injury to upper division of left facial nerve following penetrating trauma. **(A)** Scleral show and obvious lower lid laxity. **(B)** Inadequate left eye closure despite previous placement of gold weight on upper lid. **(C)** Improvement in left lower lid contour following lateral tarsal strip procedure. **(D)** Complete eye closure following placement of heavier gold weight on upper lid.

results are found with early repair. He also investigated optimal timing of repair in micropigs and found that there is a linear decrease in axonal counts and lower regeneration rate with delay of repair.[60]

The repair may be carried out with either a perineural (fascicular) or epineural repair (Fig. 53–5). Most surgeons have abandoned the perineural repair because of its increased technical difficulty without proof of its superiority over epineural repair.

The technique for extratemporal primary neurorrhaphy is carried out under the operating microscope. The nerve edges are freshened with a microblade on a tongue depressor. Since both proximal and distal (wallerian) axon degeneration occurs, the resection back to normal nerve is probably the most important surgical consideration in delayed nerve grafting.[60] Two sutures are placed 180 degrees apart and used as traction sutures. Based on the study by Szal and Miller, a total of six interrupted sutures is optimal for epineural repair.[65]

Intracranial and Intratemporal Neurorrhaphy

A complete discussion of advantages, disadvantages, and techniques of intracranial and intratemporal facial nerve neurorrhaphy is beyond the scope of this chapter, but a few salient points can be made. The interested reader is referred to an excellent review by Fisch and Lanser.[66]

Coaptation in the cerebellopontine angle is possible in experienced hands, but it usually requires the use of collagen splints to simplify coaptation and stabilize the intracranial anastomotic site.[66]

Cross-Face Grafting

Since its introduction in the early 1970s,[67] cross-face grafting has fallen out of favor except as part of staged free-muscle transplantation. In this procedure, 30 to 50% of the buccal and zygomatic branches on the nonparalyzed side are severed and anastomosed to the corresponding branches on the paralyzed side. Theoretically, this produces

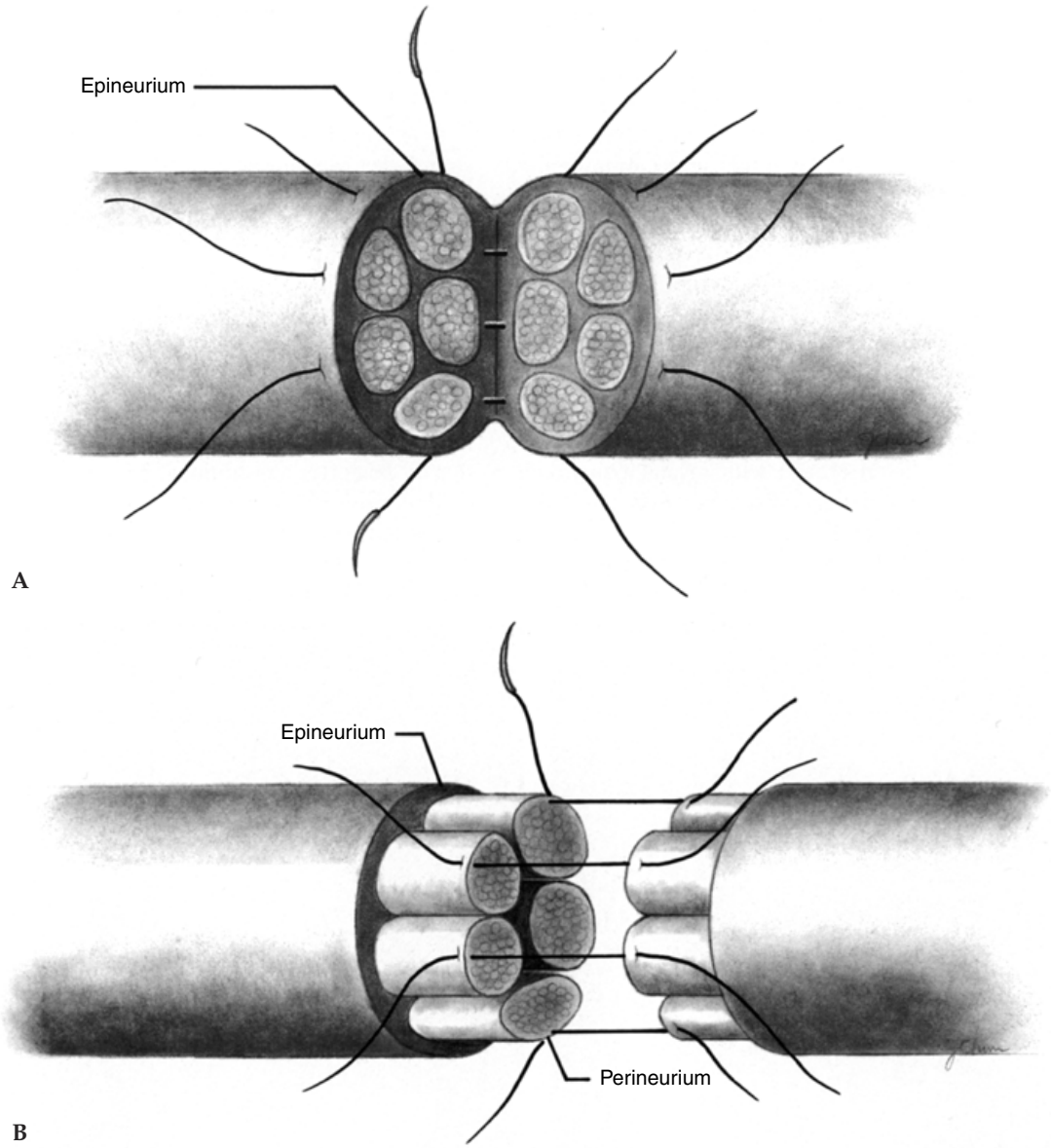

Figure 53–5 **(A)** Epineural nerve repair is performed under the operating microscope using microneural techniques with 9-0 monofilament. A tapered needle is preferred over a cutting needle. The nerve edges are freshened with Prolene with sharp microscissors. A clamp neuropathy is used beneath the nerve ends to improve visibility during suturing. Most repairs are usually sutured free hand without a frame as used in vessel anastomosis.

Normally, six sutures are used and spaced 60 degrees apart. Three sutures are placed from top to bottom on the underside of the nerve; then three sutures are placed from top to bottom on the surface closest to the surgeon. Fewer sutures could be used for smaller peripheral nerve branches. Based on the study of Szal and Miller,[65] the use of six sutures is probably close to the optimal number for epineural repair. **(B)** Perineural (fascicular) repair. The adventitia and epineurium are dissected back several millimeters, thus exposing the fascicles. Excessive removal of the adventitia should be avoided, as this strips the nerve edges of its blood supply. The epineurium should only be removed to allow access to the fascicles, as excess removal causes the fascicles to lose their orientation and separate into spaghetti-like strands. Protruding endoneurium is trimmed from the edges of the fascicles using microscissors, and single 10-0 nylon sutures are used to approximate individual fascicles. The epineurium can then be replaced or resected with no difference in end results. (From Burgess LPA, Goode RL. *Reanimation of the Paralyzed Face*. New York: Thieme Medical Publishers; 1994:16. With permission.)

minimal deformity on the normal side while restoring symmetry and some mimetic function on the paralyzed side. However, disappointing results with respect to incidence and amount of movement were reported by several respected authors.[68–70]

The technique can be performed in one or two stages. The second stage was originally added by Anderl, who postulated that fewer axons would grow through the second suture line if the scar had already formed before the axons arrived.[71]

In the first stage, the zygomatic and buccal branches of the nonparalyzed facial nerve are exposed through a preauricular, melolabial, or direct incision. The branches are stimulated electrically and blocked with local anesthesia to determine the dominant branches on the nonparalyzed side. These branches are preserved, and others (approximately 50%) are cut cleanly. The branches are anastomosed to the sural nerve grafts and crossed to the other side. The sural grafts are tunneled through the upper lip and forehead with the help of midline incisions in the philtrum and glabella, respectively. Several sural cross-face grafts can be used. However, buccal grafts are the most important and most likely to be successful. The distal ends of the sural grafts are brought out beyond the edge of the parotid gland and marked with colored sutures that are brought out through the skin and cut near the surface.

The second stage is performed 4 to 6 months later. Through a preauricular incision on the paralyzed side of the face, the distal ends of the sural grafts are identified and the neuromas resected cleanly. The grafts are then anastomosed to the paralyzed branches of facial nerve as they exit the parotid gland. Alternatively, the nerve ends can be directly implanted into the atrophying muscle on the paralyzed side after the neuromas have been excised.

Cable Grafting

Interposition facial nerve grafting is used when the proximal and distal ends of the nerve cannot be coapted without tension. Techniques have been developed for grafting anywhere along the length of the facial nerve, from the cerebellopontine angle to the parotid gland.[66]

The most complicated segment to graft is the intracranial segment, due to the lack of an epineural sheath, as well as the deep and limited exposure and the background of constant cerebrospinal fluid flow. Most commonly indicated after removal of a large acoustic neuroma, results obtained with splinting in the cerebellopontine angle have been reported to compare favorably with those at more distal segments.[66]

A more common clinical situation in which cable grafting is employed is extratemporal grafting, such as following the removal of parotid malignancy with involvement of the facial nerve. For cases in which less than 10 cm in length of nerve graft is used, a contralateral greater auricular nerve graft is harvested (Fig. 53–6). Ipsilateral nerve grafts can be used as well, provided tumor-free integrity can be established. For more than 10 cm and up to 35 cm, a sural nerve graft is used (Fig. 53–7).

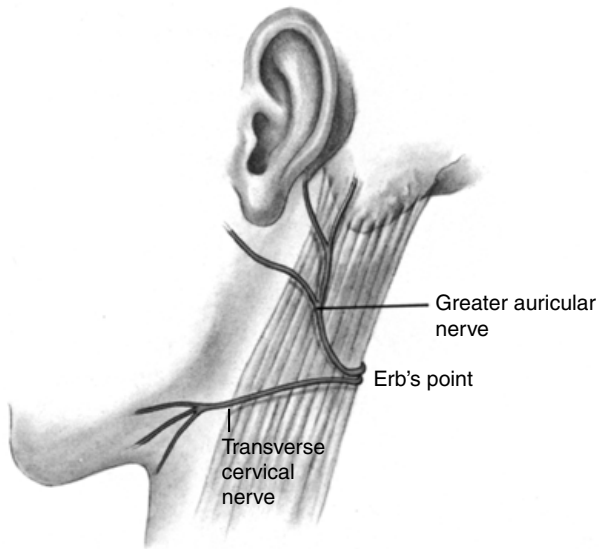

Figure 53–6 Greater auricular and transverse cervical nerve grafts. The greater auricular nerve can be identified at Erb's point or as it crosses the superior third of the sternocleidomastoid muscle on its course toward the auricle and parotid gland. The main branch can also be identified at a midpoint between the mastoid tip and the angle of the mandible. (From Burgess LPA, Goode RL. *Reanimation of the Paralyzed Face*. New York: Thieme Medical Publishers; 1994:18. With permission.)

According to the method of Fisch and Lanser, two branches are used—one to the upper and one to the lower branch. They recommend clipping the branches of the digastric muscle, the retroauricular muscle, the platysma, and most of the buccal branches. This is based on laboratory work done on rats by Mattox et al,[72] which demonstrated that ligation of peripheral facial nerve branches concentrates regenerating axons in still "open" ramifications. By this method, regeneration is directed to the more important upper and lower regions of the face while minimizing mass movement in the midface.[73]

Nerve Crossover: XII–VII, Other Cranial Nerves

Nerve crossover procedures have been useful in facial reanimation for more than a century.[74] Several cranial nerves have been utilized for nerve crossover, including trigeminal, glossopharyngeal, and phrenic, all of which have been abandoned.[75] The crossover techniques that remain in clinical use include XII-VII, XII-VII jump graft, and, rarely, XI-VII (Figs. 53–8 to 53–10). These techniques, of which XII-VII and XII–VII jump graft have been the most popular,[75] remain a dependable and effective treatment for situations in which the proximal facial nerve is unavailable but the distal nerve remains anatomically intact. Advantages include relatively low degree of technical difficulty, relative short time to movement (usually 4 to 6 months), one anastomotic

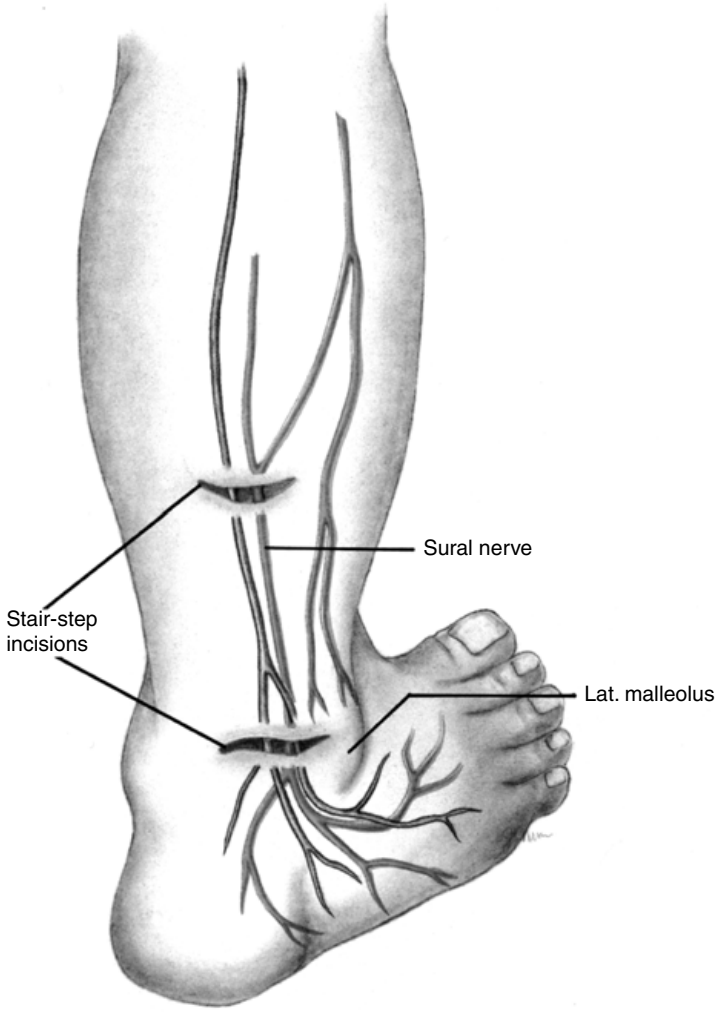

Figure 53–7 Sural nerve graft. The sural nerve is located posterior to the lateral malleolus and anterior to the Achilles tendon deep to the lesser saphenous vein system. The nerve is identified in this location and can be traced distally for added length. Gentle tugging on the nerve helps to identify its proximal course to align higher stair-step incisions. A longitudinal incision could be used instead, extending from the region posterior to the lateral malleolus to the popliteal fossa. The nerve can also be dissected by the use of a small tendon stripper.[53] After sectioning the distal nerve, it is placed through the stripper, which is gently passed in a proximal direction. After traveling the required length, the stripper is tented against the skin, and a small stab incision is made through the skin down to the stripper to divide the nerve. The nerve is then passed through the distal incision. (From Burgess LPA, Goode RL. *Reanimation of the Paralyzed Face*. New York: Thieme Medical Publishers; 1994:19. With permission.)

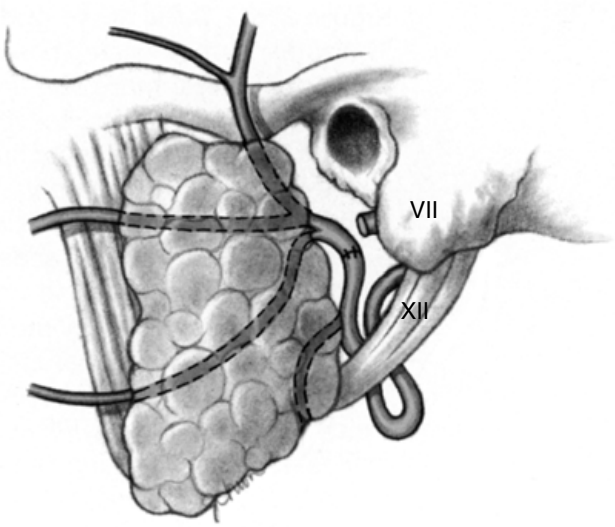

Figure 53–8 XII-VII crossover. Through a parotidectomy approach, cranial nerve XII is sectioned, rotated deep to the digastric muscle, and sutured to the pes. The nerve can also be split after sectioning and sutured to the main upper and lower branches of the facial nerve. (From Burgess LPA, Goode RL. *Reanimation of the Paralyzed Face*. New York: Thieme Medical Publishers; 1994:20. With permission.)

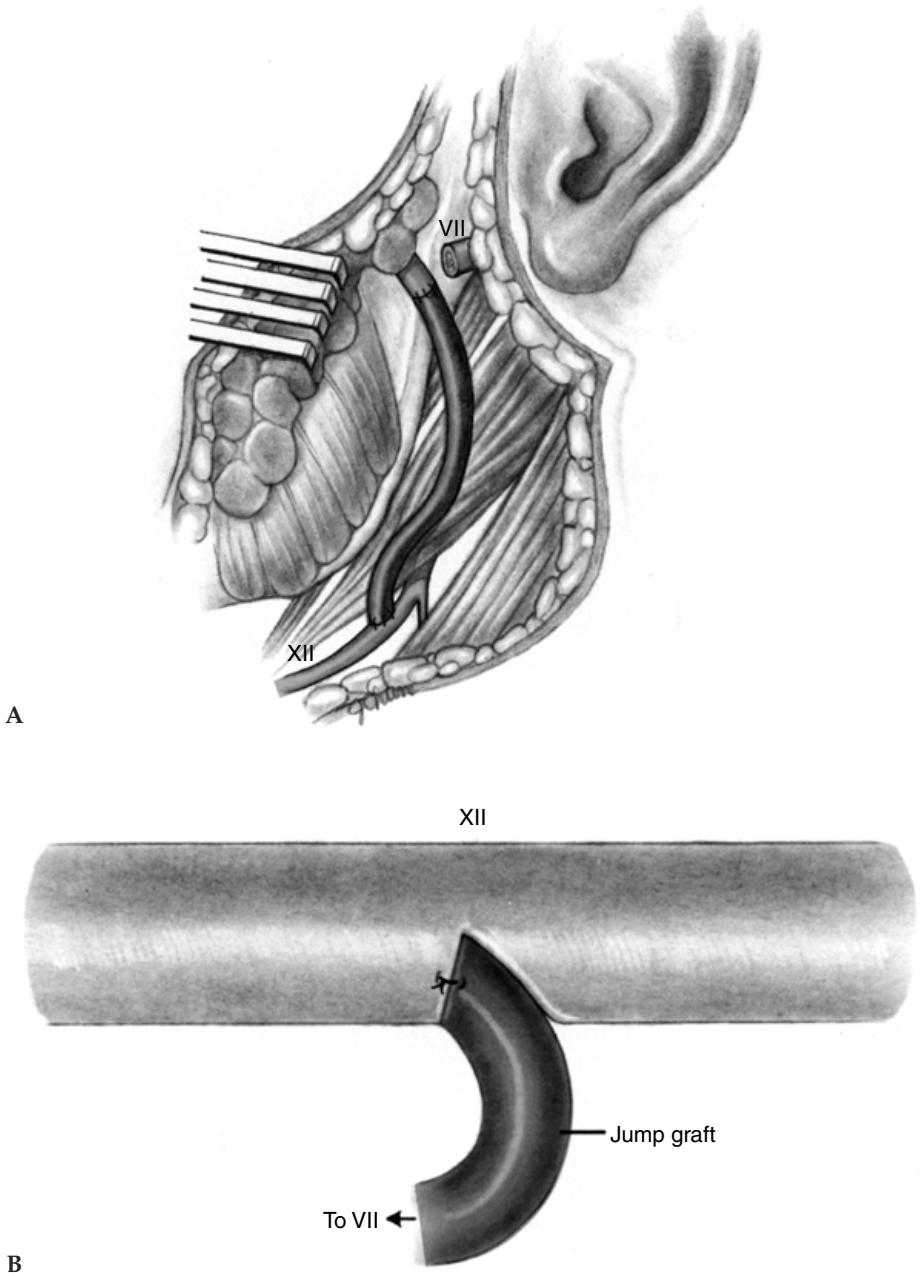

Figure 53–9 XII-VII crossover with jump graft. **(A)** Cranial nerve XII is isolated and delivered toward the surgeon. **(B)** The adventitia and nerve sheath are incised, exposing the nerve. One third of the diameter of the nerve is sectioned with a slight inward bias toward the center of the cut. A deeper incision may allow for a better match in caliber between the incised hypoglossal and the facial nerve. In this situation, the proximal trunk of XII is stimulated electrically to assess whether the major motor fibers of XII remain intact. If they do remain intact, up to one half of XII can be incised to provide more donor axons. The incision in the nerve is widened 3 to 4 mm by gently pushing the distal portion of the incised nerve trunk away from the incision. The proximal portion of the sectioned nerve is not disturbed or back-elevated. A greater auricular nerve graft is sutured between the cut segment of XII and VII. Two sutures are placed between the graft and XII, one on each side of the incision. The graft is gently looped upward and anastomosed to VII. The greater auricular jump graft should be as long as possible to allow for two tensionless suture lines. (From Burgess LPA, Goode RL. *Reanimation of the Paralyzed Face*. New York: Thieme Medical Publishers; 1994:22. With permission.)

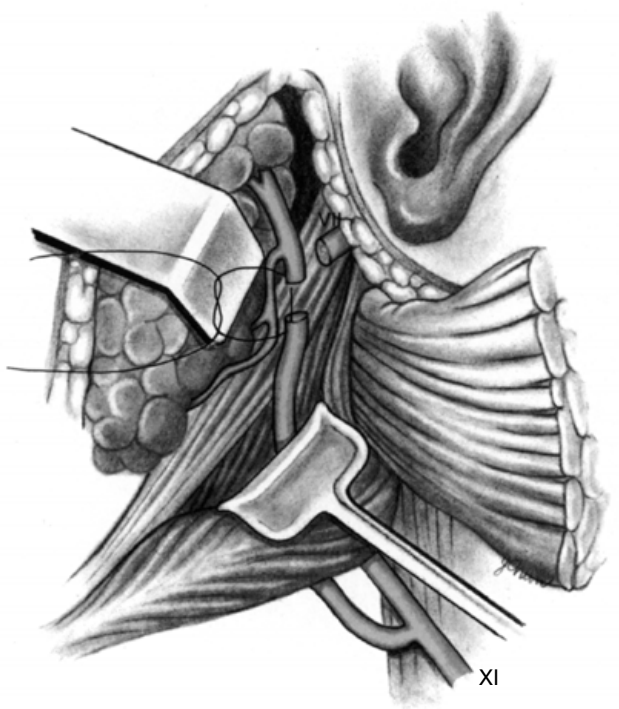

Figure 53–10 XI-VII crossover. A sternocleidomastoid branch or branches of XI are passed deep to the posterior belly of the digastric muscle and anastomosed to VII. This procedure is rarely used today. (From Burgess LPA, Goode RL. *Reanimation of the Paralyzed Face*. New York: Thieme Medical Publishers; 1994:24. With permission.)

suture line (as opposed to cable grafting with two), and motion that can resemble mimetic function with practice (Fig. 53–11). Disadvantages of all crossover techniques include donor site morbidity and some degree of mass movement.

The major problem specific to XII-VII crossover is the paralysis of the ipsilateral tongue musculature, which can result in significant speech, mastication, and swallowing difficulties. In one study, more than 15% of patients complained of these difficulties.[76] Although most patients can tolerate such deficits without significant morbidity, they can be incapacitating for patients who may develop other cranial nerve deficits—particularly those who may be at risk for tenth or contralateral twelfth cranial nerve loss. In these patients, another cranial nerve, such as the spinal accessory, or the XII-VII jump graft, or the XI-VII (eliminates risk to cranial nerve XII), offers an alternative that can spare the morbidity of sacrificing the twelfth nerve.[64,74,77]

It is important that the crossover be accomplished before significant atrophy of the facial musculature and distal facial nerve has occurred. Most clinical studies have shown that crossover procedures performed within a year of facial paralysis are successful.[59] In general, the earlier the procedure is done, the better the results; however, good results have been reported as much as 10 years following injury.[78]

Dynamic Reanimation

Transposition of the temporalis or masseter muscles for dynamic reanimation of the face has been the mainstay technique in the otolaryngology and facial plastic surgery literature, whereas free-muscle transplantation has been the more commonly described technique in the plastic surgery literature. In the past 15 to 20 years, temporalis transfer has been used more frequently than masseter transfer. As previously discussed, dual-system reanimation produces the most successful outcomes.[54] Temporalis transfer is now reserved almost exclusively for the lower region, specifically for the mouth, whereas the eye is rehabilitated with a gold weight.

The major objectives of lower facial reanimation are to achieve symmetry at rest, oral sphincteric competence, and facial movement. Temporalis muscle transposition is ideally suited for this purpose if nerve grafting is not possible or to augment facial nerve or hypoglossal-facial nerve grafting.[79]

May and Drucker have reported one of the largest series of temporalis transfers in the recent literature. They described several modifications over the originally described techniques that improved the outcome and decreased the morbidity of the procedure. They also concluded that better reanimation of the eye was achieved by techniques other than temporalis transfer and that they now use temporalis transfer exclusively for lower facial dynamic reanimation. Used as part of a comprehensive program to improve facial function, temporalis transfer provided good or excellent results in 80% and improved function in 96% of more than 200 patients.[79]

Traditionally, one of the major criticisms of temporalis transfer has been about the bulge of muscle over the zygomatic arch. This problem was worse when the whole temporalis muscle was used; now most authors report transfer of only the middle third of the muscle, and May and Drucker point out that making the tunnel wider so that the muscle lies flat in the tunnel significantly decreases the residual asymmetry.[79] Another problem is the gradual stretching of the muscle and loss of symmetry at the mouth. This may require a revision procedure to tighten the muscle.

An interesting phenomenon of trigeminal neo-neurotization may be responsible for several cases reported in the literature in which patients achieved mimetic and more organized facial movement than would be expected following spontaneous facial nerve regeneration or segmental temporalis muscle transfer alone.[80,81] Rubin et al[80] recently reported 27 patients who after temporalis or masseter transfer could smile spontaneously without clenching their teeth. Cheney et al[81] recently reported a case in which a patient obtained lower facial muscle movement innervated by neurites from the ipsilateral masseter muscle. The literature pertaining to trigeminal neo-neurotization is reviewed in this report.[81] In patients who have undergone facial nerve transection without attempt at nerve grafting but who later regain some mimetic movement, several authors have demonstrated reinnervation of the lower muscles of facial expression by the ipsilateral trigeminal nerve.[81] This reinnervation is enhanced by manipulation of the muscles of mastication, such as with temporalis muscle transfer. If this phenomenon were more predictable and reproducible, it would be very useful in the management of patients with facial paralysis.[82]

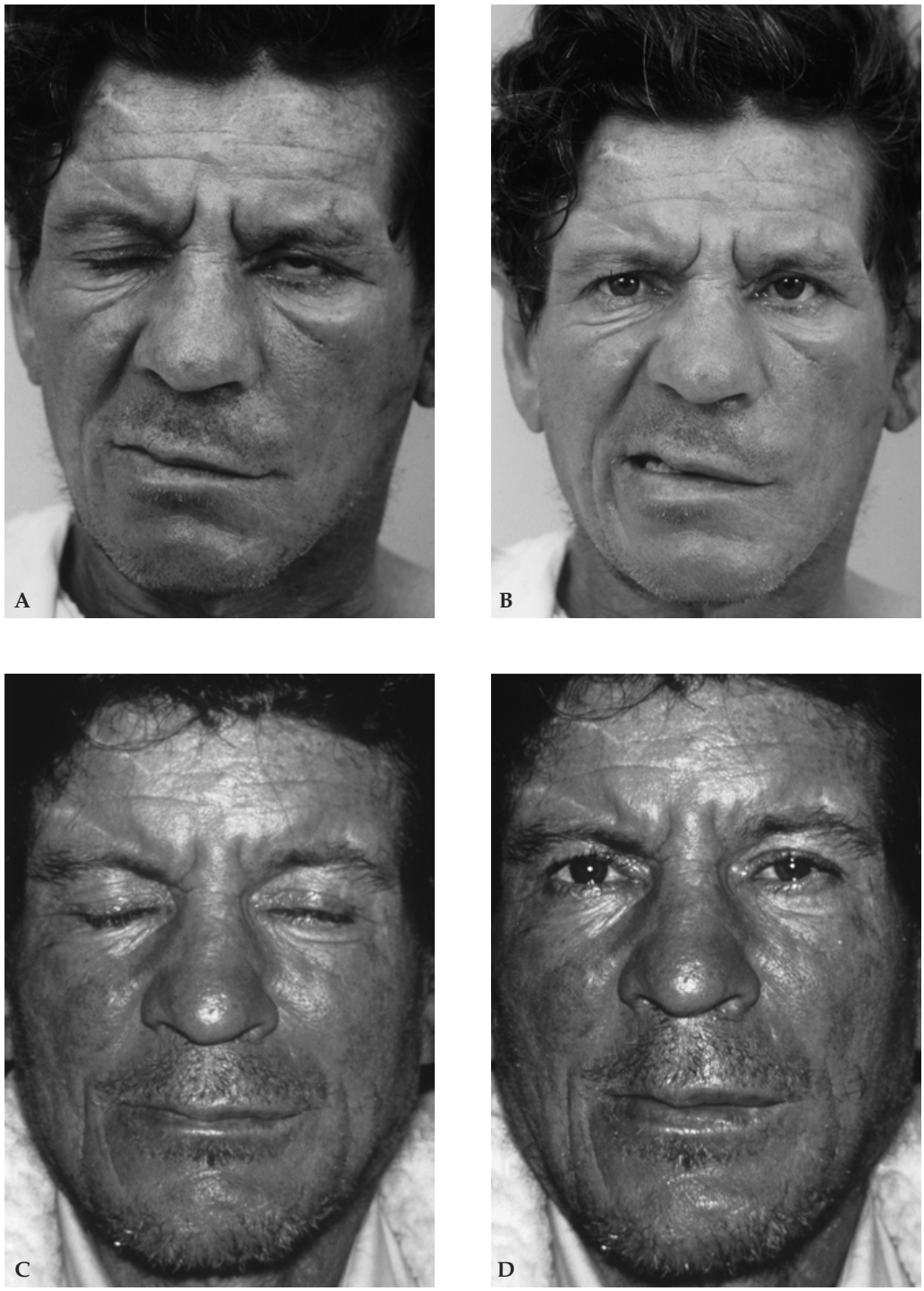

Figure 53–11 A 45-year-old man with previous comminuted temporal bone fracture and left facial nerve paralysis before **(A, B)** and after **(C, D)** XII-VII crossover. **(A)** Incomplete eye closure. **(B)** Attempted smile. **(C)** Improved eye closure 6 months after crossover. **(D)** Improved facial symmetry at rest.

Technique for Temporalis Transposition to Oral Commissure[79]

The patient's hair on the operative (paralyzed) side of the face is parted over the temporalis muscle along the proposed incision line extending from the helical crus superiorly, and slightly posteriorly, and a narrow swath of hair is trimmed as close to the skin as possible. The incision is made down to the superficial temporalis fascia (Fig. 53–12). This layer is divided with scissors to expose the deep temporalis fascia immediately

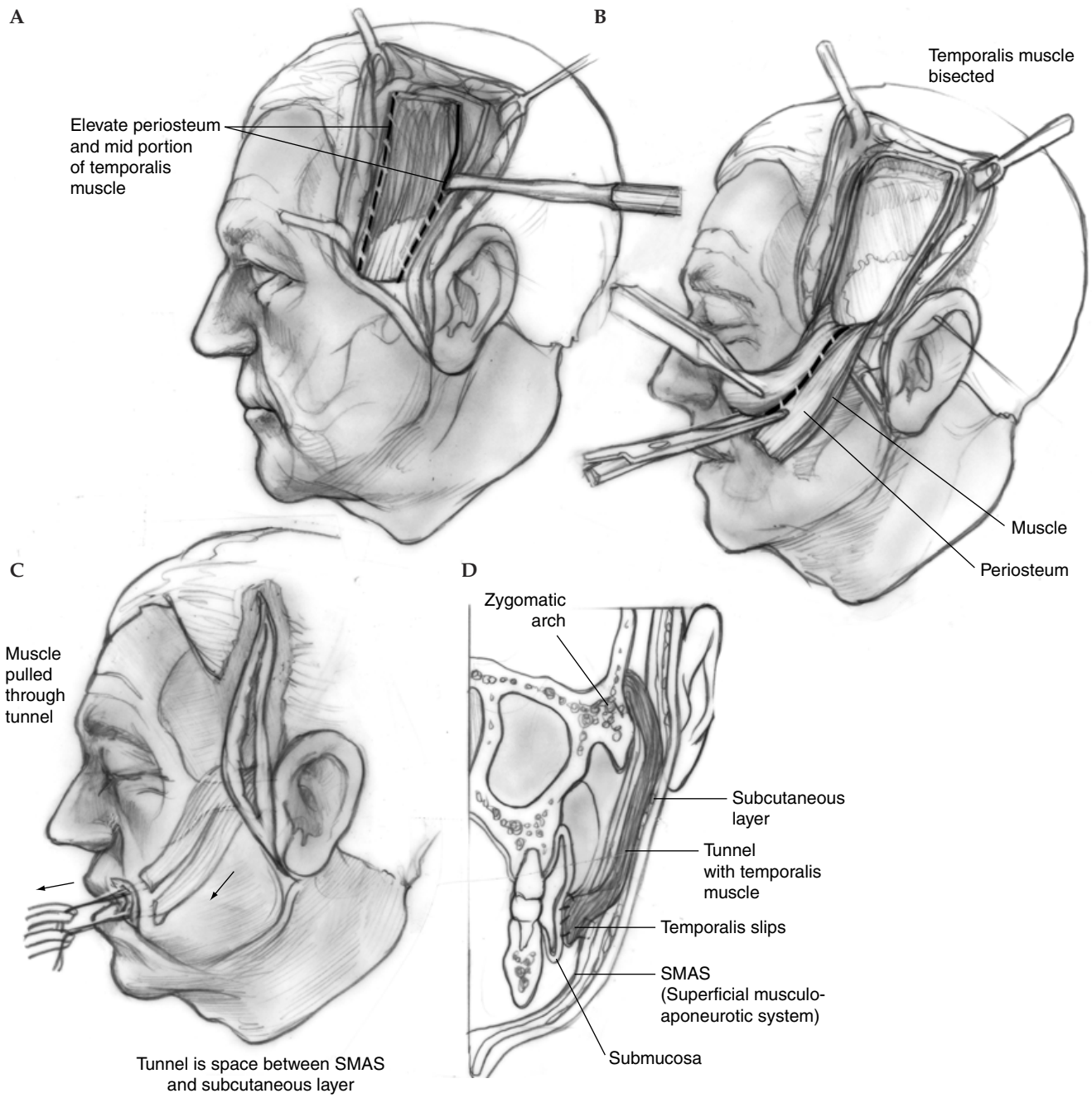

Figure 53–12 Temporalis muscle transfer. **(A)** Elevated periosteum and middle one third of the temporalis muscle. **(B)** Periosteum and distal aspect of the bisected muscle. **(C)** Tunnel to the ipsilateral oral commissure. Suture of the periosteum and muscle to the orbicularis oris muscle. **(D)** Coronal view of the tunnel.

adjacent to the muscle. The middle one third of the muscle is outlined with a needle-tip cutting cautery and is elevated deep to the periosteum from the zygomatic arch superiorly to the temporal line.

A pocket is then created superficial to the SMAS to receive the flap, down to the oral commissure. The pocket may be "hydrodissected" by saline injection prior to scissors dissection.

Next, the incision at the vermilion border or the lip–cheek crease is made. The incision extends to the orbicularis oris muscle, if present, or to the submucosa. This incision is then communicated with the preauricular incision in the supra-SMAS plane (to avoid damage to any residual functional facial nerve). The tunnel should accommodate two fingers or be wide enough to allow the transposed muscle to lie flat within it.

The distal end of the temporalis muscle is then bisected for a distance of 2 cm and figure-of-eight sutures are placed at each end. The sutures are then passed through the tunnel, thereby passing the temporalis muscle, which is sutured to the

orbicularis oris muscle or the submucosa at the oral commissure. If additional length is needed to reach the oral commissure, then either periosteum or Gore-Tex strips may be used. There should be sufficient overcorrection, which resolves by 3 to 6 weeks, to achieve the desired long-term resting symmetry.

The defect left by the harvest of the middle third of the temporalis muscle may be filled with a prefabricated Silastic implant, if necessary. Alternatively, the defect may be filled with a temporoparietal fascial flap, raised prior to the temporalis transfer. The wounds are closed over a small suction drain.

Static Rehabilitation

Although the static sling is used for lower facial rehabilitation to restore resting symmetry of the cheek and mouth and may improve oral sphincteric competence, it provides no dynamic change during smiling. This technique is generally thought to provide inferior functional outcomes in comparison with free-muscle transplantation or temporalis transposition, but may be employed when the other techniques are not feasible.

Autologous tissue, such as fascia lata, has been used as a sling material but requires overcorrection during placement and may cause poor results due to unpredictable stretching, in addition to donor site morbidity and increased surgical time.[83] Other authors have reported favorable results, with less need for overcorrection using Gore-Tex[49,84,85] (Fig. 53–13). However, patients receiving radiation therapy may be at increased risk for infection and extrusion of alloplastic implant material, such as Gore-Tex.[83]

Fisher and Frodel recently reported the use of acellular human dermal allograft (AHD allograft; AlloDerm) for static facial slings in 11 patients.[83] They found that in addition to the fact that AHD allograft allows ingrowth of host tissue and the eventual replacement of the facial sling by host tissue, there was no need for overcorrection, which allowed for much more predictable results and no initially poor cosmetic results. Ninety percent of the patients in their series eventually had good or excellent results, and 100% reported functional improvements in mastication and oral competence. No patient had an infection or implant extrusion, despite exposure to radiation therapy in more than half.

Technique for Static Facial Sling[83]

The preauricular incision is made in the temporal region just anterior to the base of the helical crus. A subcutaneous tunnel to a second incision located in the proposed new nasolabial fold is created. This incision is indicated in patients with a well-developed contralateral nasolabial fold; no nasolabial incision is created in patients without a well-developed nasolabial fold. The sling material of choice is then sutured to the orbicularis oris muscle, if present, or to the subcutaneous tissue, and to the lateral aspects of the upper and lower lips. Tension is then applied in a superoposterolateral direction to assess for symmetry with the contralateral side. Overcorrection is necessary for implant materials other than AHD allograft. Then the sling is secured to the periosteum of the zygoma with permanent sutures.

The authors have utilized an alternative approach in some patients, making a small incision over the malar eminence and initiating the tunnel at this location. A screw can then be placed in the bone if Gore-Tex is used. The wound is closed over a small suction drain.

Microvascular Free Tissue Transfer

The plastic surgery literature advocates free-muscle transplantation as the treatment of choice for longstanding facial paralysis.[86–92] Free-muscle transplantation offers the advantage of restoration of some emotional animation in addition to good tone in repose and some voluntary facial movement. Despite the theoretical advantages over transposition flaps, and despite immense efforts in both basic science and clinical research, prediction of the functional capability of the transferred muscle unit is as yet unattainable.[86] There have been no studies comparing the functional outcomes of free-muscle transplantation and muscle transposition techniques. Comparison of studies that use muscle transposition with free-muscle transplantation is difficult due to the lack of uniformity of grading systems to assess the functional and cosmetic results. In fact, there are nearly as many grading systems as there are techniques for reanimation.[92]

The evolution toward free-muscle transplantation for facial paralysis began nearly 30 years ago with the introduction of the cross-facial nerve graft, popularized by Anderl.[67] In 1976, Harii et al were the first to describe the use of free-muscle transplantation for reanimation of the paralyzed face, connecting a branch of the ipsilateral deep temporal nerve to the nerve of the transferred gracilis muscle.[93] Although the ipsilateral facial nerve would be the most desirable motor source for innervation of the transferred muscle, the clinical situations in which this would be applicable are quite limited. In subsequent reports, many different donor muscles have been utilized in two-stage procedures employing a cross-facial nerve graft in the first procedure and a free-muscle transplant in the second stage.[86,91,92]

The technique for cross-facial nerve grafting was originally described as an independent reanimation technique. However, as previously mentioned, the results in cases of longstanding paralysis were poor due to denervation atrophy and because of the time required for regenerating axons to traverse the nerve graft and reach the paralyzed side of the face.[94] Also, the number of axons is halved through each anastomosis; therefore, two anastomoses are felt by some to provide an inadequate neurite cell population to create detectable movement.

For successful reanimation with cross-facial grafting, an additional procedure may be necessary to maintain the paralyzed muscles until the regenerating axons can reach the motor end plates. Facial muscle tone can be maintained with nerve transposition techniques (as described previously). For example, a split XII-VII transposition can maintain the tone of the facial muscles and therefore "baby-sit" the paralyzed side of the face while the regenerating nerve fibers traverse the cross-face nerve graft.[95] Once the cross-facial nerve graft is in place, the XII-VII transposition can be divided.

Currently, the state of the art in free-muscle transplantation is in flux. Some favor a two-stage procedure, using a cross-face nerve graft in the first stage and anastomosis to a free-muscle transfer in the second stage. A more recently described single-stage procedure uses a long nerve pedicle

Figure 53–13 A 42-year-old woman status post resection of a left temporal bone tumor, left facial paralysis, and previous failed temporalis transfer. **(A)** Face at rest. **(B)** Attempted smile. **(C)** Improved symmetry at rest after Gore-Tex suspension. **(D)** Improved smile after Gore-Tex suspension.

that is grafted to contralateral buccal branches at the time of the free-muscle transfer.

Two-Stage Technique—General Plan

The two-stage technique employs a sural nerve graft from the contralateral buccal branches of the intact facial nerve, tunneled subcutaneously to the cheek on the paralyzed side.

After 4 to 6 months, Tinel's sign is used to clinically assess the growth of the axons along the nerve graft. This sign is elicited by percussing the nerve graft from distal to proximal until percussion produces distal tingling.[96] The zone of distal tingling does not exceed 2 to 3 cm, and the location of this zone corresponds to the location of the regenerating axons. It is generally recommended that an additional 3-month delay

be allowed before beginning the second stage so that the maximum number of axons are available at the time of free-muscle transplantion.[92] Therefore, the total time between the two stages is usually 9 to 12 months.

The second stage involves a two-team approach whereby one team prepares the paralyzed side of the face for receiving the graft and the other team harvests the donor muscle and its neurovascular pedicle.

The disadvantages to the two-stage approach are unpredictability of the function of the transplanted muscle, sural nerve donor site scar, lower leg and foot hypesthesia, long delay awaiting the second stage, vascular anastomotic complications, and scar formation on the nonparalyzed side of the face.

Two-Stage Technique—Surgical Technique

Stage One

The sural nerve is located posterior to the lateral malleolus and anterior to the Achilles tendon deep to the lesser saphenous vein system. The nerve is identified in this location and can be traced proximally and distally through either stair-step or longitudinal incisions (Fig. 53–7). It may also be harvested endoscopically. The nerve may be raised with scissors and a nerve hook or by the use of a small tendon stripper.[59]

While the harvest site is closed, peripheral buccal branches of the facial nerve on the normal side are exposed through a preauricular approach. Others have used incisions immediately over the peripheral branches or through the melolabial folds.[59] Several fascicles (approximately 50% of fibers) are transected and anastomosed to the sural nerve graft (which is in reverse orientation). The distal end of the sural nerve graft is tunneled subcutaneously to the other side (paralyzed side) of the face, usually through the upper lip, although forehead and lower lip tunnels have also been used. The distal end of the sural nerve graft is then tagged with a hemaclip for ease of identification at the second stage.

Stage Two[91]

The most commonly used muscle in the two-stage technique is the gracilis muscle. It is exposed through an incision made posterior to the line joining the adductor tubercle to the medial condyle. This corresponds to the posterior margin of the adductor longus muscle, which is tensed on abduction of the thigh. The vascular pedicle is identified on the anterior border of the gracilis at the junction of the upper quarter and lower three quarters of the muscle. The vascular pedicle is then traced to the lateral side of the adductor longus, where it meets the profunda vessels. It is then mobilized, with division of all branches from it to the adductor longus muscle. The nerve to the gracilis from the anterior branch of the obturator nerve is traced to the obturator foramen. Reduction of the muscle is carried out prior to transfer in situ, securing hemostasis before the vascular pedicle is divided and thereby reducing the risk of facial hematoma following transfer.

The length of the muscle required is measured and marked on the donor muscle. The neurovascular pedicle divides into two or three branches before entering the muscle. One of these vascular branches is ligated, and a nerve branch is divided. The segment of muscle supplied by them is separated by splitting of the muscle along its fibers. About one half to two thirds of the muscle with the main vascular pedicle is used as the graft.

If the graft is used to reanimate the whole hemiface, it is necessary to separate the muscle as two motor units; one third of the muscle is used for the upper face, and the other two thirds is used for the lower face. However, as previously discussed, better functional results are obtained when different methods are used to address the eye and the mouth.

The paralyzed side of the face is exposed by a modified facelift incision. The skin flap is elevated anteriorly to expose the upper lip and angle of the mouth, carefully preserving the cross-face nerve graft. The superficial temporal vessels are then exposed and prepared for anastomosis. The gracilis muscle is transferred to the face with the neurovascular pedicle on the deep surface, facilitating further debulking, if necessary. The distal end of the gracilis is divided into two segments and sutured with 4-0 Prolene to the muscles of the lateral aspect and angle of the mouth. Intraoperative traction on the orbicularis muscle determines the most appropriate area for attachment of the gracilis muscle. In the lip, this lateral attachment avoids adherence of the central lip. Insertion into the dermis of the nasolabial line is not recommended because this concentrates the muscle action into this line, creating asymmetry. The proximal muscle is then attached to the zygomatic arch, extending medially below the orbital margin to give a more vertical lift to the upper lip. The muscle is sutured under slight tension to slightly overcorrect the deformity.

The vessels are sutured to the facial or superficial temporal vessels and the nerve graft is joined with epineural sutures to the appropriate segment of the nerve to the gracilis. The wounds are closed with two suction drains placed above and below the muscle graft, lightly sutured in place to avoid proximity to the vessels.

Single-Stage Procedure—General Plan

To overcome the drawbacks of the two-stage method of free-muscle transfer, several authors have more recently reported the one-stage free-muscle transfer, in which the motor nerve is directly crossed through the face and sutured to the contralateral facial nerve branches. This technique has been described using several different donor muscles: the latissimus dorsi, the gracilis, the rectus femoris, and the abductor hallucis longus muscles.[87] The relative advantages and disadvantages of use of the most popular muscles for free-muscle transfer are summarized in Table 53–2. Because there is anatomic support for the latissimus dorsi,[87,90] and since the largest series of patients reported to date employing the single-stage method used the latissimus dorsi muscle,[87] this is the technique that will be discussed.

The advantages of the single-stage technique over the two-stage are one neural anastomosis, no sural nerve donor site morbidity, and, most importantly, earlier time to facial movement with diminished duration of the psychological, social, and economic sequelae.

Single-Stage Procedure—Surgical Technique[87]

Through a preauricular incision on the paralyzed side of the face, the subcutaneous tissues of the cheek are elevated superficial to the parotid fascia and SMAS. This creates a subcutaneous pocket to accept the subsequent muscle transfer. The undermining subcutaneously extends approximately 1 to 2 cm beyond the nasolabial fold to the upper and lower lips. The lateral portion of the atrophied orbicularis oris muscle and the

TABLE 53–2 Muscles Used for Facial Reanimation with Microvascular Techniques

Donor site	Blood supply/pedicle length and anatomic reliability	Nerve supply and length	Advantages	Disadvantages
Extensordigitorum brevis	Dorsalis pedis artery and vein, 3–4 cm, reliable	Lateral branch, deep peroneal nerve, 3–4 cm	…	Insufficient bulk, inadequate contraction strength, short pedicle
Gracilis	Branches of profunda femoris, 5–8 cm, reliable	Anterior branch, obturator nerve, 10 cm	Can trim muscle in situ independent neuromuscular units	Bulky
Latissimus dorsi	Thoracodorsal artery and vein, 8–10 cm, reliable	Thoracodorsal nerve, 13–14 cm	Segmental innervation, can trim in situ	Bulky
Pectoralis major	Thoracoacromial artery and vein, 4–6 cm, reliable	Lateral pectoral nerve, 4–5 cm	…	Bulky, short pedicle
Pectoralis minor	Axillary artery and vein (direct branches) or lateral thoracic artery or vein or thoracoacromial artery and vein, 4–5 cm, variable	Medial and lateral pectoral nerve, 4–5 cm	Dual nerve supply, ideal form, weight, and shape	Debulking not possible in situ; short, complex neurovascular pedicle
Rectus abdominis	Deep inferior epigastric artery and vein, 6–10 cm, reliable	Segmental thoracic intercostal nerve, 3–15 cm	Tendinous inscriptions, segmental innervation	Bulky
Serratus anterior	Branches of thoracodorsal artery and vein, 4–5 cm, reliable	Long thoracic nerve, 9 cm	Segmental innervation	Bulky

Adapted from Aviv JE, Urken ML. Management of the paralyzed face with microneurovascular free muscle transfer. *Arch Otolaryngol Head Neck Surg* 1992;118:909–912.

modiolus are also exposed. Several stay sutures are then placed at the lateral border of the atrophying orbicularis oris muscle, in the upper and lower lips, and in the modiolus. A newly created nasolabial fold, which should correspond to the contralateral nasolabial fold, is made visible by pulling these stay sutures toward the zygomatic region. Thus, the fixation position of the end of the transferred muscle segment is determined. To secure the muscle fixation to the appropriate position in the nasolabial and lateral lip regions, a pull-out suspension suture is placed between the deep subcutaneous tissue at the corner of the mouth and the skin either behind the ear lobe or in the temporal region. A small portion of the subcutaneous tissue over the zygoma is excised to accommodate the bulkiness when the other end of the transferred muscle segment is anchored to the zygoma.

Another small incision, about 2 to 3 cm long, is placed at the submandibular region to expose the facial artery and vein as the recipient vessels. The final incision, about 2 cm in length, is then made on the nonparalyzed side of the face at the anterior margin of the parotid gland to expose several zygomatic and buccal branches of the intact nerve. With a nerve stimulator, a few branches innervating mainly the zygomatic and levator labii muscles are made ready for the recipient motor nerve from the free graft.

During preparation of the recipient cheek, the other team harvests the latissimus dorsi muscle segment. Through an incision along the posterior axillary line, the neurovascular pedicle of the latissimus dorsi muscle is first exposed. To obtain sufficient length of the thoracodorsal nerve (usually about 15 cm), the nerve is traced proximally to its origin from the posterior cord of the brachial plexus and distally to the muscle. If necessary, more proximal smaller twigs of the nerve may be sacrificed to obtain adequate length. After complete dissection of the neurovascular pedicle, a muscle segment of the appropriate size (usually 3 to 4 cm wide and 8 to 10 cm long in moderate stretch of the muscle) is harvested, dividing the

proximal and distal muscle with a disposable stapler. Any sculpting of the muscle should be performed prior to dividing the vascular pedicle in situ to secure hemostasis and minimize risk for postoperative hematoma in the recipient cheek.

The harvested muscle is transferred to the recipient cheek pocket. The proximal end is fixed to the nasolabial region with the previously placed stay sutures, with the neurovascular pedicle positioned proximally and in reversed orientation. The thoracodorsal nerve is passed through the upper lip using a nerve passer and anastomosed to the contralateral intact nerve branches. Microvascular anastomoses are then carried out between the thoracodorsal vessels and the recipient facial vessels in an end-to-end fashion. Finally, the distal end of the muscle is fixed to the zygoma, giving proper tension to the muscle.[86] The wounds are closed with suction drainage in both the donor and recipient wounds.

Adjunctive Procedures

The procedures described previously constitute the fundamental, or "workhorse," procedures in reanimation. Those procedures provide basic symmetry to the two major segments of the paralyzed face (eye and mouth). The following are "touch-up" procedures, valuable in attempting to return the patient with facial paralysis to as close to a normal appearance and function as possible. In general, these procedures can be performed separately or concurrently with the previously described procedures, and with experience, the facial plastic surgeon can visualize the optimal combination of workhorse and touch-up procedures for a specific patient's situation.

Upper Face Procedures

Brow ptosis can contribute significantly to the overall asymmetry of the paralyzed face and may be even more noticeable after the mid- and lower face have been addressed. Correction of the ptosis is accomplished with a unilateral or bilateral browlift. The authors have found that in elderly patients forehead symmetry is more easily achieved using a bilateral browlift, whereas in younger patients a unilateral lift is usually satisfactory. The browlift can be approached using an endoscopic, direct, or midforehead approach. In addition to the static lift, Rubin has added a slip of contralateral frontalis muscle to provide some motion and correction to the medial brow (Fig. 53–14).[97]

One important consideration regarding the browlift is that the lift must be conservative, due to the tendency of the browlift to potentially impede eye closure. As long as a gold weight is used and the browlift is conservative, eye closure is usually not a problem.[59] Simultaneous browlift and gold weighting require preoperative manual elevation of the brow to the desired location while the gold weight is being sized.

Blepharoplasty may also be performed, but, as with browlift, it must be conservative.

The techniques for browlift and blepharoplasty are otherwise the same as for the nonparalyzed face and are described in Chapters 16 and 17.

Midface Procedures

Facelift has become a standard adjunctive procedure for facial reanimation. Due to the inherent skin laxity in the paralyzed face, even young patients require a conservative facelift. The technique is the same as for the nonparalyzed face and is described in Chapter 15.

Longstanding moderate or severe facial paralysis can result in ipsilateral nasal collapse, leading to nasal obstruction. Two techniques have been described to correct paralytic nasal obstruction. In the technique by Goode,[98] a carved piece of irradiated rib cartilage is placed in a pocket just cephalad to the ala from the piriform aperture to the nasal tip region to provide nasal valve support. In the technique by May,[51] the alar base is widened by using a strip of fascia lata or Gore-Tex to suspend the alar base from a hole in the lateral zygomatic prominence.

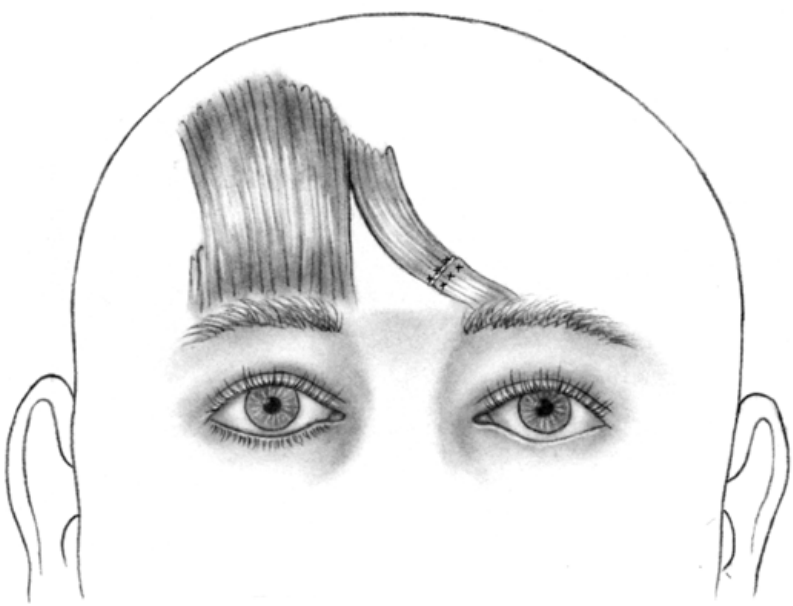

Figure 53–14 Medial browlift. A slip of the normal frontalis with an attached strip of fascia may be used to provide some correction and movement to the medial brow. The inferior edge of the incision is suspended to the periosteum, utilizing a buried vertical mattress placed parallel to sensory nerve fibers. (From Burgess LPA, Goode RL. *Reanimation of the Paralyzed Face*. New York: Thieme Medical Publishers; 1994:67. With permission.)

Lower Face Procedures

Loss of the action of the depressor anguli oris and the depressor labii inferioris results in an elevation of the lower lip, resulting in asymmetry, especially during smiling. This can be corrected by digastric transposition, as described by Conley et al.[99] In this procedure, the digastric tendon is identified and divided from the hyoid through a submandibular approach. The tendon is then split, transposed, and rotated upward to the lower lip and sutured to the orbicularis oris approximately 2 cm from the commissure through a separate vermilion border incision. This procedure, while innovative, is seldom used (Fig. 53–15).

Figure 53–15 A 62-year-old woman with an isolated right marginal mandibular nerve paralysis following resection of a parotid malignancy. **(A)** Weakness of the depressors of the right lower lip at rest. **(B)** Attempted smile. **(C)** Improved symmetry of the mouth and lips following digastric tendon transfer at rest. **(D)** Improved symmetry on attempted smile.

Symmetry and oral competence can also be improved using the cheiloplasty technique, as described by Goode.[100] In this procedure, a 2- to 2.5-cm full-thickness wedge is resected, with the lateral limb of the wedge 7 to 10 mm from the commissure. For additional lower lip eversion, the vermilion border is advanced by excision of a horizontal ellipse of skin from the commissure to near-midline (Fig. 53–16).

Two final adjunctive procedures that can be used to achieve symmetry or to limit synkinesis are contralateral selective neurectomy[101] and selective myectomy.[102] The risk in performing either procedure is the potential loss of function, especially in oral competence, when the nonparalytic marginal mandibular nerve or its muscles are ablated. Therefore, the authors do not advocate the use of these procedures.

SUMMARY

In conclusion, the patient with facial paralysis presents a challenging problem for the facial plastic surgeon. It is incumbent on those of us treating this complex disorder to be familiar with the psychosocial sequelae, the classification systems, the etiologic factors, the workup, the medical management, and the myriad of surgical procedures available to improve function and cosmesis in this patient population.

Through an integrated approach, each patient may be offered a series of individualized surgical techniques to provide the optimal functional and cosmetic outcome.

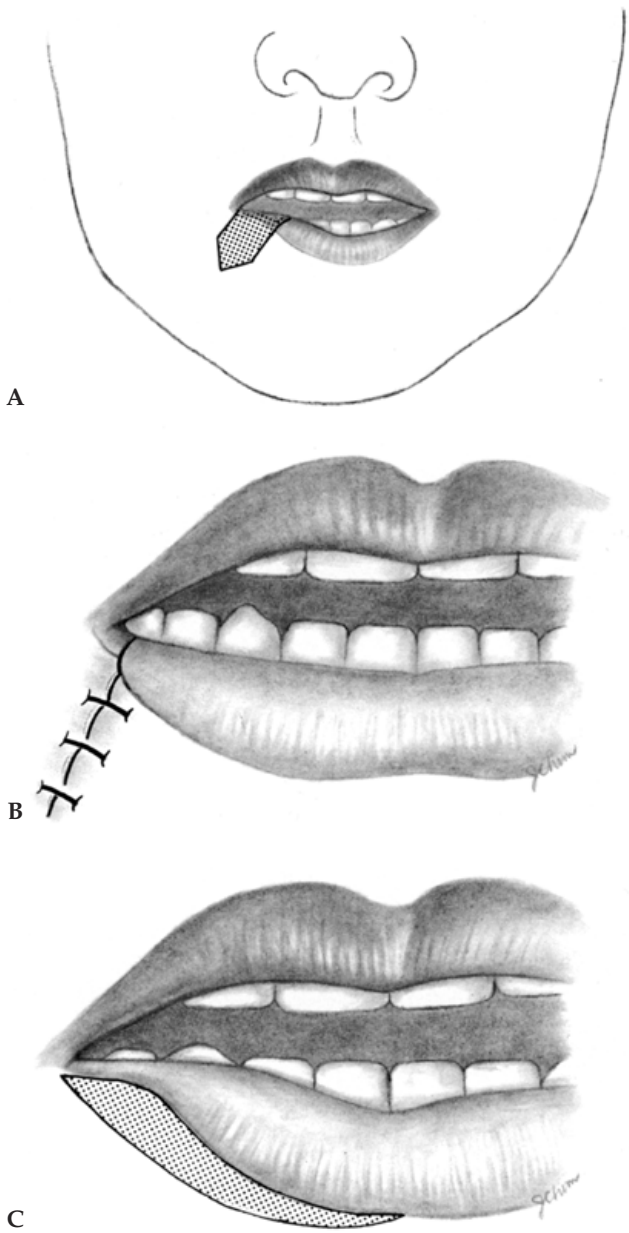

Figure 53–16 Marginal mandibular nerve paralysis—cheiloplasty. **(A)** A wedge excision is outlined, with the lateral limb of the wedge placed 7 to 10 mm medial to the commissure. The wedge extends inferiorly approximately 2 cm and is 2.0 to 2.5 cm wide depending on the overall lip dimensions. These incisions do not cross the mentolabial crease. **(B)** The lateral incision is made first, and the exact amount of skin excision is determined by pulling the lip laterally. After excising the wedge, closure is accomplished in layers with interrupted 3-0 chromic or Vicryl, similar 4-0 sutures in the subcutaneous layer, and 6-0 everting fast-absorbing gut sutures for skin closure. The vermilion is intentionally mismatched to produce the desired eversion of the lower lip medial to the incision line. Because this mismatch is placed laterally near the commissure, it is noted only on close inspection. **(C)** As an alternative to mismatching the vermilion or to add additional eversion, a horizontal cheiloplasty technique can be used to evert the lower lip. The amount of skin to be resected is carefully marked with the mouth half open. A horizontal ellipse of skin is excised from the lateral commissure to the midline or near the midline. This should not be overcorrected. (From Burgess LPA, Goode RL. *Reanimation of the Paralyzed Face*. New York: Thieme Medical Publishers; 1994:50. With permission.)

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Section

V

Trauma

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Chapter 54

Acute Soft Tissue Injuries of the Face

G. Richard Holt

Acute soft tissue injuries of the face assume great importance to the patient and to the surgeon owing to the potential resultant functional and cosmetic abnormalities. Because the face has such prominence in human social engagement, surgeons who manage facial trauma have both the responsibility and the opportunity to make a difference. This responsibility requires that the surgeon understand the biomechanics of tissue wounding, the biochemistry and molecular biology of wound healing, and the art of tissue repair.

Soft tissue wounding can have a wide spectrum of etiologic factors, from knife wound to gunshot wound, from cat scratch to dog mauling, from fisticuffs to motor vehicle accident, to name a few. Although most cases of facial soft tissue trauma are minor to moderate in nature and result, those involving massive injuries require thorough analysis and careful surgical planning. Many patients can undergo repair in the emergency room or outpatient surgery facility under local anesthesia with or without anesthesia monitoring. More difficult or complicated cases may require operative intervention under general anesthesia, particularly in young children or in those patients with multiple trauma or severe injuries.

In cases of massive soft tissue trauma, the initial challenge may be to sort out what tissues are missing and what is still present, albeit in a different form or location. With lesser degrees of injury, the history of the injury and indirect evidence becomes very important in reconstructing the angle and depth of penetration. In addition, a complete head and neck examination is vitally important, with special attention paid to neurologic findings. The ultimate goal is to have the best understanding of the mechanics of the penetrating forces as well as knowledge of its course in the facial tissues prior to formulating a surgical plan. A complete knowledge of head and neck anatomy and physiology is essential to diagnosing and managing soft tissue wounds of the face.

TIMING OF REPAIR AND ANESTHETIC CONSIDERATIONS

It is not always necessary to repair a facial wound at the immediate time of injury. However, if it is possible to do so, this "primary" closure should be accomplished within approximately 4 to 6 hours after wounding. If the wound appears to be contaminated and a concern exists that infection might occur with a primary closure (even after extensive debridement and copious irrigation), then a "delayed primary" closure can be performed. Here the wound is packed, debrided, irrigated, or whatever is required to clean it over 24 to 72 hours, followed by a closure, usually in the operating room. Parenteral antibiotics are commonly employed in this type of delayed closure.

Finally, healing by secondary intent can be allowed to occur, wherein good wound care is undertaken by both the patient (or surrogate such as a family member or visiting nurse) and the surgeon, leading to a slow but steady closure of the defect. This latter approach may be advantageous in severe diabetes, chronic hypoxia due to cardiorespiratory disease, or any other significant wound healing deficit. After the wound is healed, then the scar can be dealt with in an appropriate fashion.

Even with small children, minor lacerations can be closed using injectable local anesthesia. Here the parents are counseled regarding the steps required and given factual information in an honest but empathetic manner. If appropriate, one parent may elect to stay with the child for support, but only if the surgeon feels the parent would be of positive benefit and be able to cope with observing the procedure. A nerve block or field block around the laceration aids in decreasing the discomfort of eventual infiltration of the wound itself. Cream (licocaine 2.5% and prilocaine 2.5%) can be applied to the area of local nerve block if there is sufficient time allowable. Usually after the child has cried enough in restraint and there is no longer any discomfort, she or he will fall asleep for most if not all of the procedure. For extensive injuries, if underlying osseous or neurovascular structures are injured or at risk, general anesthesia in children will be required. The surgeon should discuss with the anesthesiologist whether evacuating the patient's stomach before administering the anesthetic or waiting several hours would be preferred—remembering that an upset child may develop a relative ileus. For that reason, the author prefers to evacuate the stomach directly with a nasal or oral gastric tube before intubation. The concern about aspiration seems to be more cogent in children owing to the shorter esophagus and the less protective capability of the gastroesophageal valve.

Most adults will not require sedation for primary closure of a wound prior to its anesthetization. However, because of their anxiety level, certain patients may benefit from parenteral sedation (diazepam) or an antianxiety/antiemetic medication (promethazine). Again, patients whose wounds are extensive should be considered for intraoperative management under general anesthesia.

It is important that the surgeon understand that although the commonly observed factors (extent of wound, presence of bleeding or foreign bodies) tend to dictate timing of wound closure, other, perhaps more subtle factors should also be considered. A surgeon who is caring for a patient with an extensive soft tissue facial wound in the middle of the night after a long day of surgery should determine if he or she is capable of doing a top-notch job. Additionally, such a wound closure might require special skills (microsurgery), special equipment, special technical support, or other factors that are not optimal at that time of the night. Under those conditions, it might be wise to dress the wound, begin parenteral antibiotics, and wait for up to 12 hours until the correct situation is present—and the surgeon is rested.

SPECIFIC WOUND MANAGEMENT

Although the general principles of wound care—assessment, debridement, cleansing, meticulous closure—compose the foundation of facial soft tissue injury management, because of the specialized structures in this area specific techniques are applied. Again, both functional and cosmetic considerations must be taken into account, with the former taking immediate precedence. However, the ultimate appearance of the repair (i.e., scarring) must be recognized for its importance to the patient.

Animal and Human Bites

Dog, cat, and human bites account for 99% of bite wounds; facial bites in general account for less than 1% of all visits to the emergency department. Lacerations from bites occur three times more frequently than puncture wounds. In the past, animal bites were treated in a way similar to human bites, that is, very few were closed primarily. Copious irrigation was performed, the wound was minimally debrided, and delayed primary closure was performed (as opposed to healing by secondary intent). This often resulted in scars that were less than ideal or even unacceptable. Scar revision was a necessity, and functional disturbances from cicatricial scarring were common.

Current standard of care has progressed significantly, particularly with respect to animal bites, based primarily on emergency wound care and antibiotic utilization.[1] Human bites remain problematic, and primary closure is selected only in the most favorable of wounds. A polymicrobial population, including anaerobic and aerobic organisms, contaminates most bites. Thus, it is common to utilize broad-spectrum antibiotics with excellent anaerobic and microaerophilic efficacy. An overriding concern in animal bites is the risk of the rabies virus, whereas in human bites one must be concerned about hepatitis B and C, herpesvirus and HIV.

Bite wounds are usually a combination of penetration and avulsion, due to the tearing action of the teeth on tissue (Fig. 54–1). Tissue loss is minimal unless a piece is missing from a protruding structure, such as the ear or nose. Depth of penetration varies depending on the resistance of the skin as well as the force of jaw contracture and shearing from the animal or human bite.

In general, human bites are less likely to penetrate deeply into facial tissue than animal bites, owing to the length and shape of the anterior human teeth. In addition, humans are loath to draw much blood during a bite due both to an aversion to having someone else's blood in their mouth and the fear of contracting a blood-borne disease. All in all, human bites are significantly less common than animal because of the availability of more sophisticated instruments of injury (knife, gun, baseball bat). Human bites are often associated with lovers' quarrels and usually involve a single region of injury (ear, nose, lip), whereas animal bites may reflect a recurring-attack pattern in multiple sites. It is good practice to treat a human bite as a possible HIV exposure, and an HIV test should be performed on both patient and attacker.

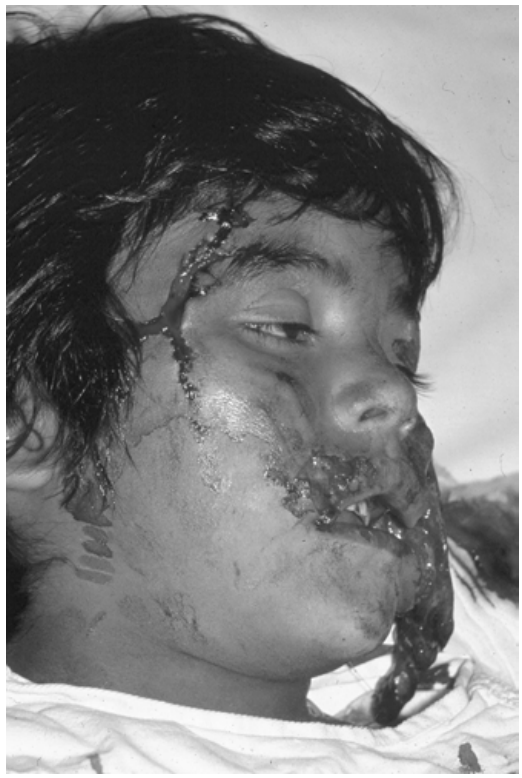

Figure 54–1 Multiple tissue avulsions of child's face due to dog mauling.

The level of penetration should be assessed and estimated, with particular attention paid to damage to underlying structures, such as muscles, ducts, and neurovascular bundles (Fig. 54–2). With animal bites, an initial deep penetration may be masked by an avulsive injury of more superficial tissues, so that exploration of the wound after anesthetization is warranted. It should be kept in mind that a bite by an older dog might result in implantation of a loose tooth deep in the wound.

Because a tremendous amount of force can be delivered to the tissues through a bite, it is also possible for bony injury to occur. When a large-mouthed dog attacks a small child, fractures of the skull or jaw must be ruled out through computed tomography (CT) if indicated. Microscopic injury to adjacent tissues is expected, and one must assess tissue via-

Figure 54–2 Presence of hematoma and/or salivary secretions in cheek one week after animal bite repair.

bility based not only on the initial evaluation but on an evolving evaluation throughout the emergency care process. Because of the short distance from the face to the neck, it must be considered that some injury could coexist within the neck in children, and a thorough assessment should be done.[2]

The most urgent priorities are to assess the airway (especially in bites involving the neck and floor of the mouth), assess the risk for a life-threatening incident, and determine the neurologic status. Fortunately, most penetrating wounds due to bites involve soft tissue only, but certain vascular regions are at risk due to their superficial locations over bony prominences—the superficial temporal, facial, and angular arteries. Included in the neurologic concerns would be facial nerve function, vision and ocular movement, and tongue motion. Appropriate consultations should be obtained, including a pediatric consultation if the victim is a child. Monitored CT scanning is mandatory if physical findings raise a concern for neurologic or osseous damage.

After the patient has been stabilized and evaluated, tetanus prophylaxis and intravenous antibiotics should be given. For those who have not previously had the tetanus series, it should be started right away. This immunization should be given early in the emergency visit so it will not be forgotten. If rabies is a possibility, the patient should receive a first dose of immune globulin on the day of the injury, followed by the vaccine at days 0, 3, 7, 14, and 28. Because cleansing the wound with povidone can eliminate 90% of the rabies risk, this should be done as well. For any significant penetrating soft tissue bite it is recommended that an intravenous bolus of a second-generation cephalosporin be administered. If penicillin sensitivity cross-reaction is a major concern with a cephalosporin, then parenteral ciprofloxacin is a good choice. Alternatively, clindamycin can be considered. This parenteral dose should be given in advance of any surgical care, so that blood levels can be available. If the wounds are severe, then consideration should be given to continued parenteral antibiotic therapy, either as inpatient treatment or home intravenous therapy. Usually, after the wounds have been cared for on an emergency bases, the patient may be discharged with an oral antibiotic that is effective against a wide range of organisms, including anaerobes. Good choices would include amoxicillin–clavulanate, cephalexin, clindamycin, and ciprofloxacin.

The main key to successful management of human or animal penetrating wounds is copious irrigation—either sterile saline or tap water from a clean outlet—to decrease the bacterial load in tissues.[3] Although several liters of saline irrigation is adequate, the author prefers a 2:1 solution of saline and povidone, usually in the region of 1.5 L. For larger wounds, a bulb syringe or intravenous tubing irrigation will suffice, but for smaller penetrations or puncture wounds, a plastic intravenous catheter on a 20-cm^3 syringe works well.

Debridement of the wounds is the second most important step for the soft tissue. Anesthesia can be obtained through regional nerve blocks (i.e., infraorbital, mental, supratrochlear, and supraorbital), as well as local infiltration after the blocks are in effect. If the procedure is likely to take longer than 1 to 1.5 hours, then 0.25% bupivacaine can be added to the local anesthetic to prolong its effect. It is also helpful, particularly with children, to buffer the anesthetic solution with sodium bicarbonate (10% of the total volume of anesthetic) to reduce the discomfort of local wound infiltration. In extensive wounds, and in many children, a general anesthetic may be warranted (and humane).

For small punctate penetration wounds from animal or human bites, the author prefers to excise the puncture tract with a 2-, 3-, or 4-mm dermatologic punch for the purpose of removing damaged and contaminated tissue. This converts the tract to a clean, cylindrical wound that can be irrigated and loosely closed with one or two dermal sutures after instillation of antibiotic ointment (mupirocin) within its depth.

Flaps of tissue should be minimally debrided. Then the surrounding tissue to which the flap will be sutured should be slightly elevated to facilitate a dermal closure, irrigated, and closed rather loosely with 4-0 or 5-0 chromic catgut suture (or polyglactin suture if some tension exists), followed by loosely placed epidermal sutures of 6-0 polypropylene or 5-0 fast-absorbing catgut (in children). Mupirocin ointment can be applied topically to the wound and utilized for approximately one week postoperatively. It may not be wise to apply sterile adhesive strips to a bite wound, as it is important to observe the wound for infection and to allow a slight laxity of the wound margins for seepage of serous fluid.

Human bites deemed not safe for primary closure may be packed open with frequent dressing changes and application of topical antimicrobials, then closed in a delayed fashion 2 to 4 days after wounding (if clean) or left to heal by secondary intent. The latter will likely require subsequent scar revision. Replacement of completely avulsed tissue is generally not productive, unless the facial part is an entire ear, nose, eyelid, or lip, wherein microvascular reanastomosis should be attempted, if feasible.

When the above wound care precautions are utilized appropriately, most penetrating wounds due to animal and human bites heal reasonably well. However, the patient and family should be prepared for a less than ideal result from the beginning and understand that subsequent scar revision will likely be required. This might include one or more of the following: excision of the scar and reapproximation; steroid injection(s); dermabrasion; laser resurfacing; and reorientation of the scar. There is some clinical evidence that the use of silicone gel or sheeting may affect the subsequent scar in a positive manner. For movable areas, such as the lips, the gel is more practical than the sheeting. Scar revision is a process that may extend over several years, with multiple procedures, and such a possibility should be explained very early in the counseling process, usually in the emergency room.

In addition to caring for the physical sequelae of an animal bite, particular attention must be paid to the psychological impact of injury to the child by a family pet, if that is the case. The child may blame himself or herself, especially if the animal is euthanized, and the surgeon should be supportive and seek counseling for the child and family if the child becomes withdrawn or generally fearful.

Injuries of the Cheek

The cheek is a common site for facial injuries because of its large surface area. Both penetrating and avulsive injuries may be seen, although the relative resistance of cheek tissue, and the fact that it is "tethered" between fixed points of the zygoma, ear, and mandible, may favor a reduced risk for major avulsion. Knife wounds, gunshot wounds, and automobile accidents account for the majority of the soft tissue wounds to the cheeks, with animal bites down the list a bit.

Penetrating wounds to the lateral face are of considerable concern because of the risk to the parotid gland, facial nerve, and facial vasculature. Fortunately, due to the thickness of the parotid gland and the overlying superficial musculoaponeurotic system, the facial nerve is injured only with the deepest penetration. However, in the usual case of a knife or gunshot wound, it is rare not to have sufficient penetration to involve at least one branch of the nerve.

Facial nerve testing is usually limited to the peripheral trunk and branches after exit from the stylomastoid foramen. Therefore, elicitation of voluntary motion in the conscious patient will determine which, if any, branches are involved. However, electrical stimulation of the facial nerve peripherally in the emergency room is helpful treatment for unconscious or uncooperative patients.

Wound inspection before irrigation may reveal a salivary leak from the body of the gland or from the parotid duct anterior to the masseter muscle. Because the duct and the buccal branch of the facial nerve are closely aligned in their courses, both structures may be injured. Even in the face of an intact nerve, severance of a specific facial mimetic muscle (i.e., zygomaticus or depressor labii inferioris) may mimic facial nerve injury.

In the lateral face, just anterior to the jaw and auricle, the superficial temporal artery and internal maxillary artery can be injured. Active bleeding may be encountered, or an expanding hematoma may be present in the pterygomaxillary space. Severe epistaxis may occur from an internal maxillary artery injury and emergency arteriography with vascular embolization or occlusion required. A gunshot wound to the lateral face can also directly injure the mandible, maxilla, and internal carotid artery. If this is suspected by virtue of the location of the entry wound and likely course of the penetration, as well as other signs on the physical examination, then the patient should undergo angiography (if stable) and CT to assess possible osseous damage. Foreign bodies may be present deep in the wound yet remain "invisible" to the examining surgeon; radiographic evaluation may reveal these objects.

Neurologic injuries can be present and can involve the nerves of the orbit, sympathetic chain, and even the spinal cord, nerve roots, and intracranial contents via the infratemporal fossa.[4] A cervical spine injury should be deemed present with all significant facial trauma until ruled out by radiographic studies. Cranial nerves IX to XII can also be at risk at the skull base.

The airway becomes an issue if there is a spinal cord injury, expanding hematoma in the lateral pharyngeal space, penetration of the brain or brain stem, and damage to the tongue, palate, or floor of the mouth. The latter would include fractures of the mandible and maxilla from gunshot wounds. The airway should be secured with an endotracheal tube or tracheotomy as indicated.

As mentioned previously, bleeding from a vessel such as the superficial temporal or facial artery can usually be controlled by compression in the emergency room setting. It is not wise to randomly clamp these vessels in a facial wound unless absolute necessary because of the risk to the facial nerve and its branches. Injury to larger vessels, such as the internal maxillary artery, internal carotid artery, or jugular vein, require arteriography for precise diagnosis and embolization or emergency exploration to repair or ligate.

Injuries to a peripheral nerve, such as the facial nerve, should be explored as soon as feasible and the extent of injury identified (Fig. 54–3). If exploration is performed within 72 hours of injury, it will be possible to utilize the nerve stimulator intraoperatively to assist in the identification of the distal branches of the severed nerve(s). The use of loupe magnification (4 to 4.5 power) or the operating microscope is essential for identifying the nerve endings in the traumatized tissues and in facilitating repair of the nerve(s). It is unusual to be able to perform a primary anastomosis of a nerve severed by a traumatic penetration, as it is necessary to sharply trim the ends of the cut nerve to obtain undamaged neural bundles for repair. Thus, a cable or interposition graft will likely be required. This graft can be obtained from a sensory nerve, such as the greater auricular nerve or, if that is not available due to the trauma, the sural nerve in the calf. Unfortunately, these nerves are not similar to the facial nerve and its branches in cross-sectional diameter, so that one or more fascicles can be "stripped" from the donor nerve and sutured into interposition. No tension should be placed on the interposed graft, but if the nerve is too long, then reaxonization will be delayed. An epineural closure should be performed, using 8-0 or 9-0 nylon, or a single fascicle can be used with only a few fine nylon sutures at the periphery. The wound should again be copiously irrigated after closure to reduce the risk of local infection and inflammation in response to the presence of foreign materials or dead cells.

Figure 54–3 **(A)** Massive right facial soft tissue injury due to motorcycle accident'. **(B)** Intraoperative wound cleansing, debridement, and repair of severed facial nerve branches to eye. **(C)** One year post-repair and scar revision with normal eye closure.

It is usually necessary to perform a superficial parotidectomy to expose the proximal branches and trunk of the facial nerve. If the gland has been penetrated, it is also wise to debride it through a parotidectomy approach. The deep lobe of the parotid can usually be left intact, as it will not be a likely source of leakage of saliva. If, however, the parotid duct has been severed, the surgeon has the choice of repairing the duct or removing the gland. In most cases, it is possible to perform a ductal anastomosis using 6-0 or 7-0 nylon and loupe magnification. It may be necessary to cannulate the duct through Stenson's orifice as one can perform the anastomosis circumferentially, taking care not to suture the duct closed. Postoperatively, the wound should be compressed to reduce the stasis of saliva and a bland diet utilized for 7 to 10 days.

All obviously devitalized soft tissue should be debrided, as well as any suspicious, marginally vital tissue. This might include muscle, as the masseter muscle as well as the lateral muscles of mimetic activity can be injured. The wound edges of the skin should also be sharply debrided and the wound closed in layers. If a large dead space exists or if an avulsed flap is replaced, it may be necessary to place a small drain, either suction or nonsuction. If the duct or parotid gland has been injured or removed, then a suction drain may be preferred, though not required.

If osseous trauma is present, then the bone should be debrided, occlusion obtained, and internal stabilization plates applied. Even if the wound appears to be contaminated, small plates and mandibular/maxillary fixation can still be utilized, in conjunction with wound drainage, high-dose parenteral antibiotics, and copious irrigation.

Primary anastomosis of a facial nerve disruption should lead to early recovery—within 12 months. If an interposition graft is used, then the length of time to potential recovery varies directly with the length of the graft and how far distally the injury was located. The longer the graft, the more the length of recovery might approach 24 months; a distal injury is more likely to recover in just over half that time. If a long recovery time is anticipated, one should consider a static rehabilitation of the face in the interim, including a gold weight to the upper eyelid, canthoplasty (in an older individual), suspension of the nasal ala and oral commissure with AlloDerm (Lifecell Corp., Branchburg, NJ) or Gore-Tex (W.L. Gore and Co., Flagstaff, TX). This will provide a pleasant appearance in repose yet not interfere with the chance of later motion. If recovery does not occur or is incomplete, then one has a viable static support in place. The use of transcutaneous electrical stimulation of the facial musculature to maintain bulk and prevent atrophy has been advocated. There is no apparent contraindication to this, and the patient may feel comfortable performing some self-assistance.

If reanastomosis of the parotid duct is not successful, then the duct will stenose and the gland will become engorged and inflamed. Treatment with antibiotics, massage, heat, and sialogogues may help with the acute obstruction, but the gland either will atrophy or will require secondary parotidectomy. Because of the protracted course of parotid

inflammation after traumatic stenosis of the duct, the surgeon may elect to perform a preemptive primary parotidectomy at the time of surgical exploration and repair of the wound to avoid that complication.[5]

Postrepair infections of the face are uncommon after traumatic injury repair, owing primarily to the excellent blood supply available. However, other deterrents to infection include copious irrigation in the emergency room and operating room, judicious debridement of devitalized tissue, wound drainage if indicated, and perioperative administration of antibiotics for 7 to 10 days, depending on the extent of the tissue damage. Hypertrophic scarring is more likely to occur with traumatic injuries and can be lessened by using silicone gel applied twice daily for up to 2 months after initial wound healing. If persistent cosmetic problems ensue, scars of the cheek caused by avulsions or puncture injuries can usually be managed by reorientation into the lines of relaxed skin tension, breaking up with geometrical broken line closures, and dermabrasion. Makeup camouflage is also helpful from the beginning.

Midfacial Soft Tissue Injuries

Soft tissue injuries of the midface may present with bleeding, edema, difficulty with speech, and airway and muscle injury. In this area, the lips, nose, and periorbital structures are the main structures of concern. Because the lips are mobile, they are subject to stretch and avulsion. Penetrations may affect the teeth and attached gingiva and oral cavity. Nasal injuries occur because of the projecting position of the nose on the face, making it the first contact structure in most full-face wounding episodes.

Bleeding and hematoma are the main focus of the nasal evaluation. Whereas anterior epistaxis will usually result from trauma to the soft tissues of the nasal tip, alae, and columella (Fig. 54–4), posterior bleeding is more dangerous and may herald an injury to the greater palatine or sphenopalatine arteries. Inspection after suctioning, using either a head mirror and nasal speculum or a nasal endoscope, will usually identify the source of the injury. Septal hematoma is an emergency and must be identified. In a stable patient, the source of significant bleeding may best be identified through carotid angiography. If the nasal cartilages are avulsed or separated, they will require surgical reapproximation. Also at risk for damage from penetrating wounds to the nose and nasal cavity are the palate, nasopharynx, paranasal sinuses, cribriform plate, and intracranial contents. Cerebrospinal fluid leak can be identified through the crude filter paper test or from chemical analysis of the clear nasal drainage.

Evaluation of the lips should identify whether the injury is through-and-through; that is, involving the labial mucosa. If the penetration is close to the vermilion border, the labial artery might have been severed. The status of the orbicularis oris muscle must be ascertained; if separated in continuity, a deficit of closure will result. Deeper injuries may avulse teeth or implant them in the surrounding soft tissues; all teeth must be accounted for. Soft tissue wounds may be associated with alveolar or segmental fractures of the dental arches. If the tongue and floor of the mouth are involved through edema, hematoma, or laceration, the airway must be secured. Gunshot wounds are more likely to cause airway compromise than any other cause of penetrating trauma (Fig. 54–5).

Neural injury to the infraorbital, mental, or supraorbital nerves should be identified through pinprick tests in the area of their distribution (Fig. 54–6). These nerves may be directly injured through severance by penetration, may be rendered neuropraxic from edema or shock, or may be involved in a fracture site. CT scans may identify which is present.

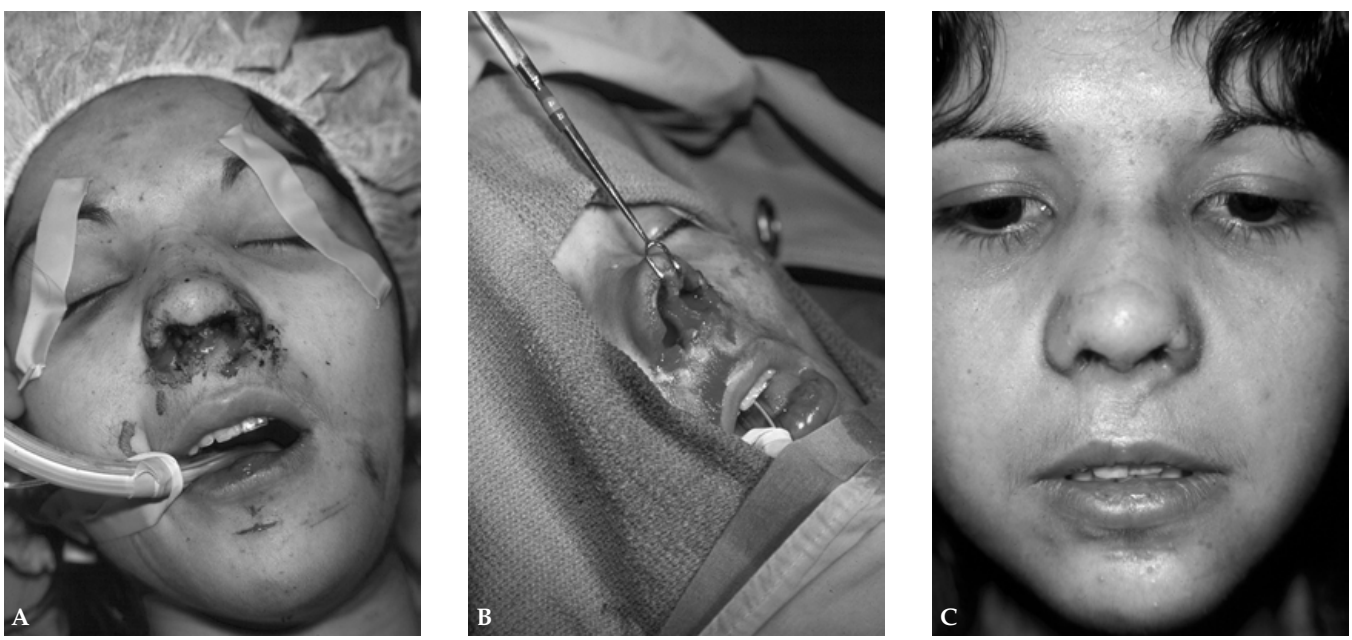

Figure 54–4 **(A)** Avulsion distal nasal tip from motor vehicle accident. **(B)** Exposure of extent of injury at time of surgery. **(C)** One month satisfactory result without stenosis.

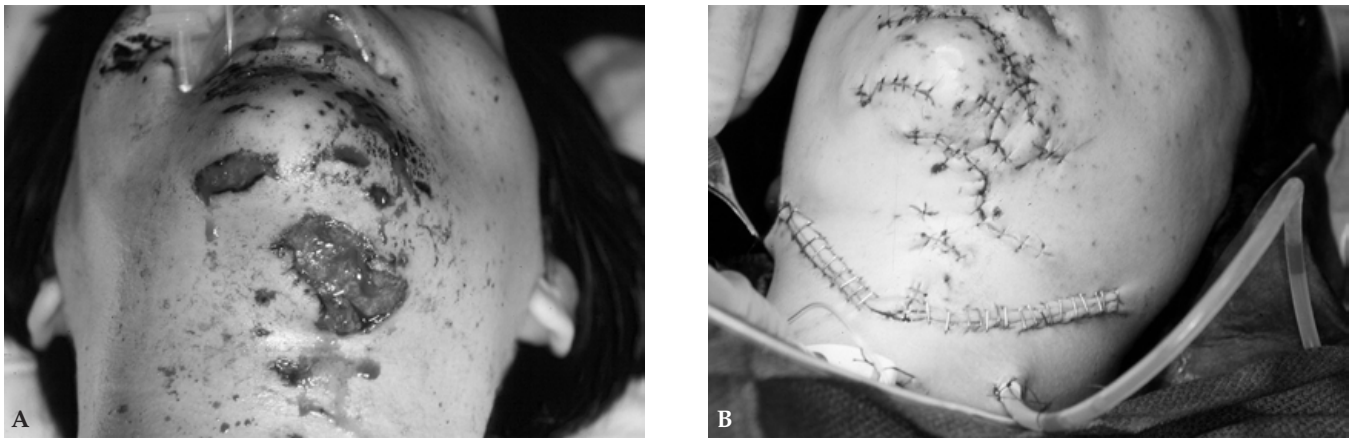

Figure 54–5 **(A)** Gunshot wound to chin and lips, causing hematoma of sublingual tissues. **(B)** Post soft tissue repair, exploration of upper neck, and control of bleeding.

Figure 54–6 **(A)** Motor vehicle accident injury to forehead with tissue separation, and damage to supraorbital and supratrochlear neurovascular bundles. **(B)** One year post nerve repair and scar revision with improving sensation of forehead.

The airway must first be controlled if at risk. This may require something simple, such as an oral airway or placement of a suture retraction for the tongue. If severe obstruction exists, then nasal intubation, cricothyrotomy, or formal tracheotomy should be performed in the emergency department to secure the airway before any other diagnostic or therapeutic procedures are performed.

Nasal bleeding will require urgent packing (either non–adhesive pads or microfiber surgical sponges soaked with otrivin and topical thrombin) or the insertion of nasal tamponading balloons. If a cerebrospinal fluid leak is suspected, then the nasal packing should be used only as a temporary measure to control bleeding until the patient can be taken to surgery for vessel ligation or to the angiography suite for embolization. For operative control of significant intranasal bleeding, the location of the bleeding, as identified on the nasal cavity endoscopy, will guide the surgical approach. If the bleeding is in the inferior nasal cavity, then the internal maxillary can be ligated, via a trans-antral approach, using fine metallic ligature clips. The greater palatine artery can also be injected via its foramen in the oral cavity for temporary cessation until the internal maxillary artery can be ligated. If bleeding is found to be high in the nasal cavity, then an external ethmoidectomy approach can be utilized, identifying both the anterior and posterior ethmoid arteries and clipping or cauterizing with the bipolar cautery bayonet forceps. The anterior artery must be divided after ligation or cautery to approach the posterior ethmoid artery, but the latter need not be divided after control is obtained. It provides a valuable guide to the distance to the optic foramen.

If the alar cartilages have been split or avulsed, then the cartilage should be minimally debrided and sutured into proper anatomic position using 4-0 chromic catgut. Puncture wounds of the nose generally heal well with minimal

debridement and loose closure. For through-and-through nasal punctures, only one surface—usually the skin surface—need be closed. Special care must be taken to carefully reapproximate the alar margin (rim) if it is severed, as any misalignment will be noticed. The skin wounds may be closed with 6-0 polypropylene.

Nostril stenosis is perhaps the most common complication of soft tissue injuries to the nasal tip and may require Z-plasty widening of the vestibule or composite grafting from the auricle. Dilations, injections of steroids, and soft nostril stents can be helpful. If the nasal valve region has been damaged and is incompetent, then internal splinting using onlay cartilage grafting usually works well.

The management of lacerations of the lip depends on the depth of penetration. If the lip is only partially involved, then dermal and skin closure will suffice. If the muscle is violated, then it should be reapproximated with either 4-0 chromic catgut or 4-0 polyglactin suture, taking care to close its entire dehiscence so that a continuity defect does not occur. If the penetration is full thickness, then the inner mucosal layer should be loosely closed with buried 4-0 chromic catgut sutures so that saliva does not become entrapped and an infection ensue. Special care should be taken to reapproximate the vermilion–skin border—loupe magnification can be quite helpful in discerning this line. The vermilion can be sutured with 6-0 silk, as the suture "tails" lie down flat on the vermilion surface and are not irritating to the patient.

If sutured properly, lip penetrations heal well and the sphincter effect of the oral stoma is maintained. If the oral commissure has been blunted, a commissuroplasty using intraoral mucosa can be performed. Notching of the lip ("whistle deformity") from incomplete closure of the orbicularis oris muscle can be reconstructed by excising the notch deformity and reapproximating the muscle and dermis well. The vermilion border, if malaligned, must be revised and realigned as closely as possible.

Lacerations of the eyelids can be difficult, even when uncomplicated. For a vertical laceration of the free margin of the upper or lower eyelid, 5-0 or 6-0 silk sutures should be placed in the anterior and posterior marginal lines, as well as through the meibomian gland region between the margins, tied with long "tails" and sutured beneath skin stitches of the eyelid skin. These silk sutures should be left in place for approximately 2 weeks, so that the margin heals completely. The tarsal plate can be reapproximated with mattress or figure eight sutures of 5-0 Vicryl and the orbicularis oculi muscle closed with 5-0 chromic catgut. Skin sutures can be 6-0 polypropylene. An ophthalmic antibiotic ointment, such as tobramycin, can be applied to the suture line.

A horizontal laceration of the eyelid is more worrisome, owing to the fact that the elevator muscles of the upper eyelid (levator and Müller's muscle) and the retractors of the lower eyelid might have been violated. If fat is seen in the wound, then the orbital septum is not intact, increasing the risk for damage to these structures. A complete ophthalmologic evaluation should be conducted and the wound explored. If the upper eyelid elevators are found to be cut, then they should be reapproximated in their anatomic positions with 5-0 Vicryl sutures and the position of the eyelid noted. Future reconstructive surgery might be necessary if the result is less than optimal. The lower eyelid retractors are not as important in terms of reapproximation, but the surgeon should ensure that the inferior rectus and inferior oblique muscles are not damaged—repairing them if necessary. Injuries to the medial or lateral canthal tendons should be reapproximated or reattached to the orbital periosteum, whichever is indicated. The cornea must be protected at all times and kept lubricated using a balanced salt solution irrigation. Violation of the lacrimal drainage system will require cannulation with soft silicone tubing, tied in the nasal cavity and left in place at least 2 weeks, but optimally 6 weeks. The tubing can be removed endoscopically. Conjoint surgery with an ophthalmologist could prove beneficial in complex injuries.

CONCLUSION

Soft tissue injuries of the face can be complex, requiring careful identification of the involved structures and extent of damage, a careful analysis of options, and the development of a surgical plan, which includes options for future reconstruction. Obtaining adequate comfort for the patient through anesthetic techniques allows the surgeon to focus on the wound care and closure. Copious irrigations, careful debridement of devitalized tissue, reapproximation of anatomic structures, and meticulous skin closures are key features of optimal wound care. Injuries to important and vital underlying structures should be suspected and identified, and then treated appropriately. Topical and oral or parenteral antibiotics, good wound care, use of silicone gel to reduce scar formation, and selected techniques for scar camouflage and revision complete the postsurgical management. Finally, an extensive knowledge of the physiology and three-dimensional anatomy of the face and underlying structures is critical to achieving the best possible functional and cosmetic result. Psychosocial and emotional support must also be given to the patient and family. Scar revision and functional rehabilitation may require long-term care, multiple procedures, and commitment, and the patient should understand this possibility as early in the course of care as possible.

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Chapter 55

Craniofacial Bone Healing and Repair: Basic Principles

Craig D. Friedman

Surgery of the craniofacial skeleton is an integral part of facial plastic surgery. A basic knowledge of fundamental bone biology and applied biotechnology helps to ensure improved outcomes for therapeutic interventions. Significant advances in the understanding of basic molecular biology of bone, genetic control of bone formation, and increasingly sophisticated surgical techniques of bone repair and fixation have permitted unprecedented success for patients. This chapter will review basic concepts and principles of bone formation and repair important for facial plastic surgeons.

WHAT IS BONE?

Bone tissue is a specialized composite of extracellular matrix proteins that is mineralized under the surveillance of associated cells that maintain the structural integrity of the bone while responding to the metabolic requirements of the organism.

BONE FORMATION

During embryologic development there are two primary processes of bone formation. *Intramembranous* bone formation occurs independently of a preexistent model or structure; *endochondral* bone formation occurs via replacement of a cartilaginous structure or model/template.

In membranous bone formation the ossification process takes place by direct mineral deposition into the organic matrix of mesenchymal tissues. The mesenchymal cells receive signals to induce differentiation to an osteoblastic lineage. Within the craniofacial skeleton this is the major process observed. The frontal and parietal bones, nasal bone, the maxilla, zygoma, and the mandible are all of membranous origin.

In endochondral bone formation, mesenchymal cells differentiate to form a cartilage template. The cartilaginous structure proceeds through a hypertrophic state to become mineralized and ultimately replaced by differentiated bone cells. The removal and replacement of the mineralized cartilage is accomplished by the invasion of the template structure by osteoclast (large multinucleated) cells and blood vessels. Following removal of the mineral matrix, osteogenic precursor cells repopulate the template structure and form bone. This mechanism of bone formation is the basis of the axial skeleton; in the craniofacial region, endochondral origin is observed in the nasal septum and portions of the nasal bone complex, the occipital bone, skull base, and mandibular condyle.

Appositional growth in all bones (of either embryologic origin) proceeds via membranous bone formation. Due to ongoing metabolic modeling and remodeling processes, no remnants of calcified cartilage are detected. The role that bone origin might play in healing and repair versus the impact of local regulatory factors has not been established. Many new insights regarding the molecular biology of bone formation are now being revealed, such as the interplay of various morphogenic proteins (e.g., bone morphogenic proteins; BMPs), developmental gene control for limb development(e.g., hox/HOM gene network), and local regulation (e.g., parathyroid hormone–related protein). Although beyond the scope of this chapter, further elucidation of the biology of bone formation will have an impact on clinical bone repair in the future.

BONE STRUCTURE

Grossly bone can be descriptively classified as either *cortical* or *cancellous*. These terms refer only to the structural architecture, not cellular origin or composition. Cortical (or compact) bone is immediately beneath the periosteum, adjacent to the endosteum, and these surfaces are lined with envelopes providing vascularity and osteoprogenitor cells for repair. The envelopes form a system of lacunae and canaliculi around the mineralized matrix for the transport of metabolites; this limits the outer diameter of the osteon (or basic bone unit) to approximately 100 μm of maximum diffusion and 200 μm of trabecular plate width. Within the cancellous bone a trabecular architecture is often described. The size, volume density, and dimension are variable and depend on the age, site, and loading of the bone. The transitions between the compact and cancellous bone are an area of flux; thus osteoclast cells may erode cavities inside of compact bone allowing for cancellous bone to form. Conversely, osteoblasts may fill spaces within the trabeculae of cancellous bone to form new compact bone.

On the next level of microscopic exam bone is usually classified as *woven* or *lamellar*, although some authors take the classification further. Woven bone is characterized by its random collagen fibril orientation. Woven bone forms rapidly on the order of 3 to 5 μm/day in humans and can cover a relatively large physical territory, with resultant diminished biomechanical properties. Lamellar bone is characterized by elaborate

orientation and therefore its formation is more demanding and time consuming. Lamellar bone requires a preformed solid scaffold for its deposition; there is strict parallelism of the underlying lamellae to the underlying surface. Any irregularities of the surface are usually addressed by woven bone prior to lamellar bone deposition. The linear appositional bone formation of lamellar bone is approximately 1 to 2 μm/day.

Remodeling of bone is a concerted and coupled action of bone resorption and formation that takes place on the surface and interior of compact bone. During remodeling osteoclasts drill or create tunnels. Local signals (growth factors and other regulators) induce osteoblasts to follow and deposit lamellar bone, thereby contracting the tunnel walls around the nutrient capillary forming secondary osteons or Haversian systems. Bone remodeling allows for continued renovation and metabolic restoration while preserving functional capacity or the bone structure.

The blood supply to bone in the craniofacial region is abundant. Within the bony structure the vascular supplies follow the Haversian system and are cross-connected by Volkmanns' canals. Peripheral to the capillaries are the canulicular envelopes. These are related spatially to the osteocyte–perfusion exchange as noted above, limited to 100 μm. The blood supply to compact bone, especially as its thickness increases, is dependent on long low-pressure connections, thus making it more susceptible to disruption and longer recovery. In contrast, in cancellous bone the vascular supply reaches its anatomical destinations more directly without significant branching. Therefore, all processes of healing and remodeling that would require reestablishment of vascularization occur more rapidly and efficiently. Within the craniofacial bones the vascular supply is more consistent with the cancellous bone model, with a relatively large surface area to bone volume; therefore, these bones are less prone to vascular compromise. The mandible is a mixture of vascular supply types and somewhat more susceptible. Overall the plentiful blood supply decreases the risk of infectious complications in comparison with the extremities and appendicular skeleton.

BIOCHEMICAL STRUCTURE OF BONE

The noncellular composition of bone matrix is usually divided into organic and inorganic components. The inorganic bone matrix comprises approximately 70% of the dry weight of bone. The major constituent of the inorganic or mineral phase is calcium and phosphate in a unique biologic crystal structure termed hydroxyapatite. Although hydroxyapatite conveys a specific chemical stoichiometry [$Ca_{10}(PO_4)_6(OH)_2$], various apatitic species of calcium phosphate exist (such as amorphous), with hydroxyapatite the most prevalent. The remainder consists of additional ionic species of sodium and magnesium as well as very small concentrations of other inorganic ion species.

The *organic* matrix of bone is usually divided into *collagenous* and *noncollagenous proteins*. Collagen composes 90% of the organic matrix in the form of a bone-specific type I unique in its specific glycosylation and cross-linking. The direct fibril–apatite interaction gives rise to the special biomechanical properties of bone. The remainder of collagen species present in bone are associated with blood vessels or are known to influence fibril diameter (types III, V, XII, and XIII).

The noncollagenous proteins comprise the remaining 10% of the organic matrix. They are generally divided into proteoglycans, glycoproteins, Gla-containing proteins, and growth factors. The proteoglycans are composed of glycosaminoglycans (GAGs) covalently linked to core proteins. Examples of proteoglycans are decorin and fibromodulin with associated GAGs such as chondroitin and heparin sulfate. These proteoglycans are thought to play a role as binding reservoirs for various growth factors, such as basic fibroblast growth factor and transforming growth factor β (TGF-β).

Glycoproteins are represented by fibronectin, osteonectin, osteopontin, and bone sialoprotein. Glycoproteins share arginine–glycine–aspartic acid (RGD) cell attachments sequence. A major role of these proteins is in modulating cell attachment and adhesion and mediating mineralization of the organic matrix.

Gla-containing proteins represented by osteocalcin take part in vitamin K–dependent enzymatic reactions. The final grouping of proteins is that of growth factors such as TGF-β, BMPs, insulin-like growth factors, and an ever-growing list of growth factors and their associated binding proteins. These factors, though present in small amounts, are thought to play important roles in bone formation and repair. Specifically these factors can induce cellular differentiation of mesenchymal cells to osteoblastic lineage. In addition, they have complex interactions locally on the genetic control of repair and development of tissue. In summary, the extracellular matrix of bone is an extremely complex solid-state matrix that interacts with cellular components for the regulation of bone physiology.

BIOMECHANICAL CONSIDERATIONS

The composite nature of bone affords it unique mechanical properties to support its physiologic role. Bone also has anisotropic properties, meaning different properties along different axes. Measurements of bone strength are subject to various modeling and experimental considerations; however, comparison to steel places it at 10% relative strength. Compression of bone can be achieved because of the structural makeup, which permits force transduction. The result of compressibility is shortening or deformation of the bone; clinically the response to such compression is resorption, or "creep." When bone is deformed by elongation, deformation is limited to approximately 2% before fracturing. The structure of bone, whether compact or cancellous, affects its strength, with cancellous bone having less than 10% the strength of compact bone. Measurements of bone strength have reported cortical bone with compressive strength of up to 140 MPa and torsional or elastic modulus of 14 GPa. Various pathologic conditions, such as osteoporosis, affect the microstructure of bone and thus the mechanical strength, which in turn affects the potential for fracture.

The craniofacial skeleton has evolved to provide protection to neurosensory structures (brain and eyes) and allow mastication. The structure of the calvarium, midface, and mandible allows for efficient function and protection. The skull and midface perform protective functions; therefore, repairs of these are usually less dependent on mechanical factors during healing.

The mandible, along with muscles of mastication transduct forces at their attachments and dental occlusal plane. Model analysis of the mandible reveals that the muscle forces paralyze

maximal at the angle and vertical ramus. The reactive forces generated in the occlusal plane, bend the mandible forward, creating zones of tension in the alveolar region. When repairing mandibular disruption, attention to these zones of tension is imperative. Bite forces (up to 700 Newtons) are generated along the occlusal planes. Calculation of the force and force-moment should be considered in the selection of fixation repair with certain minimum load resistance. These considerations are important in the design and placement of fixation devices, particularly in the mandible due to the active function.

FRACTURES

Fractures are the result of mechanical overload, that is, failure to resist deformation under loading resulting in the loss of structural integrity. Detailed analysis of the configuration of fractures has been done in terms of the force or load, energy release, and specific tissue characteristics. Torque, avulsion, bending, and compression result in specific patterns such as transverse, oblique, impacted, or comminuted. The structural disruption is accompanied by disruption of the osseous blood supply and is dependent on the dynamic nature of the injury disruption of soft tissues and associated neurovascular injuries. The vascular compromise is more significant in the mandible due to the relative thickness of the compact bone component affecting intracortical blood supply. However, the overall abundant blood supply aids in the healing and resistance to infection.

FRACTURE HEALING

Restoration of function and original structure can be evaluated on a biologic and mechanical basis. Most fractures reach mechanical functional healing prior to histologic or biologic restoration of premorbid structure. The basic tenets of wound healing in bone are the requirement for functional cells, adequate nutrition (i.e., vascular supply), and mechanical environment to support the fragment ends in apposition. The initial events result in a process of internal and surface remodeling; almost immediately there is an increase in DNA synthesis and cell proliferation in the subperiosteal region. Nonperfused bone is replaced by vital bone via remodeling, and proliferating cells secrete osteoid (extracellular matrix), which then is mineralized and forms bone spicules. Throughout the bone spicules are large spaces that contain vascular channels and undifferentiated cells. Osteoclasts are seen within the healing callus as soon as new bone is formed. With progressive healing and osteoclast remodeling, bone spicules are replaced by mature lamellar bone and trabecular marrow spaces develop.

Within the extremes of interfragmentary motion two general patterns of healing are described. Realistically this is a continuum; however, it is best to consider the two classically described processes. With limited interfragmentary motion the conditions for bone formation exist as decribed above; the contact zones of the fragments are not deformed and permit the osteoclasts in the "cutting cone" to cross the contact zone and connect newly formed osteons linking the fragments. This is described as *primary bone healing or union*. Gaps across the contact zone allow for primary lamellar bone formation if immobilization is maintained; larger gaps induce a pattern of woven bone, which is then secondarily remodeled to lamellar bone. Larger but still immobilized gaps reach critical defect size, cannot support bone formation conditions, and are filled with fibrovascular tissue.

Under conditions of greater interfragmentary motion the distractive forces in the fracture gap exceed the level of requisite stability necessary for primary healing across the gap. A process or "cascade" of tissue differentiation ensues with the formation of granulation tissue to connective tissue, fibrocartilage, mineralized cartilage, woven bone, and then compact bone. This process via formation of a cartilaginous callus is considered *secondary bone healing*, or the extraperiosteal reaction to fracture with chondrogenesis and eventual endochondral ossification (Fig. 55–1). The cellular events are well documented based on experimental studies. Attached muscle and other soft tissues immediately outside of the periosteum show increased activity. Extravasated blood (or hematoma) is noted between the muscle fibers and periosteum. Inflammatory cells are noted in the hematoma (polymorphs and then macrophages). This follows the changes in the adjacent muscle with proliferation of fibroblasts and other cells within the degenerating muscle fibers. The basement membrane of the muscle fibers loses its structural integrity, allowing the fibroblast to intermix with the hematoma cells and periosteal cells forming a greater callus mass. The callus mass is then quickly vacularized with formation of small arterioles and venules.

The next stage in the tissue cascade is formation of cartilage within the callus and adjacent to areas of membranous bone formation near the junction between the cortex and subperiosteal bone. The cell proliferation decreases and a basophilic matrix is secreted devoid of blood vessels. The area becomes more avascular and laccunae form around the cells with hypertophy of nuclei consistent with chondrocytes. Chondrogenesis continues in the same fashion as growth-plate formation during bone formation or maturation. The mature matrix and hypertrophic cells are calcified and invaded by blood vessels from the immediately adjacent membranous bone and then remodeled to woven and then ultimately lamellar bone indistinguishable from subperiosteal bone formed via membranous ossification.

Cartilage formation is the primary mechanism of fracture healing in long bones and within the craniofacial region. It is usually seen in the mandible but is also seen at other sites where conditions do not favor primary bone healing. Clinical conditions, including interfragmentary motion, can affect the local healing response. Diabetes and metabolic insult (chemotherapy), which impair cartilage formation, also play a role. It has been noted that within a fracture both types of healing can be noted.

Local regulation of fracture repair has received considerable attention. Growth factors important in local control can be produced by the associated inflammatory cells and found within the bone matrix itself. Osteoblasts, macrophages, or chondrocytes within the callus can also synthesize the factors. Growth factors prevalent in the fracture site are presented in Table 55–1. What has been initially discerned by various investigations is that TGF-β released from platelets initiates callus formation. Acidic fibroblast growth factor appears to regulate the proliferation of chondrocytes, and as the callus matures synthesis of TGF-β is increased in the matrix and, along with other factors, induces chondrocyte maturation and initiation of endochondral ossification. There is significant interplay among these local regulators of bone repair,

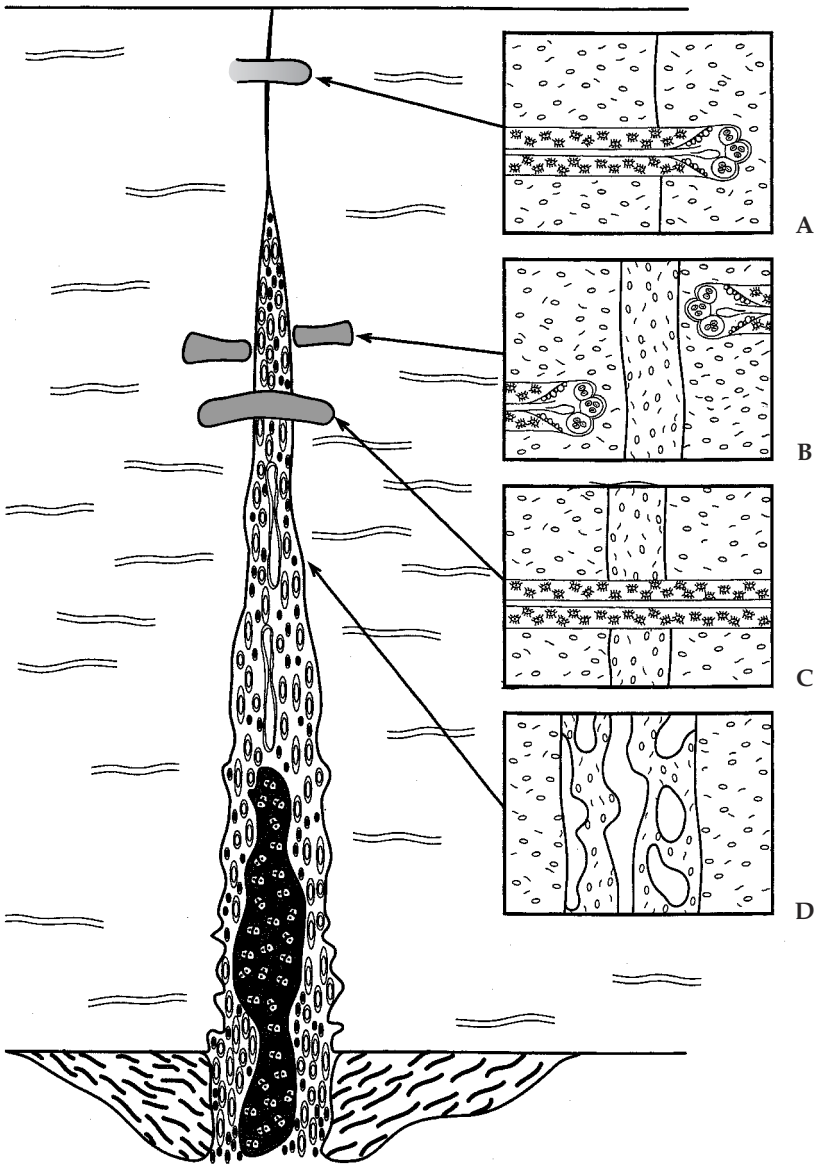

Figure 55–1 Patterns of fracture healing. The appearance of a healing fracture is determined by the geometry of the fracture zone, the degree of immobilization at various sites, and their changes occurring over time.

An absolutely perfect alignment of the entire fracture is not possible; direct contact between the fragment ends is restricted to only small portions. The remainder consists of a gap of varying width. Complete absence of interfragmentary motion is possible only in contact areas and in gap zones in their close vicinity. If this zone is completely immobilized, whether from the beginning or as a sequel to bony bridging at other sites, direct intracortical remodeling across the fracture plane may take place at contact sites **(A)**. In a first step small immobilized gaps are filled directly with lamellar bone **(B)**. Then secondary remodeling **(C)** in the axis of the bone gradually leads to reconstruction of the original integrity. This phenomenon of fracture healing without intermediate steps of tissue differentiation is called direct, or primary, bone healing. Pure direct healing, an extreme healing pattern on the one side of the scale, seems to be relatively rare.

The further away from the contact areas, the higher is the chance of interfragmentary motion of various degrees, and usually the higher is the gap. The healing pattern in these zones is characterized by resorption of the fragment ends, callus formation, and interfragmentary ossification via a cascade of tissue differentiation. This leads to a gradual immobilization during the healing process. This pattern, found on the other extreme of the scale, is common. Intermediate stages, for instance, the subdivision of a wide gap by the formation of woven bone **(D)**, may be observed between the two extremes.

At a specific phase during the healing process it may happen that some sites of the same fracture are under relative motion while others become immobilized. Thus in a single fracture it is possible to observe a broad spectrum of different healing patterns. As a routine, however, only a narrow band from the full range of healing patterns reflects the situation of that specific fracture.

TABLE 55–1 Growth Factors Found in the Fracture Callus

Growth factors*	Source	Matrix location†	Responding cells	Unique characteristics
TGF-β	Platelets, inflammatory cells (monocytes, macrophages), osteoblasts, chondrocytes	Bone is the most abundant source of TGF-β in the body	Most cells have TGF-β	Inactive precursor peptide, most potent chemoattractant identified for macrophages, promotes angiogenesis, activates a serine-threonine receptor
BMPs (BMP-2, BMP-4, BMP-5, and BMP-7)	Chondrocytes, urinary bladder, epithelium, brain	BMPs were originally identified in bone, but now are known to be widely distributed throughout the body	Unknown	TGF-β-like structure; may be involved in cartilage formation, important regulator during embryogenesis
Fibroblast growth factors (aFGF, bFGF)	Inflammatory cells, osteoblasts, chondrocytes	Binds HSPG in bone and cartilage matrix	Most cells of mesoderm or neuroectoderm origin	Stimulates neovascularization, evidence for an autocrine, intracellular function; stimulates type IV collagenase
Platelet-derived growth factors (PDGF-AA, AB, or BB)	Platelets, monocytes, activated macrophages, endothelial cells	Interactions unknown	Most cells of mesoderm origin	Activates a tyrosine kinase receptor

*TGF-β = transforming growth factor β; BMP = bone morphogenetic protein; aFGF = acidic FGF; bFGF = basic FGF. †HSPG = heparan sulfate proteoglycan.

(After Bolander, ME. Regulation of fracture repair and synthesis of matrix macromolecules. In: Brighton CT, Friedlander G, Lane JM (eds). *Bone formation and repair*. Rosemont, IL: American Academy of Orthopedic Surgeons, 1994. With permission.)

including the BMPs synthesized by osteoblasts. Further elucidation of osseous wound healing will undoubtedly aid in the development of new strategies for fracture repair.

CLINICAL CONSIDERATIONS IN FRACTURE HEALING

The clinical monitoring of fracture healing has been by the utilization of conventional radiologic imaging. After reduction the fracture line is minimally visible. Subsequent to the internal remodeling process there is a decrease in the radiologic density, and the fracture site becomes increasingly diffuse in appearance. Over time there is characteristic loss of the visible fracture line. Determination of when healing is sufficient to enable progressive functioning has evolved from clinical experience and experimental models. Remodeling to full load bearing in the craniofacial skeleton can take up to 6 months in the mandible. Other areas of the facial skeleton may require significantly less time for healing. Reduced and fixated fractures can be returned to progressive function and loading beginning at 4 weeks. With the advent of rigid internal fixation plates the time to function recovery has been decreased to essentially immediate limited functioning.

Potential complications of fracture healing include infection, refracture, delayed healing, nonunion, implant failure, and implant loosening. Due to the proximity and likely involvement of the oral cavity, infections that do occur usually involve oral flora and begin in the soft tissue adjacent to bone. Neurosensory injury is most likely secondary to the initial injury and most commonly involves trigeminal nerve branches and facial nerve.

Delayed healing is defined by clinical experience and can be said to occur in the midface after 6 weeks and in the mandible after 12 weeks if little or no healing has occurred. The management of delayed healing can be a spectrum from the replacement of the fixation apparatus to the curettage of the fibrous union with or without bone grafting. Implant failures usually stem from technical deviations during placement. Some common etiologic factors are use of monocortical screws lacking stability, insufficient number of screws, stripping of screws (when using self-tapping screws), and bone damage when inserting into an incompletely or poorly placed pilot hole.

CLINICAL INDICATIONS FOR FRACTURE TREATMENT

The goal in operative treatment of facial fractures is to promote rapid recovery of form and function. Stability of the reduction and fixation needs to be optimal for the specific anatomy. When this can be achieved normal healing can be maximally stimulated. The decision to treat a fracture with closed or open techniques will always be individualized for the patient and the specific condition. Conservative closed splinting with maxillary mandibular fixation with interdental arch bars can successfully correct fractures that are closed and simple in nature. Internal fixation of fractures is best used for complex injuries in which return to function can be expedited. Functionally stable internal fixation is indicated for:

- Multiple or comminuted fractures
- Panfacial fractures
- Fractures with bone loss
- Open-wound fractures
- Severe midface dislocation
- Geriatric atrophic mandible fracture
- Infection or nonunion due to conservative treatment

Social considerations, such as mental or cognitive variations that make conservative treatment more difficult, must be considered. In summary, open internal fixation of fractures should be carefully considered when warranted by the clinical status.

FIXATION TECHNOLOGY

Materials used for fixation implants must be strong and ductile, adaptable to fit the bone surface, and biocompatible. Metals have been used extensively in skeletal surgery; stainless steel, chromium–molybdenum alloys, and commercially pure titanium are the most commonly used. Titanium is now almost exclusively utilized for craniofacial repair. The advantages of titanium are (1) its resistance to corrosion by the formation of a surface oxide layer and (2) excellent tissue tolerance providing a practical inert physiologic status. It is noted that over time small particulate metallic debris, either from natural degradation processes or from imperfections in the metal implant, allow for uptake into the reticuloendothelial system. This can produce instances of lymphadenopathy and measurable metal ion deposition in the liver.

Biodegradable polymeric materials have recently been introduced after many years of research and development. Most are based on various copolymers of ortho esters of lactic acid, although newer formulations with novel polymer constituents are being developed. Use of these for fixation is preferred because of the anticipated resorption of the implant over time, which precludes the need for implant removal. Due to the limited functional biomechanical capacity these implants are best utilized in the areas of the craniofacial skeleton with the least amount of stress loading, such as the skull and orbitomaxillary region and in the pediatric population where concerns regarding growth inhibition with metal implants exist. Long-term follow-up of the newer formulations of polymeric plates is pending, and concern over local healing effects remains unresolved to date.

Splinting is the connecting of a stiffer device to the fractured bone. In craniofacial surgery this most often consists of interdental arch bars that serve as an external splint. The goal of such splinting is to reduce fracture fragments without surgical intervention. There will always be mobility at the fracture site with this technique. Internal splinting in the form of wire suture or plate is more effective in reducing the interfragmentary motion and aiding the healing process.

Compression is a method of further reducing interfragmentary motion. Compression fixation consists in pressing the two surfaces together, bone to bone, or implant to bone. Compression produces a preload in the fracture plane and increase interfragmentary friction. Maintaining an axial preload greater than the tensile load produced by function and interfragmentary friction prevents displacement by shear forces, the fracture will remain immobilized. Bone compression can theoretically be maintained for weeks to months, thereby aiding bone healing between the fragments. The biological and mechanical advantage of compression for fracture healing is that it allows stability for primary bone healing process to happen, and it allows for the load sharing between the implant and bone permitting function. Compression may be achieved with a screw or a combination of a screw and plate. In the craniofacial area the mandible is the primary bone to benefit from fracture compression. In the midface and orbitocranial region compression is not necessary and is technically difficult to achieve. Onlay and inlay bone grafts are best fixated with compression if possible.

Compression with a screw (Fig. 55–2) can be achieved using the "lag screw" technique developed by woodworkers. Ideally the screw should cross the fracture plane at a perpendicular angle. The outer cortex or surface is drilled to create a "gliding hole" by overdrilling, thereby allowing the screw to only engage at the cortical surface–screw head interface; the second surface or cortex is drilled and threaded to create a hole that accepts the screw threads intimately. Placement of the screw then produces interfragmentary compression. The use of screws to produce compression is efficient; however, clinical situations

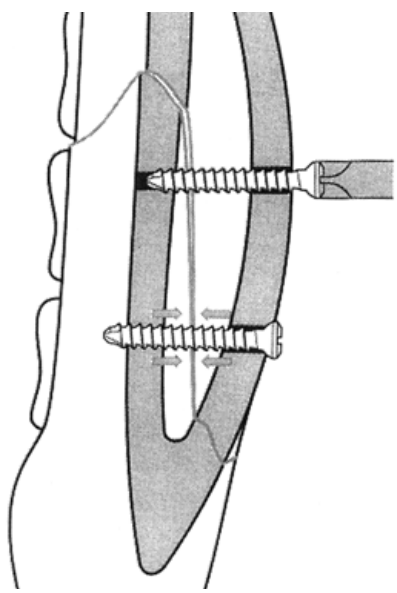

Figure 55–2 Compression of oblique mandible with "lag–screw."

usually require application of more than one lag screw or use in conjunction with a plate to overcome shear forces that cause fragments to distract in very oblique fracture angle.

Compression with a plate and screw (Fig. 55–3) is achieved by the combination of the design of the screw hole in the plate and the eccentric placement of the screw, which then allows interfragmentary compression in an axial direction when the screw is driven into the screw hole. Compression-plate screw holes are inclined horizontal cylinder shapes that permit the downward and horizontal movement of the screwhead. The screwhead engages the outer rim of the plate hole. The screw than glides horizontally toward the opposite (inner aspect) of the plate hole. The screw is also engaging the underlying bone, which is in turn moved toward the inner aspect toward the fracture line. Only one eccentrically placed screw is used on either side of the fracture line. The remainder of the screws are placed centrally so as not to produce additional forces that would counteract the compression or distract the fracture fragments. Complete reduction of the fracture occurs only beneath the plate and at the opposite side of the bone; a gap may result, necessitating the use of a tension band in the form of a small plate or dental splint.

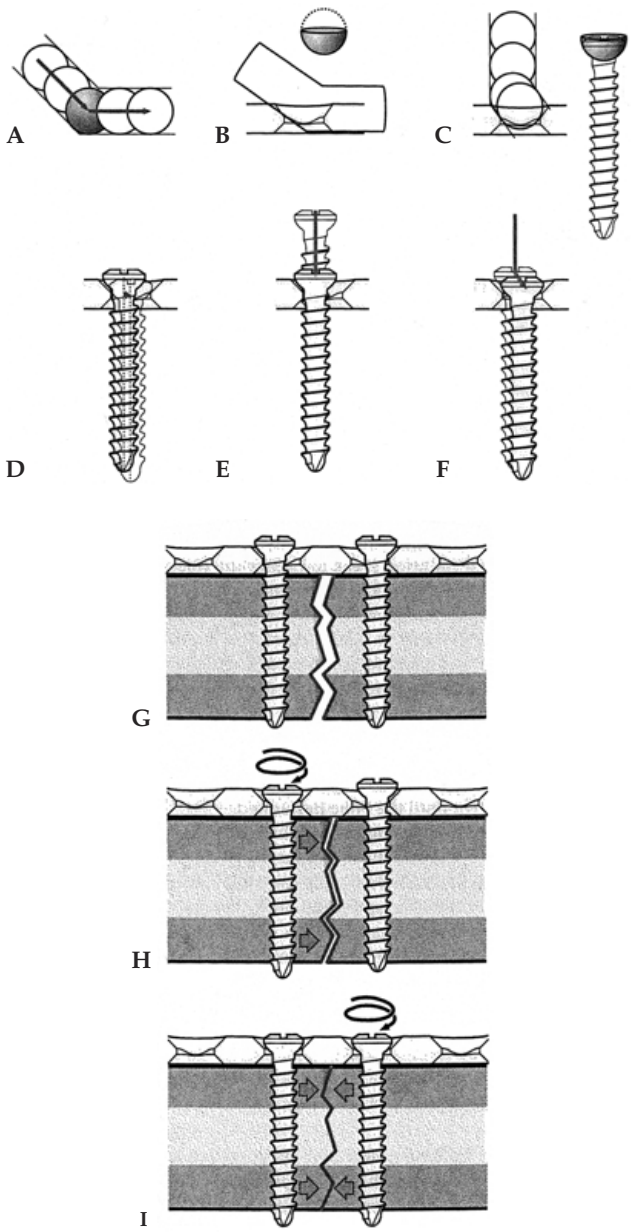

Figure 55–3 Compression with plate and screw **(A)** The screw head moves in the oval-shaped plate hole like a ball in an angled cylinder. **(B)** The screw hole is a section from of an inclined and a horizontal cylinder. **(C)** Movement of the screw head with its spherical undersurface in the DC hole of the plate. **(D)** The eccentrically placed screw arrives at the rim of the platehole. **(E)** As the screw is driven in, it glides within the platehole to its final position **(F)**. **(G)** The two innermost screws should be placed eccentrically within the DC holes. **(H)** As these screws are driven in, they approximate the fragments. **(I)** With final tightening of the screws compression is achieved.

Screws function as a basic element in conjunction with plates to hold bone fragments together. The correct selection and placement of screws are essential for the successful stabilization of fragments. Screws are designated according to the outside diameter of their thread. Figure 55–4 shows the basic elements of a screw. "Tapping" or creation of a recipient thread for the screw in the solid bone can be achieved by specific tapping instruments or by a "self-tapping" screw that has a specialized distal tip design allowing for the cutting and simultaneous placement of the screw. Screws impart vector forces to engage the plate downward toward the bone; an additional screw configuration used in mandibular plates is that of the "locking" screw head, which is an expanding screw head that locks the plate and screw together as one unit. The advantage is less loosening of mandible screws over the long term.

Plates have been designed in various configurations for craniofacial surgery. The adaptation of plates for specific sites, such as orbit, midface, and mandible, does not preclude maintaining the basic design to ensure stable fixation and screw placement. Specialized plates for compression and mandibular replacement share the same basic components.

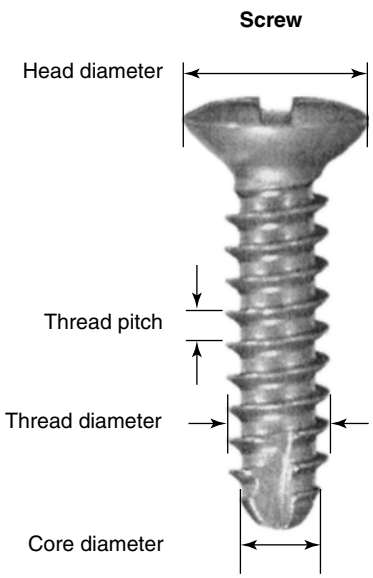

Figure 55–4 Basic elements of a screw.

SUMMARY

Principles of craniofacial bone healing are important to the facial plastic surgeon's basic knowledge. An understanding of bone biology allows for successful treatment of various clinical states. Fracture repair as well as reconstruction for oncologic or developmental pathologies requires application of these principles. The basics of bone formation and repair aid the surgeon in selecting appropriate and effective therapies. Further elucidation of the interrelationship between bone formation development, and wound repair will lead to newer techniques and treatment strategies.

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Chapter 56

Facial Plating Systems

Peter D. Costantino and Matthew Wolpoe

In 1968, Hans Luhr was the first to introduce the idea of plate fixation in the craniomaxillofacial skeleton when he used compression plating adapted from othopedic surgery to repair a mandibular fracture.[1] In the time since Luhr's innovation, plating of this region has become a highly reliable tool employing a complex combination of technique and technology. This is due in large part to the understanding of the mechanical forces affecting various areas of the craniomaxillofacial skeleton coupled with the fabrication of specialized hardware. The metals now used for rigid internal fixation have physical and mechanical properties that maximize both stability and flexibility while minimizing corrosiveness and tissue reactivity. Current plating systems are adaptable to a wide variety of skeletal defects as well as having reduced size and visibility. However, regardless of the type of plates employed, it is essential that the craniomaxillofacial surgeon have an understanding of the principles of rigid internal fixation. The purpose of this chapter is to describe the various plating systems now available, the principles guiding their application, and the basic indications for their use.

HISTORY AND DEVELOPMENT OF RIGID INTERNAL FIXATION FOR THE CRANIOMAXILLOFACIAL SKELETON

Hansmann is credited by most as the first person to apply the concept of rigid internal fixation (RIF) when he used a metal implant in 1886 to repair a defect in the extremities. However, numerous technical difficulties prevented this method of skeletal stabilization from being practical until the latter half of the twentieth century.[2] In 1949, after years of basic science research, Danis, a Belgian surgeon, advanced the previously unrecognized concept that bones immobilized by rigid internal fixation devices could heal primarily.[3] In 1958, a group of 15 Swiss surgeons under the direction of Maurice Miller formed the Association of Osteosynthesis and the Association for the Study of Internal Fixation (AO and ASIF). These groups went on to perform many ground-breaking experiments using RIF in the extremities. On the basis of this research, the AO and ASIF derived four basic concepts that they deemed essential to rapid recovery of form and function with RIF. These principles were (1) anatomic reduction of bone fragments; (2) functionally stable fixation of the bone fragments; (3) preservation of the blood supply to bone fragments by utilization of atraumatic surgical techniques; and (4) early, active, and pain-free mobilization.[4–6]

Incorporating these principles, RIF soon became a widely employed method for treating traumatic injuries in the extremities. Although this is true, adapting these techniques to the craniomaxillofacial skeleton proved more difficult. Finally, after years of experimentation, Hans Luhr successfully adapted the AO and ASIF rigid fixation principles to treat mandibular fractures in 1968. Luhr, concurrently with Shenck and Willenegger, solidified the earlier theories of Danis and showed that it was possible to achieve primary healing in rigidly fixed bone ends. In 1973, Michelet devised the second of the two currently used major plating philosophies.[7] Unlike the AO and ASIF, which is based on the idea that bone ends should remain tension-free during the healing process, Michelet proposed that some forces could be beneficial. He essentially introduced the concept of "stress shielding," where the prevention of the transfer of forces to bone across a site of osteosynthesis could be deleterious to the healing of that bone defect. Michelet rationalized that in the physiologic process of osteosynthesis, bone formation occurs along lines of stress. Therefore, Michelet designed a miniplate system that allowed micromotion at the fracture site. Three classic experiments done by Champy in 1976 verified the soundness of Michelet's theory. The first experiment evaluated physiologic forces in freshly prepared cadaver mandibles.[8] This experiment showed that plating devices could withstand the masticatory forces and functional loading present at mandibular fracture sites. The two subsequent experiments by Champy et al expanded on these principles in the clinical setting.[9–11] Later, with the use of smaller plating systems with lower visibility, Champy showed these principles to be applicable to the midface.[12]

Despite these advances, rigid internal fixation of the craniomaxillofacial skeleton did not gain wide popularity until the 1980s. Contributing to this surge in popularity was the development of smaller plates and screws, including the newer microplating systems for infants and children.[13] In the early 1990s, Eppley pioneered the use of resorbable plating systems for use in the adult midface, as well as in infants and children.[14] Eppley's work in children was born out of studies by Yaremchuk and others, which found that metallic plating systems could limit growth and potentially be extruded from the growing craniomaxillofacial skeleton.[15] As a result, the first commercially available plating system, composed of poly-L-lactic and polyglycolic acid became available in 1996

(Lactosorb, Walter Lorenz Surgical Corp., Jacksonville, FL). The culmination of these efforts and the refinement of available materials have made plating of the craniomaxillofacial skeleton a widely employed and effective method for achieving reduction and *primary* union of fractured bone ends as well as bone grafts in the postablative setting.

ANATOMIC CONSIDERATIONS

The craniomaxillofacial skeleton is not a homogeneous entity, but rather is composed of bones of different sizes and thickness exposed to a disparate array of forces. Therefore, it is helpful to have an understanding of these differences to facilitate proper application of RIF equipment in the most efficacious anatomic location.

Mandible

Perhaps the region of the craniomaxillofacial skeleton exposed to the greatest amount and variety of stresses is the mandible. This is the result of its primary role in both mastication and articulation of speech, which expose the mandible to a great many torsional, compressive, and tensile forces. The masticatory forces of the mandible are generated by its shape, the position of the teeth, as well as the insertions of the major muscles of mastication. These factors are distributed in such a way that tensile forces are felt at the upper border of the mandible and compressive forces at the lower border. This concept is critical to an understanding of the requirements of plates applied for mandibular reconstruction. A line separating the anatomic regions subjected to these various forces, known also as the *ideal line*, is the plane where compressive forces equal tensile forces, and is located at the base of the alveolar processes just under the root apices (Fig. 56–1). In addition to these tensile and compressive forces, in the region anterior to the canines, the mandible is subjected to a variety of torsional forces as well.

Besides the forces of mastication, screw-and-plate application must take into account the location of the apical processes of the teeth and the position of the inferior alveolar nerve that runs within the mandibular canal. By the same token, it is important to understand that the cortex of the mandible is of varying depths throughout its length. Specifically, posterior to the third molar the cortex is thickest at the inferior border, and anterior to it at the upper border. Furthermore, there is also thick cortical bone in the region of the chin. Knowledge of these various anatomic differences will allow screw placement and plate application in a geometry that maximizes their fixation strength.

Many of the previous principles were incorporated by a group of French surgeons who founded the Groupe d'Etudes en Biomecanique osseuse et articulaire de Strasbourg (GEBOAS). By recognizing the physical properties of the mandible, this group sought anatomic reduction, complete and stable fixation, as well as painless mobilization of this structure. GEBOAS proposed that because of the force distribution and presence of the mandibular canal, specifically in the dentulous mandible, it is necessary to place plates beneath the alveolar canal near the inferior mandibular border. Furthermore, they maintained that because the upper border of the mandible is subjected to distractive tensile forces, it is necessary to use a "tension band" to allow a good reduction. The concept of the tension band is also fundamental to successful internal fixation and stabilization of the mandible. Finally, GEBOAS maintained that in the area of the mandible anterior to the mental foramen, where torsional forces are greatest, it is wise to use both a subapical plate and a plate at the lower border of the mandible to achieve a sufficient reduction.[2]

Despite the fact that the plating principles put forth by GEBOAS are still employed, it was later found that use of a tension band can be avoided in situations where eccentric compression plating is used. This system utilizes oblique compression holes, set at an angle of approximately 75 degrees from the main axis of the plate. By orienting the screw holes in this manner, compression is applied at a vector such that it counters the tensile forces present at the upper border (Fig. 56–2). As a result, it is possible to position eccentric plates below the mandibular border and achieve both a good reduction and stable fixation, without the use of a tension band.

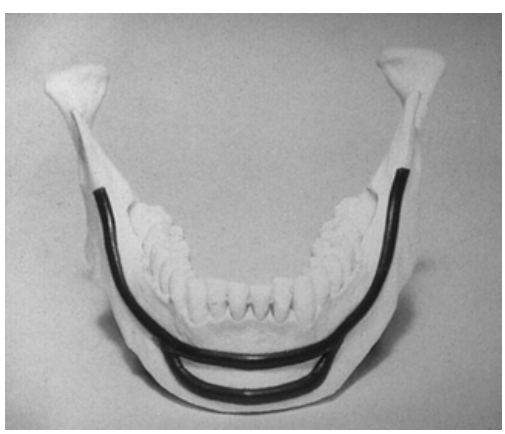

Figure 56–1 Model of mandible with depiction of the ideal line.

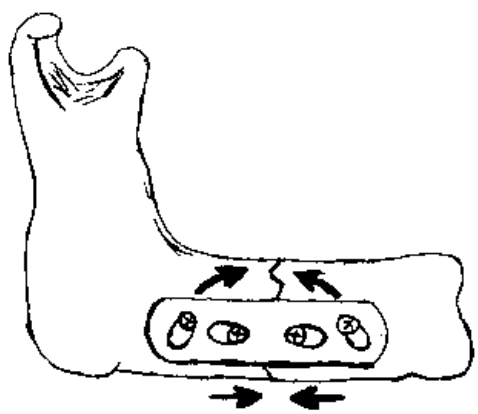

Figure 56–2 Depiction of eccentric compression plating showing how orientation of oblique holes produces compression at upper border mandible when plate is placed below ideal line.

Midface and Upper Cranium

Although this region of the craniomaxillofacial skeleton is subjected to lesser forces than the mandible, various considerations must be kept in mind when plating in this region. The area of the midface most exposed to the tensile forces of mastication is the zygomatic complex, particularly due to attachment of the masseter muscle. Rigid fixation in this region must be sufficient to overcome these forces and stabilize the zygomatic buttress. In addition, in the midface only a finite number of anatomical regions have cortex of sufficient thickness to accommodate placement of screws. These include the cranium, nasal bone, orbital rim, zygomatic bone, and buttress as well as the piriform aperture. Although with newer, smaller microplating systems this tenet holds less true, anatomical variability should be kept in mind when contemplating reconstruction of the midface and cranial vault.

EQUIPMENT FOR RIGID INTERNAL FIXATION

Metals

There are a multitude of factors that must be considered when evaluating metals for use in craniomaxillofacial fixation. For fixation implants to be tolerated by the body they must be composed of biocompatible and immunologically nonreactive metals. By the same token, the metal must resist corrosion and breakdown to avoid adverse local tissue reactions and systemic toxicity over time. In addition, the metal must have sufficient strength and flexural resistance to stabilize the fractured bone ends and to maintain anatomic position in three dimensions with minimal projection above the surface of the bone. Furthermore, it is imperative that rigid internal fixation equipment be composed of a material that is somewhat malleable and therefore can be intraoperatively contoured to the skeletal surface to achieve a good reduction. Lastly, the metals used for plating should produce a minimal amount of scatter on computed tomography (CT) and magnetic resonance imaging (MRI). This allows accurate monitoring of fracture-healing, plate placement, and in the case of reconstruction following tumor ablation, evaluation for recurrence.

Although several materials have been evaluated for use in craniomaxillofacial fixation, currently only three metal alloys are widely used commercially: titanium, vitallium, and stainless steel. Stainless steel, which is primarily composed of iron with lesser amounts of chromium, nickel, molybdenum, and manganese, was first used in orthopedic surgery in 1926.[6,16] Steel is available in several forms on the basis of the ratio of the aforementioned materials; however, the austenitic form, which minimizes corrosion and scatter on radiograph, is the primary form used currently for rigid fixation. Although stainless steel is still used on a limited basis, it has fallen out of favor and been replaced by titanium and vitallium, which have more favorable mechanical and physical properties such as the ability to osseointegrate with adjacent bone (Fig. 56–3).[17]

Scientists have appreciated the favorable qualities of titanium for a variety of purposes for several hundred years. However, it was not until the 1950s that an effective extraction and purification system for this metal was developed. Titanium, which is available primarily as an alloy mixed with small amounts of aluminum and vanadium, has found widespread use in craniomaxillofacial fixation. Primarily, titanium's success as an implant material is due to its remarkable biocompatibility and resistance to corrosion. In addition, it is a remarkably light material that possesses high tensile strength. Furthermore, titanium produces minimal scatter on MRI and CT scans. Despite these positive attributes, of the three currently used metals, titanium has the lowest elastic modulus, which necessitates use of thicker implants to yield the same degree of stability as other alloys, such as chromium-molybdenum and stainless steel.

Figure 56–3 Histologic preparation showing ossseointegration of bone into a titanium metal plate.

Vitallium is a metal alloy used in the Luhr Maxillofacial Plating System (Stryker Corporation, Kalamazoo, MI) and is composed of cobalt and chromium with small amounts of molybdenum, nickel, and tungsten, and occasionally other elements. Vitallium has a biocompatibility and susceptibility to corrosion similar to that of titanium. In contrast, vitallium possesses a much higher elastic modulus and is 1.5 times stronger than titanium, making it similar in strength to stainless steel. This allows vitallium plates to be thinner, with less visibility, than most other metals. Despite this fact, it is important to recognize that these vitallium plates produce significantly more radiographic scatter on CT scans than the larger titanium plates (Fig. 56–4).[18,19] Although this is true, vitallium was the metal alloy used originally by Luhr for mandibular compression, and because of its numerous favorable mechanical and physical properties it remains a highly popular metal for rigid fixation today.

Screws

Screw Characteristics

The properties of the screw used for rigid fixation determine much of the holding power and stability of the plating unit. There are several components of the screw that may impact its

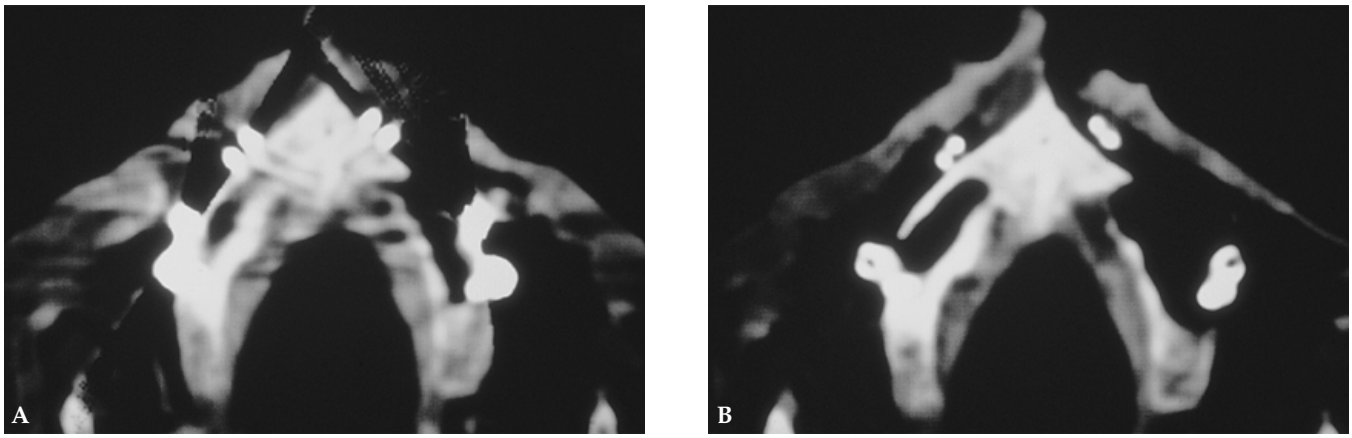

Figure 56–4 CT scans comparing degree of radiographic scatter produced by vitallium **(A)** versus titanium **(B)** implants.

ability to provide this stability. These include the size and shape of the screw head, the length and diameter of the screw, the pitch and width of the threads, as well as the presence or absence of flutes. The height of the screw head and, in part, the shape of the screw hole determine the visibility of the screw. Specifically, thinner, flatter screw heads result in less vertical dimension than thicker, more conical screw heads. Therefore, screw heads of this type are less likely to be palpable in regions with limited soft tissue coverage. In addition, there are numerous types of slots available for screw heads that accommodate different styles of screwdrivers. These include hexagonal, cruciate, single, or Phillips slots. The shape of the slot determines both the axial pressure necessary for screw insertion as well as its tendency to strip. Phillips slots have the highest axial pressures and therefore require the most force to secure the screw head during insertion. In contrast, hexagonal slots have low axial pressure and are applied more easily than Phillips slots but also have a greater tendency to strip. Cruciate slots have low axial pressure and low risk of stripping, making this an effective screw design.[20,21]

External screw diameter and thread width in large part determine holding power. However, studies have shown that outer screw diameters greater than 2.0 mm do not improve the stability of screws in thin cortical bone.[2] The pitch of the threads determines the amount of bone purchase per turn. However, in thin cortical bones, especially those of the midface, a large pitch means in essence that only one or two threads may engage the cortex after insertion, making the screw potentially unstable. Therefore, when screws are designed for rigid fixation equipment, one must try to maximize screw purchase and holding power, (i.e., microplates have threads with a smaller pitch than standard plates relative to screw size).

Another factor that varies depending on the type of screw is whether or not it requires tapping or placement of a pilot hole prior to screw insertion. In contrast to screws requiring holes, self-tapping screws have three cutting flutes at their tips. These screw flutes shave bone of the internal surface of the screw hole as the screw is turned into the hole. This avoids binding and accumulation of bony debris in the screw hole, thus decreasing purchasing power. The disadvantage of self-tapping screws is that the cutting flutes reduce the tension at the head of the screw and therefore must extrude through the bone edge to achieve the same degree of stability as a pretapped screw. In addition, these screws also require more torque for placement and therefore risk stripping during insertion.

Lag Screw Osteosynthesis

Lag osteosynthesis refers to a method of screw placement where the screw only purchases the distal bone segment as it crosses a fracture line (Fig. 56–5). This allows compression of the two bone ends toward one another, thereby holding these fragments in stable union. The compression results from the force that is generated as the distal bone segment (which is caught by the screw threads) is pulled against the screw head, thereby trapping the proximal segment of bone between those two points. The main indication for the use of lag screws, which can be used with or without an intervening plate, is for sagittal fractures caused by shearing forces. Lag screws work best in an environment with thicker cortical bone and therefore are useful in almost any region of the mandible. Although the midface has thinner cortical surfaces, lag screws still may be used in selected situations, such as the periorbital and subnasal regions.[22,23]

There are a number of technical considerations when employing lag screw osteosynthesis. First, when implanting

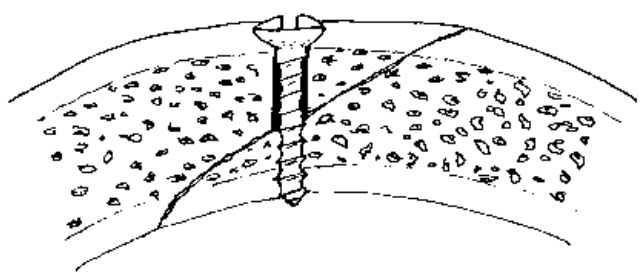

Figure 56–5 Lag screw osteosynthesis. Notice that the hole in the proximal fracture segment does not engage the screw threads, whereas the distal segment does.

a lag screw across an oblique fracture, the two bone fragments are first held in motionless continuity using modified towel clips (bone reduction forceps). Next, the proximal segment is drilled utilizing a bit as wide as the outer diameter of the screw to be implanted. The ideal angle of this hole is said to be found by drawing two imaginary lines, one perpendicular to the bony surface and the other to the oblique fracture, and drilling the hole halfway between them. Most surgeons contend that good compression can be achieved by simply drilling at a 90-degree angle from the fracture line. After a hole has been drilled through the proximal segment, a guide is inserted to protect the canal. Next, the distal segment is drilled using a bit the size of the core diameter of the screw to be inserted. If the drill hole in the proximal segment is too small, then the screw threads will engage the proximal bone segment and nonunion of the two fragments will occur. This is analogous to screwing in a bolt utilizing a washer and a nut. In this setting, screwing in the bolt will advance the nut and washer toward one another, thereby achieving compression. However, if two nuts are used on the same bolt, then these nuts will move in parallel and no compression will occur.[22] Overall, it is generally accepted that for wide sagittal fractures a lag screw alone will suffice, whereas for short sagittal fractures an intervening plate may be necessary to achieve an adequate reduction.

Emergency Screws

Included in all commercially available plating systems are emergency screws that can be used in the event that the initial screw stripped the bony cortex during insertion. An emergency screw is simply one that has an *inner* or core diameter that is equal to the *outer* diameter of a *regular* screw that was initially inserted. This allows rescue of a screw hole that has been stripped and thus avoids loss of that screw placement site, which can be critical in certain situations.

Plates

Prior to the use of plates, it was customary to wire fractured bony fragments together (Fig. 56–6). Although this practice still has its indications, it has been shown that rigid internal fixation with plates promotes superior healing, and in contrast to wire interfragmentation, allows *primary* union of fractured bone fragments. *Primary* healing is defined as direct healing across a site of osteosynthesis without a gap or deposition of osteoid (immature bone). When this type of union occurs, there is no chance that fibrous healing will occur. In contrast, *secondary* osteosynthesis is defined as healing by deposition of osteoid at a fracture site and its subsequent remodeling into mature bone. In this situation, there is the potential for fibrous healing and instability as a pseudoarthrosis. Thus, depending on the local environment during the healing process, metallic implants may be incorporated or osseointegrated into surrounding bone, or may remain nonintegrated and become a nidus for pseudoarthrosis (Fig. 56–7).

Primary union is not possible with wires because with these fixation devices it is only possible to reduce motion in two dimensions; therefore, rotational and torsional forces still occur. By using plates and screws, with the caveat that at least two screws must be used on either side of a fractured segment, macromotion in three dimensions can be prevented. This allows the bone fragments to be held in close continuity in a relatively motionless environment, thereby encouraging healing by *primary* union.

There are several types, shapes, and sizes of plates that are now commercially available. These plates vary in size and configuration based on different indications and location of implantation. From a practical standpoint, it is very important to be familiar with the various categories of plating systems, along with their primary indications. This will ensure the best possible reduction and will maximize healing and minimize morbidity.

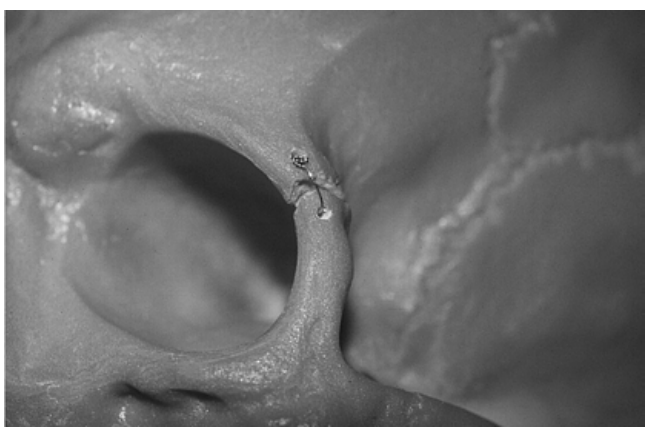

Figure 56–6 Interfragmentary wire fixation.

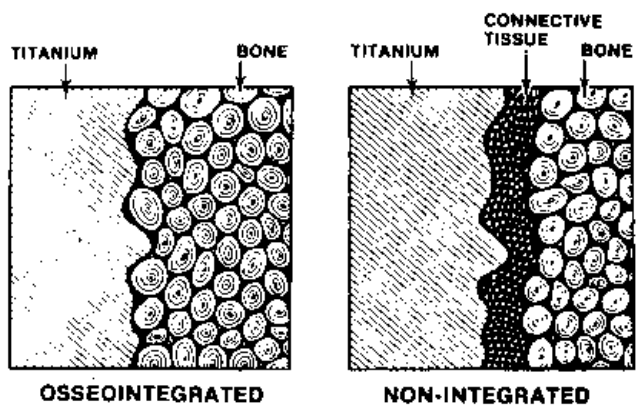

Figure 56–7 The local environment as well as reactions to metallic implants in large part determine the success of a reconstructive procedure. On the left is depicted successful integration and primary healing of a titanium implant. In contrast, on the right the titanium implant has failed to integrate and therefore a stable reduction cannot occur.

Compression Plates

Danis was the first to advocate the use of compression plating to reduce the incidence of fractured bone fragments.[3] It was shown later by Luhr that with compression it was possible to achieve primary union following mandibular fractures.[1,24,25] As the name implies, compression plates are designed to apply a reducing force to close the gap between two fractured bone ends. This compression produces a preload, which counters the functional loading forces that promote distraction of fractured bone ends. In addition, if adequate compression is achieved, a frictional force is also generated between the two bone ends that reduces torsional and translational motion.

Compression is achieved by using the "spherical gliding principle." The compression plate has oval holes and is configured in such a way that the smaller end of the hole is too small for the upper portion of a conical screw. Therefore, if the screw is inserted at the smaller end of the compression hole, as it is advanced it will become progressively larger and thereby move toward the larger end of the hole. By advancing in this manner the screw forces the two bony segments to slide toward one another and achieves compression (Fig. 56–8). On a standard compression plate there is usually a compression hole on either side of a fracture segment as well as a round or neutral hole. However, some plates may have two compression holes on either side, allowing for greater tension. In addition, it is possible to use compression plates in a neutral fashion if the screw is applied at the larger end of hole in the compression plate.

In actuality, there are two types of compression plates: dynamic compression plates (DCP) and eccentric dynamic compression plates (EDCP). DCPs were designed to achieve compression in a plane perpendicular to the plate itself. However, when using DCPs on the inferior border of the mandible, it is often necessary to use a tension band across the upper (alveolar) border to avoid distraction of fractured bone segments during mastication.[26] This is because in the dentulous mandible, as a way of protecting teeth roots and the inferior alveolar nerve, it is necessary to place plates at the inferior border of the bone. Therefore, there is a tendency for the tensile forces of the superior mandibular border to distract fracture bone ends. This makes placement of a tension band at the level of the teeth necessary to achieve a good reduction. A tension band can consist of either a miniplate along the alveolar border of an edentulous mandible or an arch bar segment attached to the teeth adjacent to the fracture site.

In contrast, EDCPs were designed to counter these distracting tensile forces when placed at the inferior mandibular border. This is achieved by utilizing two types of compression holes. The inner compression hole is the same as that in dynamic compression plates and achieves tension in a plane perpendicular to the plate, along the lower mandibular border. However, the outer holes of these plates have compression holes placed at oblique angles. These oblique holes are oriented in a manner that promotes compression along the superior mandibular border, thus obviating the need for a tension band. Although this is true, it should be noted that EDCPs are much more technically demanding to use and therefore are not favored by most surgeons.

Compression plates are indicated in edentulous mandibles for virtually all types of fractures, with the exception of highly comminuted fractures, fractures of the condylar neck, for fixation of bone grafts, or in highly atrophic mandibles. In these cases, a mandibular compression plate or titanum hollow-screw reconstruction plate system may be necessary (see the following). In dentulous mandibles, compression plates are indicated in displaced fractures of the mandible, fractures of the mandibular body and temporomandibular joint, moderately comminuted fractures, when maxillomandibular fixation is not desirable, and in cases of polytrauma.[26,27] In the midface, where there are fewer masticatory forces and thinner cortices, the indications for compression plates are much narrower. However, these plates can still be used in complex fractures of the zygoma and periorbital region, as well as following craniomaxillofacial trauma.[27]

Mandibular Reconstruction Plates

The mandibular reconstruction system (MRS) was described by Reuther in 1975 for functionally stable bridging of mandibular defects in the postablative setting (Fig. 56–9).[28] The plates are constructed to maximize strength with a low modulus of

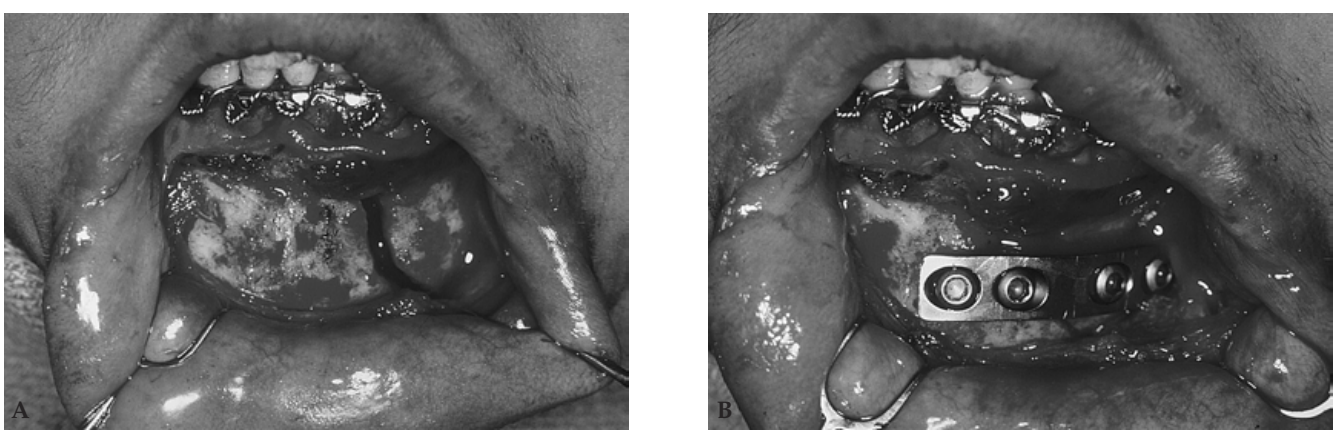

Figure 56–8 Reduction of displaced fracture of mandibular body. Application of compression plate reduces larger gap in body of mandible **(A)** to produce a good occlusion with aid of a tension band **(B)**.

Figure 56–9 Mandibular reconstruction plate bridging a postablational mandibular defect.

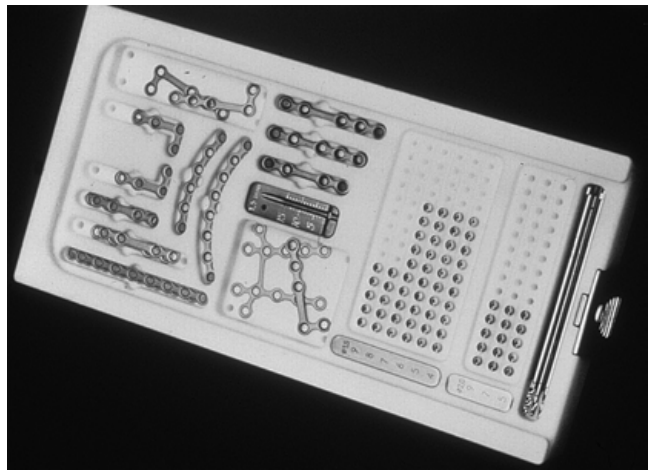

Figure 56–10 Miniplates for Luhr vitallium maxillofacial system.

elasticity to maximize stability and compression. The plates are either straight or curved and have two neutral and two compression holes on each side. It is felt that this configuration provides the greatest overall holding power. It should be remembered that when applying plates of this type, the compression holes and screws are always placed first, followed by the neutral holes. If this is not done, compression will not result.

There are three main indications for the MRS: alloplastic bridging of mandibular defects following tumor ablation, reduction of highly comminuted mandibular fractures as in shotgun wounds, and rigid fixation of bone grafts. The MRS is particularly suited for situations where long-term mandibular fixation is required and in injuries involving the mandibular symphysis.[27–29] When applied for these indications, the MRS provides support for the tongue as well as structures of the oropharynx and larynx. Often when using MRS, maxillomandibular fixation may also be indicated, at least for the short term. Furthermore, it is imperative when using the MRS plates that bicortical fixation be used, that the plates be contoured exactly to the defect to be bridged, and that four screws be used on each side of the injury. This avoids the high tendency for these types of injuries to result in distraction and nonunion. Though monocortical fixation has been described as effective, we believe that bicortical stabilization is intuitively superior and should be used by the most "nonexpert" operators.

Miniplates and Microplates

Although traditional plating systems were found to work well in the mandible and for limited indications in the rest of the craniomaxillofacial skeleton, they proved too bulky for use in the majority of midfacial injuries, the cranial vault, or in infants and children. Miniplates, first introduced in 1973 by Michelet, followed soon after by Luhr, Champy, and Wurzberg, thereby widened the indications for rigid internal fixation of the craniomaxillofacial skeleton.[7,29] Miniplates are now widely accepted and employed for a variety of applications.

When compared with traditional sized plates and screws, miniplates are thinner and have lower profile screw heads (Fig. 56–10). Therefore, these plates can be used in areas with minimal soft tissue covering. Miniplates are available in compressive and noncompressive forms. Although they may be used in most mandibular fractures, their use is contraindicated in highly comminuted fractures or those in which delayed healing is expected. In terms of the midface and cranial vault, miniplates are available in a variety of shapes for the fixation of fractures in a wide variety of locations. Nevertheless, most contend that these plates should be used primarily in areas subject to masticatory forces, such as the frontonasal region, as well as the zygomatic and sphenoid buttresses. Miniplates also provide a good reduction of complicated midfacial fractures including Le Fort fractures. In addition, miniplates may be used in most fractures in children, especially those in teeth-bearing regions. Furthermore, these plates have enjoyed wide use in general orthognathic surgery.[29]

Microplates, which, as their name implies, are smaller with even less visibility than miniplates, represent the newest technology employed for craniomaxillofacial fixation (Fig. 56–11). Though very useful, miniplates can still be seen beneath the thin skin of the midface (periorbital region) and forehead.[30] Anything thicker than 0.5 mm and placed below the dermis can be seen in these areas. As a result, microplates were developed. Though not usually visible, microplates can frequently be palpated beneath the skin's surface.

Whereas larger plates and screws are needed in areas subject to forces of mastication, several areas of the craniomaxillofacial skeleton are not subject to such stresses and may be repaired with microplates. These include midfacial fractures at sites other than the zygomatic buttress, nasoethmoid fractures, fractures of the infraorbital area and of the frontosinus wall, and skull reconstruction. In addition to these situations, microplates are particularly efficacious in the repair of fractures in areas with minimal soft tissue covering,

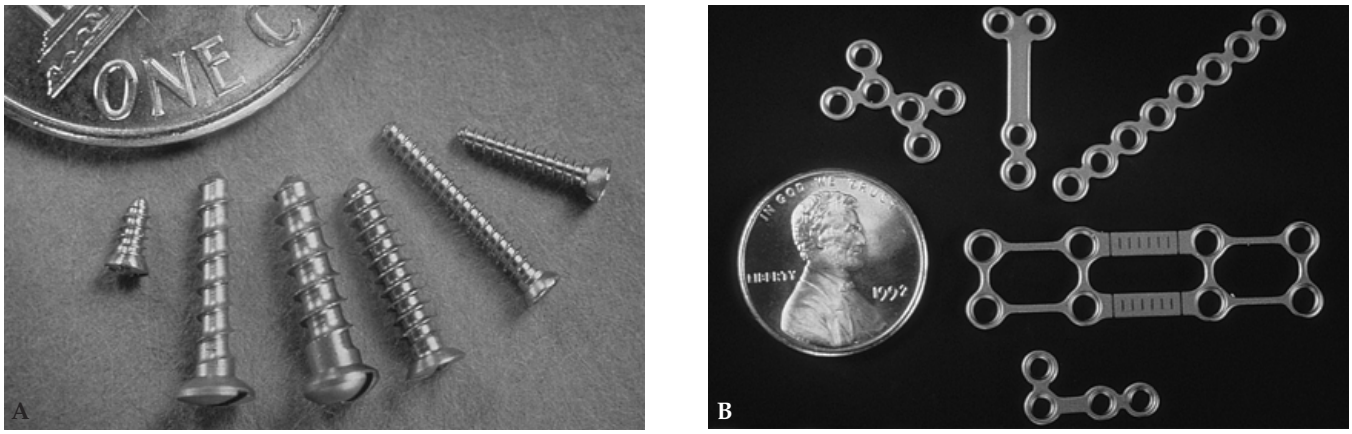

Figure 56–11 Microscrews **(A)** and microplates **(B)** with penny for size comparison.

such as the glabellar region, as well as in infants and small children.[29] From a technical standpoint when using these plates, as with traditional mandibular plates, it is necessary to place two screws on either side of the injury as well as to achieve good contouring of the plate to the defect to be reduced.

Three-Dimensional Plates

Although these plates are some of the newer adjuncts in rigid internal fixation, they have gained wide popularity and have been used for a variety of indications (Fig. 56–12). By design these plates offer a great stability in both horizontal and vertical dimensions. This feature offers distinct advantages when a variety of defects are being repaired. This is especially true in the mandible, which is exposed to a disparate array of forces requiring support in multiple directions to achieve proper occlusion. When used in the mandible, the three-dimensional plates are capable of countering both distractive and torsional forces to produce a stable reduction. This type of fixation is particularly useful in the region of the mandibular body, which is exposed to more of these forces than any other region of the mandible.

In addition to mandibular reconstruction, three-dimensional plates have demonstrated utility in the midface and upper cranial vault. This is especially true in the orbital floor, where a stable reduction is essential to avoid herniation of orbital contents. Specifically, three-dimensional plates can be used after orbital blow-out fractures, as well as in the postablation setting to rigidly fix bone grafts. In addition to the orbital floor, three-dimensional plates are used for rigid fixation of heavily comminuted fractures of almost every part of the craniomaxillofacial skeleton. This is because in these

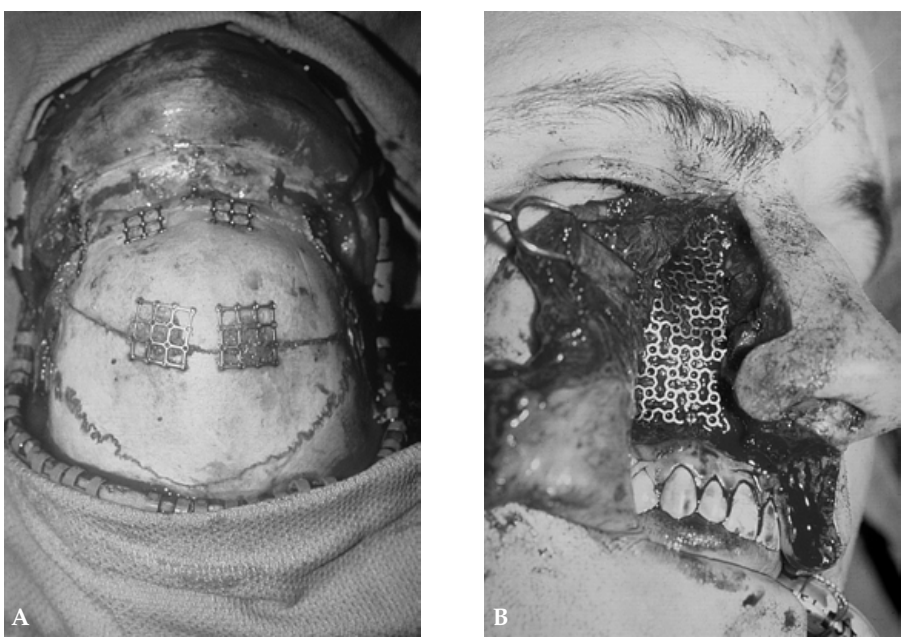

Figure 56–12 Uses of three-dimensional plates. These plates have many uses, including repair of large or comminuted calvarial **(A)** and orbital **(B)** defects.

situations there are multiple distracting forces that can cause instability if sufficient support is not generated by the plating unit. As the three-dimensional plates offer stability in multiple directions, they are ideally suited for these types of defects.

Ancillary Equipment

A variety of equipment can be employed to achieve a proper reduction of fractured bone ends (Fig. 56–13). This includes a plethora of tools besides the plates and screws themselves. Among these are screwdrivers that accommodate specific head types, including Phillips, hexagonal, cruciate, and simple slots. In addition, some screwdrivers have a sleeve designed to pick up the screw in the box and hold it until insertion is complete, allowing the surgeon to maintain a free hand (Fig. 56–14A). Depth gauges are designed to measure the depth of a hole to facilitate insertion of a screw of the proper length. Taps are threaded instruments with the same dimensions as the screw in a particular kit that are designed to cut grooves into the bone hole into which the screw threads will fit for screws without self-tapping flutes. Drill bits are available in several sizes depending on the particular kit, with diameters that correspond to the inner diameters of the screws to be inserted. These bits are often used in conjunction with a guide so the drill head does not wobble during insertion. When wobbling is allowed to occur during drilling, an irregularly shaped screw hole is created that will ineffectively engage the screw head.

There are several devices designed to bend and shape plates to correspond to the three-dimensional configuration

Figure 56–13 General ancillary equipment for use in Wurzberg titanium system.

Figure 56–14 Various pieces of ancillary instrumentation. Screwdriver equipped with sleeve to allow screw placement with one hand **(A)**; Tin template for a mandibular reconstruction plate **(B)**; Three-dimensional plate benders demonstrating protection of screw hole shape during manipulation **(C)**.

of the fracture site. However, before this occurs a template is commonly used as a guide by which to mold the plate into the dimensions of the fracture site. These devices are usually composed of tin, which is malleable but also maintains its shape after bending. To mold the plate into the necessary configuration, first the template is applied to the fracture site and molded into the necessary shape. Then, using plate benders and the template as a guide, the plate itself is conformed to the dimensions of the fracture site (Fig. 56–14B). There are several different types of plate benders available, and which one is used depends on the plate to be bent and the preference of the surgeon. These include bending irons that are designed to work in pairs; flat, pronged, and side-bending pliers; as well as 90-degree bending pliers. In addition, there are bending pliers with a post, and three-pronged pliers designed to protect the shape of a hole during the three-dimensional bending process (Fig. 56–14C). Most kits also include a plate cutter in case a fracture requires fixation with a plate size that is not included in the kit. By the same token, most rigid fixation kits also include instruments designed to hold bone in a motionless and reduced state during plate-and-screw application. These include towel clip–like, bone-holding forceps, bone-holding clamps, reduction/compression pliers, and reduction/compression pliers with side rollers (for applying tension on the alveolar border of the mandible when a tension band cannot be placed).

PLATING SYSTEMS

Several different plating systems have been developed to date. Usually each system is marketed by more than one commercial dealer. The following section gives a general description of the equipment that is included in various systems marketed by the major plate fabrication companies.

Luhr Vitallium Maxillofacial Systems

Luhr developed an extensive plating system for broad indications including a mandibular compression system, a mandibular reconstruction system, as well as miniplates and microplates. Taken as a whole, the equipment of the Luhr system is sufficient to address almost all fractures within any region of the craniomaxillofacial skeleton. As stated previously, the Luhr maxillofacial system is composed of vitallium, which is one and a half times stronger, but produces three times as much scatter as titanium plates used in other systems. Therefore, although the Luhr plates are smaller than those of other systems, they produce more radiographic distortion (Fig. 56–15A, B). All Luhr systems are currently sold by Stryker-Leibinger Corporation (Kalamazoo, MI).

The Mandibular Compression System (MCS) has plates composed of vitallium that are either straight or curved, and each has two eccentric compression and two neutral holes. The straight plates are mainly applied to fractures of the mandibular body, whereas the curved plates are generally indicated for fractures involving the mandibular angle. Also included in the MCS kit are three-dimensional plates that are designed to reduce the occurrence of multiple mandibular fractures.[27,28] Like DCPs the three-dimensional plates provide compression perpendicular to the angle of the fracture site and therefore require placement of a tension band to achieve a good reduction. The screws in the MCS are self-tapping and designed for bicortical insertion.

The minisystem was developed mainly for implantation in the mid-face and cranial vault. The plates are smaller and have lower profile than the mandibular plates and screws, and can be used with or without compression. These plates are available in a variety of shapes, including straight, curved, L, T, and double-T. The screws are self-tapping and have a flat head that fits into the countersink of the plate to reduce vertical profile.

The MCS microsystem is mainly indicated in areas not subject to masticatory forces, and for use in infants and small children. As in the other Luhr kits, the screws are self-tapping but have a much narrower diameter. By the same token, like the screws in the minisystem, the screws in the microsystem have flat heads and are designed to fit into the countersink of the plate hole to minimize vertical profile. The plates for the Luhr microsystem are straight or T-, L-, or H-shaped. Also in

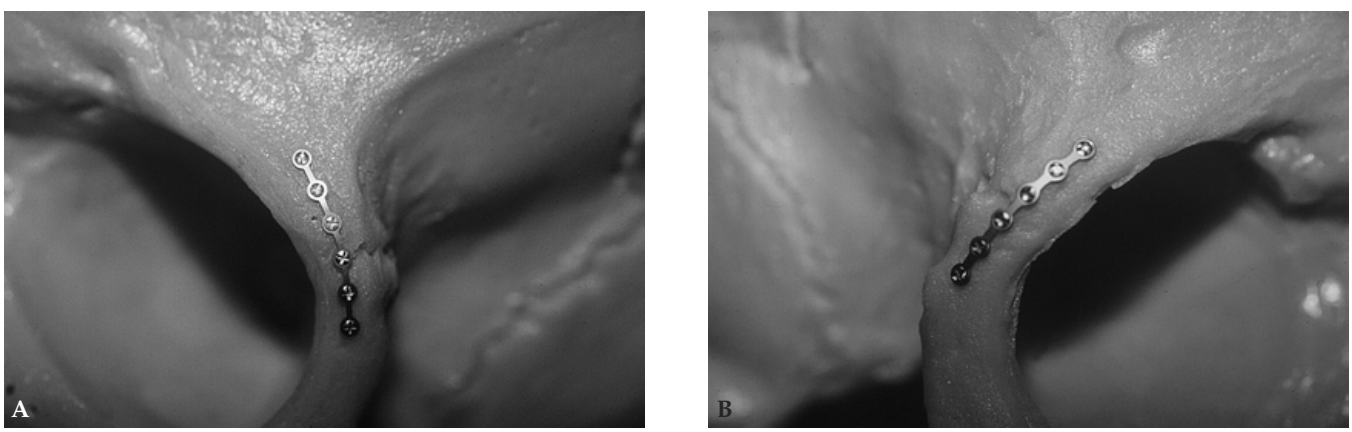

Figure 56–15 Depiction of difference in profile between plates made with various metals. Notice that vitallium plates **(A)** have a significantly smaller profile than the larger titanium plates **(B)**.

the microsystem kit is micromesh, which is mainly used in periorbital reconstruction.[30]

The Wurzberg Titanium System

Similar to the Luhr system but composed of titanium, the Wurzberg system (Synthes Corp., Paoli, PA) is based on the adaptation of principles of rigid internal fixation of the long bones to the mandible, and later to the midface. Included in the Wurzberg system is a compression plate system, a mandibular reconstruction system, a miniplate system, and a dental implant system. The compression plate system has several indications but it is used primarily for badly comminuted mandibular fractures, fixation of bone grafts, and for anticipated delayed healing.[29,31] The screws for this system are designed to be bicortical and can be pretapped (recommended for highly comminuted fractures) or self-tapping. The system includes both DCPs and EDCPs and is available in either curved or straight configurations.

The MRS is used primarily for stable bridging of bone segments in the postablation setting. The screws for the MRS are pretapping, with conical heads, and are available as straight as well as right- or left-angled plates. The plates have two compression and two neutral holes on each side but also can be used for neutral plating when fixing an implant in place.

The miniplate system, which was designed based on the work of Champy, is intended for use in the upper margins of the mandibular region of the alveolar crest as well as in the midface. The screws are self-tapping and have a flat head with a single slot that fits within the screw hole in a manner that minimizes screwhead visibility. The miniplates are designed for three-dimensional deformation and are available as straight, T, right and left L, Y, X, and complexly shaped plates.[29,31]

The Champy System

There are two original schools of thought that developed in parallel with regard to rigid fixation of the craniomaxillofacial skeleton. The first plating philosophy extrapolates the AO and ASIF principles originally intended for fixation of long bones for use in the craniomaxillofacial region. The main principle of this system is that any extrinsic forces that are present at a fracture site are potentially disruptive. As a result of this, the rigid fixation system must assume all of these stresses and strains, thereby keeping the fracture site absolutely motionless.[4–6] In contrast to this school of thought, Michelet in 1973 developed a craniomaxillofacial plating system based on the notion that in the course of normal osteosynthesis bone is laid down along lines of stress.[7] Therefore, he maintained, it is unnatural to maintain absolute rigidity at the fracture site. He proposed that if properly channeled, micromotion in this region would encourage primary union in planes that maximize bone stability. Among the proponents of Michelet's principles was Champy, who developed a rigid internal fixation system composed of titanium for fixation of mandibular fractures. In the Champy system, as in other systems, the miniplates have minimum profile and are available as straight in a variety of sizes, as well as in Y, T, and L shapes. More recently, the Champy system has come to include separate plates specifically designed for fixation of orbital fractures, sagittal split osteotomies, and mandibular reconstructions. The screws for the Champy system are monocortical, self-tapping with conical heads. The head of the screw is designed to accommodate insertion at a maximal angle of 30 degrees from the bony surface, thus maximizing hold while allowing nondistractive micromotion to occur.[32]

AO and ASIF System

As mentioned previously, the AO and ASIF system is based on extrapolation of principles of rigid internal fixation of the long bones for use in the craniomaxillofacial skeleton. Therefore, the system relies on the principle of "absolute stability," meaning it is designed to assume all forces transmitted across the fracture site. Included in this system are plates and screws designed for mandibular compression, mandibular reconstruction, and application to the midface and the rest of the cranium. All components are composed of stainless steel or titanium.[4–6]

Two types of plates are used in the mandible: linear and reconstruction. Linear plates are designed either as EDCPs or as DCPs. To achieve eccentric plating, the EDCP plates are equipped with oblique holes set at a 75-degree angle from the bony surface. The reconstruction plates are available in straight or curved shape and are designed for three-dimensional bending. Screws for the mandibular system are bicortical, with hemispherically shaped head with a hexagonal recess, allowing angling of the screws with respect to the bone surface. The screws have no flutes and therefore must be pretapped.

All equipment in the AO and ASIF craniofacial system is composed of titanium. This system is indicated for use in the craniofacial skeleton and for orthodontic applications. The plates for this system are designed for three-dimensional bending to accommodate the disparate regions of the cranium and upper face.[5] Also included are plates designed for use in the orbital floor, which can be cut and molded in a variety of configurations to achieve good stability in this region. The screws for the AO and ASIF craniofacial plating system are self-tapping with a conical tip. They have a low-profile hemispheric head and a cruciform slot to allow angulation of the screw head with the bone surface.

Titanium Hollow-Screw Reconstruction Plate System (THORP)

It has long been noted that as a consequence of natural bony remodeling screws lose stability over time. Therefore, in situations where a long-term reduction is necessary, normal screws may prove inadequate. As a result of this, in 1987 a new system of screws was developed to optimize mechanical and physical forces necessary to achieve a long-term reduction. Indications for this system include complex fractures of the mandible where long-term reduction is needed, and for reducing postablation mandibular defects.[33–34] However, because the THORP system is significantly more expensive than traditional rigid internal fixation systems, the added expense is not justified for the plating of simple fractures in which rapid healing is likely.

Overall, it is the screws of the THORP system that make it unique. These screws are designed to disperse local stresses and strains over a maximal area, to inhibit completely any micromotion at the screw plate interface, and to encourage maximal osseointegration of the fixation device. Inclusively, these properties give the THORP system many of the same advantages as an external fixation device. The THORP screws

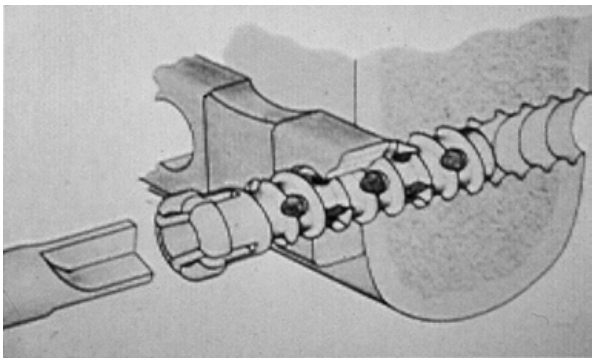

Figure 56–16 Depiction of insertion of titanium hollow-screw reconstruction plate system (THORP) screw into bone. Notice that the shaft of the screw is hollow to allow osteointegration and that the screw head accommodates an expansion bolt to reduce micromotion at the screw–bone interface.

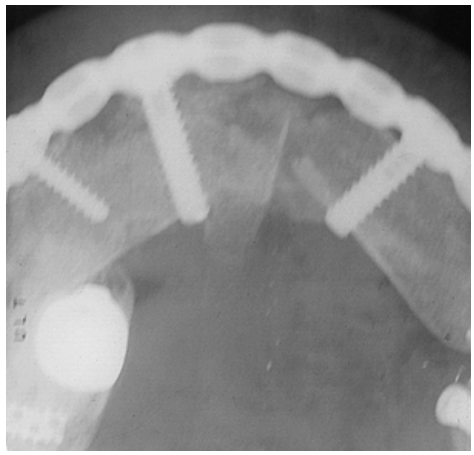

Figure 56–17 Radiograph showing differences in shape between THORP and traditional screws.

are available in two basic types: a normal full-bodied titanium screw and a perforated, hollow, argon-coated screw (Fig. 56–16). The screws are designed with a small thread pitch to allow maximal holding power, even when used in thin cortical bone. Although this is effective, a high bone to metal ratio is preserved by decreasing the overall thread depth. The screw is also equipped with lateral perforations and is coated with argon. This facilitates bony ingrowth into the screw, which produces great long-term stability (Fig. 56–17).[35] Furthermore, the hollow screw head is expandable and accommodates an expansion bolt that is inserted after the screw has been tightened in place. This produces complete rigid fixation of the screw head and minimizes motion at the screw–bone interface. In contrast to the THORP screws, the normal titanium full-body screw is indicated when the surgeon intends to initiate early screw removal.

Although it is the THORP screws that account for most of the long-term stability of this system, the plates also have physical properties that contribute to this longevity. One such property is that the THORP plates were designed to evenly disperse the force of functional loading throughout their length. This in theory should increase the plate strength and its ability to achieve a long-term reduction.[35] These plates are available in a variety of sizes, and several shapes, including straight and curved, can be used with a temporomandibular junction endoprosthesis.

Resorbable Plates and Screws

Although metal plating systems are the standard of care and have proven effective over the last several decades for a variety of clinical applications, they do have some disadvantages. First, metal plates are inherently permanent, and as a result there is concern about their long-term safety in infants and children. Specifically, there has been concern that these systems may limit growth when implanted into the immature craniofacial skeleton or erode through the calvaria into the intercranial space. Although the results of animal studies done by Yaremchuk and others have shown overall that metallic plates provide modest growth retardation if placed at suture sites, they have been associated with other problems, such as translocation into the inner table of the calvaria, and extrusion.[15] In addition, despite the advent of smaller plates and screws, because children have a limited quantity of subcutaneous soft tissue covering in many portions of the skull, metallic plates and screws are often palpable or even visible below the skin. In a slightly different vein, in the adult, while growth is obviously not an issue, there may be situations where short-term reductions are necessary, making resorbable plating systems an attractive option. In addition, there are areas of the adult craniomaxillofacial skeleton where soft tissue covering is limited (e.g., the glabellar region), and therefore metallic screws may be palpable below the skin surface.

Based on these concerns, a great deal of time and effort have been invested in the development of resorbable plating systems. Resorbable plates and screws are intended to provide the same stability and support for fractured bone segments as permanent implants while undergoing resorption over time. In 1971, Cutright and Hunsuck were the first to report experimental use of resorbable fixation devices in the craniofacial literature. These authors constructed sheets composed of polylactic acid (PLA) and used them to repair blowout fractures in rhesus monkeys.[36] The first clinical study done with resorbable plates was done by Roed-Petersen in 1974, who reported unfavorable results with PLA plates in two patients with complicated fractures of the mandible.[37] Salyer et al were among the first to examine the effects of resorbable plates in a pediatric setting.[38] They compared the outcome of facial plating using either titanium or a commercially available resorbable plating system in growing beagle dogs. Salyer and colleagues found that at the conclusion of the study the bioresorbable plates and screws had been entirely resorbed, leaving no residua or scar tissue, while providing the same degree of support as the titanium plating system. Since then, Eppley has performed a plethora of animal and clinical studies that have demonstrated the utility of resorbable systems, primarily in the growing craniomaxillofacial skeleton.[14]

Overall, while complications have been reported with the newer resorbable systems, these systems seem to offer several of the advantages of metal rigid fixation while forgoing many of their shortcomings. The resorbable plates and screws facilitate primary bone healing, allow three-dimensional control while

not interfering with radiologic imaging. Furthermore, because resorbable plating systems are eventually broken down by the body, they do not restrict long-term growth and drastically reduce the risk of translocation to the inner table of the calvaria. With continual refinement of bioresorbable materials these devices are quickly becoming the treatment of choice for internal fixation of facial fractures in the pediatric population.

The main commercially available resorbable system is Lactosorb (Walter Lorenz Surgical Corp., Jacksonville, FL). However, a number of other companies are positioned to commerically produce similar bioresorbable systems in the near future. The Lactosorb system is composed of 82% PLA and 18% polyglycolic acid (PGA). According to the manufacturer, the plates and screws maintain 70% strength at 6 weeks and are completely resorbed at 12 months. These resorbable plates and screws are normally degraded by hydrolysis into glycolic acid and lactate, which are incorporated directly into the citric acid cycle. Although this is true, it has been shown that if certain resorbable substances are not broken down by the body in this manner, a localized foreign body reaction can occur. This reaction can be so severe as to induce formation of a cyst, which can persist for as long as 3 years postoperatively. However, it should be noted that these outcomes were reported for resorbable plates composed of polyglycolide, not the PLA and PGA used in the Lactosorb system.[13]

The Lactosorb system is indicated in comminuted fractures of the nasoethmoidal and infraorbital areas as well as of the frontal sinus wall, in trauma and reconstructive procedures of the midface or craniofacial skeleton, in mandibular osteotomies and graft fixation, in browlift procedures, as well as in infant and pediatric craniofacial surgery. The Lactosorb system has a wide variety of plates available and also three-dimensional panels for repair of intra-orbital and some orbital floor defects (Fig. 56–18). The plates are available as straight, curved, T-, X-, or L-shaped. The Lactosorb plates are somewhat malleable but must be heated to the transition temperature of the material (approximately 60°C). This can be done using a commercially available heat pack (Biomet Inc., Warsaw, IA) into which distilled water is injected to initiate a chemical reaction. The plates are then immersed into the pack for 10 to 15 seconds, after which they can be easily molded into the necessary shape with a plate bender designed specifically for the Lactosorb system.

The resorbable screws used as part of this system are of two types: standard and suspension. The standard resorbable screws have almost identical dimensions as metal screws used for similar indications. The suspension screws are specifically indicated for endobrow applications and have an eyelet that can accommodate a suture for brow suspension. Overall, when used for the proper indications and with sufficient surgical experience, resorbable plates and screws have shown a great deal of efficacy. In addition, with further advances in biomaterials research, there is no doubt that resorbable systems will become available that possess holding power nearly identical to that of traditional metallic implants.

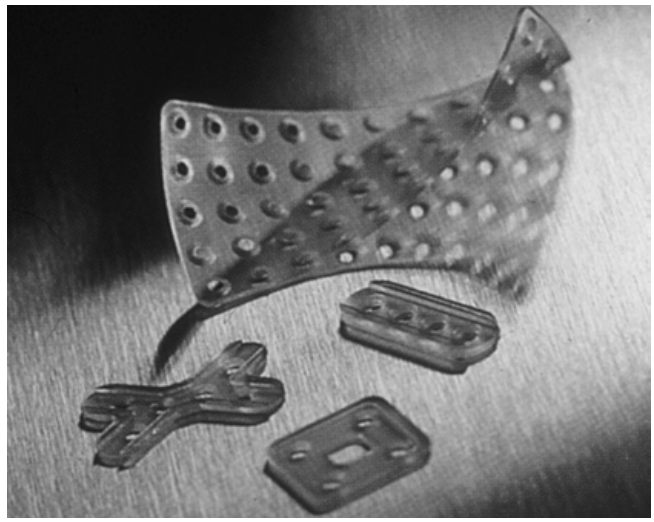

Figure 56–18 Resorbable mesh and plates for use with Lactosorb system.

SUMMARY AND CONCLUSIONS

Since its inception in the late 1960s craniomaxillofacial plating has undergone an impressive revolution in technique and technology. Currently available plating systems can be used to repair almost any type of defect in any area of the craniomaxillofacial skeleton. These systems have been shown to provide a superior functional and aesthetic outcome over the older interfragmentary wire fixation devices. This is the direct result of the ability of plating systems to provide three-dimensional control of fractures and other defects. Although metallic systems now dominate the market, resorbable plating systems are gaining wide popularity, especially for use in the pediatric population. Familiarity with the technique and the equipment used for rigid internal fixation in the craniomaxillofacial region is essential for proper application and maximal efficacy, and is best obtained with long-term exposure to the diverse clinical situations in which these devices are employed.

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Chapter 57

Clinical Applications of Bone Plating Systems to Facial Fractures

Robert M. Kellman

Whether repairing fractures, fixing osteotomies, or reconstructing skeletal defects, the goal of the surgeon is to effect a bony union as rapidly and dependably as possible with limited morbidity and complication rates. Recent experience indicates that rigid skeletal fixation, when properly applied, is most likely to achieve these goals. There are numerous plating systems in use today, each with its own unique designs, instruments, plates, screws, and metals. Yet all systems have in common the following central principle: a screw screwed into a bone can remain tight and withstand functional stress over time. With this demonstrated, the following three principles support the various methods of rigid fixation in use throughout the craniofacial skeleton: (1) overlapping bone fragments can be screwed together stably with lag screws; (2) stability of fixation can be increased when fragments are compressed together with compression plates; and (3) plates screwed to bone fragments maintain and replace the structural integrity of damaged bone, even across a significant gap (bony defect). These principles form the foundation for the successful use of any bone plating system.

Initial attempts at plate fixation failed because of a lack of understanding of the biomechanical principles involved in bone repair. The earliest attempts at rigid fixation in facial bones were in mandible fractures, where improper plate positioning resulting from a lack of understanding of the tension and compressive forces acting on the mandible in function resulted in instability and, frequently, infection and failure. These failures were misunderstood and were thought to be due to excessive stability failing to provide the motion needed to effect bone healing. This misconception was corrected by research in orthopedic surgery. It was found that failures were due to inadequate (rather than excessive) stabilization. With a better understanding of the dynamic forces acting on bones, more stable fixations and high success rates were achieved. It was then some years before the biomechanical principles upon which proper stabilization of mandible fractures depends were elucidated. In the last two decades, facial plating techniques have gained wide acceptance as the advantages of rapid and effective healing with early function have become commonplace.

BONE HEALING

Although osseous healing has been addressed in Chapter 54, a few comments are appropriate here. Bone healing depends on the stabilization of fractured or osteotomized fragments. Whether guided by medical intervention (e.g., cast, splint, fixation device) or allowed to occur spontaneously, bone healing generally ensues. Healing depends on the growth of osteons across the fracture or defect so that the injury is bridged by new bone. This new bone remodels in response to physiologic stresses, and healing is complete. However, motion disrupts the growing osteons. The body therefore produces a callus that stabilizes the fragments, allowing osteon growth and healing to proceed. The callus is nature's rigid fixation device. Casting and splinting [e.g., mandibulomaxillary fixation (MMF)] and even interosseous wiring and external fixation partially immobilize the fracture and guide the position that the fragments will be in when the callus stabilizes them. If the degree of motion is too great or if infection intervenes, stabilization may not occur at all, and the gap may widen and fill with fibrous tissue. If this occurs, a nonunion (fibrous union, pseudarthrosis) frequently results. A pseudarthrosis, as its name implies, is essentially a fibrous union, and motion occurs where the bone fragments are held together by fibrous tissue, thus creating a "false joint" or pseudarthrosis.

When bone injury occurs, bleeding results in a fracture hematoma. Early ingrowth of blood vessels and fibroblasts begins the differentiation cascade of bone healing. The development of chondroblasts, the conversion of fibrous tissue to fibrocartilage, and ultimately the ingrowth of osteoblasts that lay down osteoid result in callus formation.[1] This process begins subperiosteally on either side of the fracture, and the callus grows across from both sides, bridging and stabilizing the fracture. The same process is repeated across the fracture site. Finally, osteons grow across this area, and remodeling completes the healing process. This natural process, like surgically assisted healing, is dependent on the ability of the callus to stabilize the fragments, which in turn allows for the ultimate bridging of the fracture by bone. If the forces acting on the fragments are so great that stabilization cannot occur, ultimate bony union will be unlikely. Furthermore, in the absence of surgical guidance, even if healing does take place, it will often be in a poor anatomical alignment (malunion). [Note that although remodeling in response to stress can result in normal bone strength, it will not correct a malocclusion, a problem unique to malunions (malpositions) of mandibular and maxillary fractures.]

Rigid fixation techniques are designed to stabilize the fractured fragments, thereby increasing the likelihood that bony union will take place (in the correct position) and minimizing the chance for nonunion. As mobility leads to callus formation, the greater the stability of the surgical fixation, the less callus

that develops. Though microscopically there is always some callus formation, when a very rigid fixation is accomplished there will not be enough callus to show on x-ray. Therefore, the finding of a callus at the fracture site on radiographic evaluation of a patient after surgical repair has been used as an indication of inadequate stabilization of the fragments.

APPLICATION OF RIGID FIXATION TECHNIQUES TO MANDIBULAR FRACTURES

Occlusion

In any discussion of facial bone repair, a discussion of occlusion must take a central role. Regardless of the stabilization techniques used, the surgeon must reestablish occlusal relationships between mandibular and maxillary dentition before repairing fractures of the related bones. MMF is generally applied before fracture repair, and the occlusion is periodically assessed to make certain that a malocclusion has not been created by osseous repositioning and repair. When a malocclusion is detected, the bones should be repositioned because a rigidly fixed malocclusion will not be improved by healing and bony remodeling. Proper occlusion is necessary for function; therefore, establishing a proper and functional occlusal relationship should be the priority in all but the severest of traumas. This generally means that if the appropriate position cannot be defined, use of a less rigid fixation (e.g., MMF alone) should be considered. When severe disruption of bone makes healing unlikely without rigid fixation, then the need to achieve healing and prevent infection may sometimes take priority over establishing the exact occlusion. This difficult and controversial clinical decision must be made by the facial plastic surgeon at the time of repair. Note that screws can be used for establishing occlusion. Two screws can be placed in the maxilla and two in the mandible, and wires can be tightened around these, thereby establishing MMF. Specially designed screws with large, protruding heads and holes through which the wires can be passed have been produced specifically for this purpose. Note that although this method is fast and simple, it is not an ideal technique because tightening of the wires tends to create lingual version of unstable fragments due to the buccal positioning of the fixation points.

Biomechanics

Proper use of rigid fixation requires placement of fixation devices so that immobilization of the fracture fragments is accomplished during motion as well as when the bones are at rest. The forces acting on the mandible are complex and variable, shifting depending on the site of the food bolus being chewed and the status of the dentition. To effectively stabilize the fragments, the surgeon must have some understanding of the forces of distraction that will be generated by muscle activity so that these can be overcome. Failure to accomplish this adequately can lead to motion around the implant during function. Not only does this increase the likelihood of implant failure and nonunion; it also increases the probability of wound infection and, ultimately, osteomyelitis. (The surgeon, believing that the plate has created stability, may be unaware that adequate fixation was never accomplished, and rigid fixation will be blamed for the failure.) Proper understanding of the biomechanics of the mandible in function will lead the surgeon to apply the appropriate number of plates of the correct size and strength in the proper position. When the forces of distraction are overcome by the fixation appliance, healing occurs most dependably and frequently, and the failure rate is kept to a minimum. Therefore, it is necessary to be familiar with the functional forces operating on the mandible in each anatomical area, and plate fixation techniques must be applied in each area to overcome the distracting forces and to take advantage of the naturally occurring compressive forces.

Most bones do not bear weight symmetrically, so that in function there are generally areas that are under pressure and areas that are under tension. Figure 57–1 is an extremely

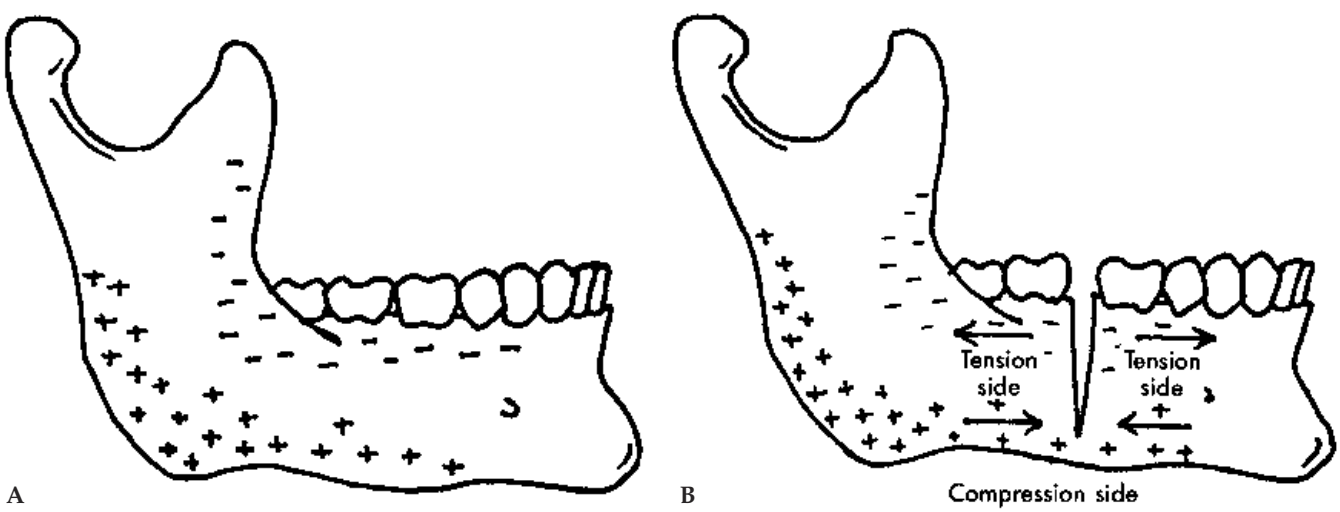


Figure 57–1 **(A)** Commonly accepted diagram of the forces of tension and compression occurring in the mandible in function. Minus signs indicate areas of traction or tension; plus signs indicate areas of compression. **(B)** The effects of tension and compression forces on a fracture occurring in the mandibular body. (This is a marked oversimplification, that nonetheless serves as an aid to proper fixation.)

oversimplified depiction of the forces affecting the mandible during chewing. In Fig. 57–1A, the plus signs indicate the compressive forces acting on the mandible during mastication and the minus signs show areas under tension. When a fracture occurs, these forces tend to distract the tension side of the fracture, whereas the fragments will be compressed together at the pressure side (Fig. 57–1B). Although this represents a markedly oversimplified description of the forces acting on the functioning mandible, the concept of tension and compression areas is fundamental to the proper placement of miniplates and compression plates for the repair of mandible fractures. This important biomechanical concept was first appreciated in the study of long-bone fracture repair.[2] Initially, it was thought that a rigid plate fixed to two pieces of bone with two fixation points in each fragment would create a stable fixation and prevent movement of the fragments relative to the plate and to each other. Early clinical failure in both the long bones and the mandible can be attributed to this misconception. Thoughtful analysis reveals that a rigid plate with two fixation points in each of two fragments can provide stability only if the forces transmitted to the plate and screws in functional loading are less than the strength of the plate and the forces holding the screws in place. When plates and screws of proper design and tensile strength are correctly positioned and applied according to biomechanical principles, stability is achieved and healing usually results. In fact, adequate plate and screw design was achieved early; proper plate positioning was understood later, when tension and compression forces were appreciated.

Using the femur as an example (Fig. 57–2), it should be intuitively apparent that weight bearing on the femoral head produces distracting forces on the lateral cortex and compresses the medial cortex. A plate placed on either cortex (across a fracture) holds the fragments together at rest, and a compression plate adds a positive (compressive) force across the fracture. In function, however, the distracting forces on the lateral cortex generally exceed the compressive forces of a medially placed plate; therefore, the dynamic forces vary from positive (rest) to negative (weight bearing). Screw loosening frequently results, and motion leads to nonunion and even osteomyelitis. On the other hand, when the plate holds the tension side together, distraction cannot occur unless a screw fails, and the compressive forces of weight bearing are added to any static compressive forces applied by the plate and distributed across the fracture. Although the forces across the fracture vary, they never become negative (distracting), and healing generally ensues.

It should also be apparent that the more biomechanically advantaged the repair, the less dependent it will be on the size and strength of the hardware. When repairing a fracture in an area of tension, so long as there is extensive bony contact in the compressive area and minimal torque on the fixation point, small fixation appliances (so long as they can overcome the distracting forces at the site of placement) will generally prove adequate. On the other hand, when large distracting and rotational forces are found in areas with weak bone or minimal contact areas between the fragments (as in the atrophic mandible), larger fixation devices will generally be necessary. The most extreme example is an area of bone loss, in which case the implant used (if no bone replacement is performed at the time of repair) must be large and fixed with large screws using multiple fixation points.

Armed with an understanding of the above principles, the reader should see why certain techniques of mandibular repair succeed and why others fail.

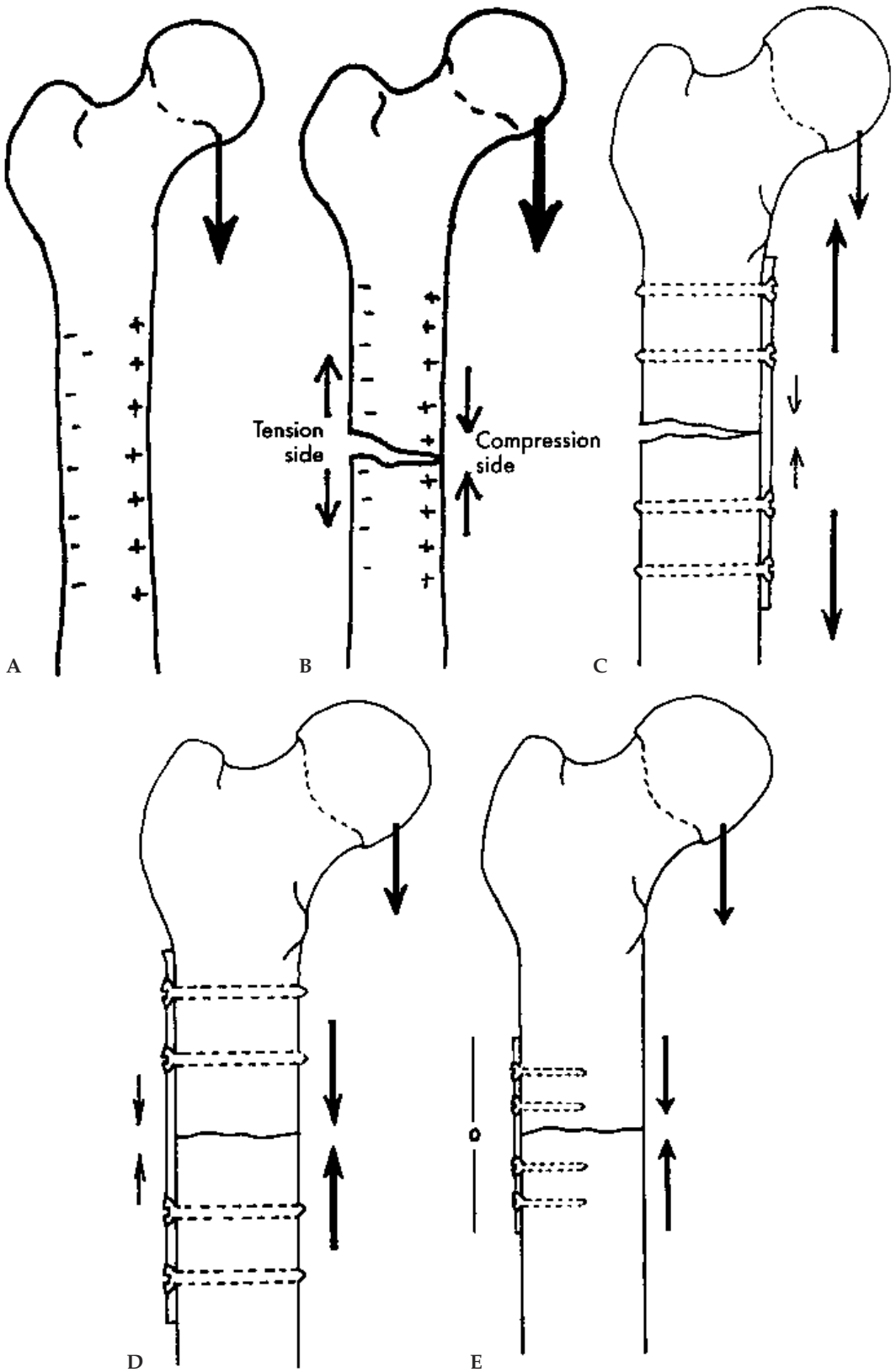
Arch Bar Fixation with MMF

It has long been thought that MMF splints the mandible in a fixed position and puts it at rest. This is not entirely true, and even swallowing generates large forces across the mandible. However, since a well-placed mandibular arch bar puts tension across the teeth, it holds the area of distraction together. If there is large bony contact, and the torsional forces are minimal, the mandibular arch bar creates enough stability to allow a callus to form, and healing results. Of course, the significant failure rate seen when MMF alone is utilized has led to a need for more dependable fixation techniques (along with a desire to avoid prolonged periods of MMF).

MMF with Interosseous Wire Fixation

Interosseous wire fixation was added to MMF in an effort to overcome the high failure rates seen when MMF was used for unstable fractures. When the wire repair was placed in the

Figure 57–2 The femur illustrates the effect of tension and compression forces on an intact and fractured bone. **(A)** It should be apparent that the weight-bearing force acting on the femoral head is positioned medially so that a compression force (plus signs) is directed along the medial side of the bone, and a distracting force (minus signs) is distributed along the lateral portion of the bone. In the absence of a fracture the full bone supports weight. **(B)** In the presence of fracture the force of weight bearing results in compression of the medial side and distraction of the lateral side. **(C)** Placement of a compression plate along the compression side will not overcome the stronger distracting forces of weight bearing. The small arrows represent the compression force applied by the plate, and this compression force is exerted across the fracture at rest. The large arrows represent the sum total force experienced across the fracture with weight bearing. Thus, a compression plate placed across the compression side of the fracture does not prevent distraction at the tension side. **(D)** In this case, the compression plate has been placed along the tension side of the fracture. Again, the small arrows represent the static compression force applied by the plate. The heavy arrows represent the compressive force across the entire fracture that results from weight bearing. The stenting of the tension side of the compression plate prevents any distracting force from acting across the fracture, and the sum total is a stronger compressive force. **(E)** Schematic representation using a miniplate. The screws are monocortical. The force across the fracture at rest is 0. However, this plate (if strong enough) will hold the traction side of the fracture together, allowing the force of weight bearing to act across the entire fracture as a compression force. (This is an illustrative diagram and does not represent a technique used for the femur in clinical practice.)


Tension side
Compression side
A
B
C
D
E

biomechanically advantaged tension areas of the mandible, success rates improved. However, when failures occurred, the presence of the wire frequently resulted in a foreign-body infection and osteomyelitis was common. Prolonged periods of MMF were also required and when delayed union occurred, MMF could be needed for as long as 6 to 12 months. Furthermore, although many surgeons believed that complex, basket-weave types of wire placement provided marked stability, the early work of Luhr[3] demonstrated the weakness of wire fixation—and even external fixation—compared with fixation with plates and screws (Fig. 57–3).

Miniplate Osteosynthesis

In an effort to improve techniques of mandibular fracture repair, Champy studied the biomechanics of mandibular fractures and found that a properly positioned miniplate can often take advantage of the dynamic compressive forces occurring in function.[4] A miniplate placed along the tension side of a fracture holds it together at rest without compression; under functional loading, when the fixation is strong enough to hold (i.e., to merely withstand the distracting forces), compression of the fracture fragments results (Fig. 57–2E).

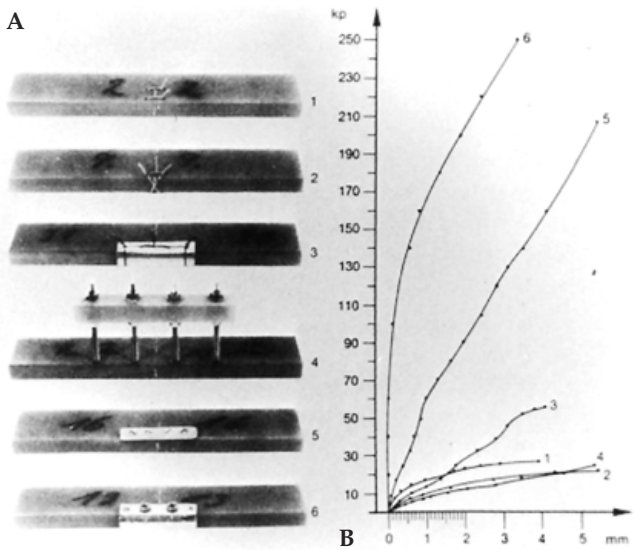


Figure 57–3 **(A)** Models of osteosynthesis tested. (1) Two parallel wire ligatures (wire thickness of 0.5 mm). (2) Horizontal wire ligature combined with figure-of-eight ligature. (3) Groove-shaped, 0.5 mm, stainless steel splint 38 mm in length attached with three 0.5-mm wire ligatures (similar to the method advocated by Haward, 1962). (4) Pin fixation as modified by Becker (1958). Four percutaneous osteosynthesis screws are connected by a 10 × 10 mm bar of cold-curing acrylic (Paladur). (5) Normal four-hole bone plate (Venable bone plate, 38 mm vitallium). (6) Compression screw plate (CSP), 38 mm. **(B)** Stability of different types of osteosyntheses under bending stress. Shown is the gap width between pairs of test pieces as a function of load. Even relatively small loads of 20 kP a lead to loosening of osteosyntheses 1–4 (gap widths, several millimeters). The usual screw plate system (5) is considerably more stable, but it is far exceded by a compression screw plate. (From Luhr HG. Compression plate osteosynthesis through the Luhr system. In: Kruger E, Schilli W (eds). Oral and maxillofacial traumatology. Vol 1. Chicago: Quintessence Publishing, 1982. With permission.)

The success of this approach for the repair of mandibular fractures depends on several factors. First, it is critical to determine where the miniplates must be applied to effect the stabilization necessary for healing. This was painstakingly accomplished by studying the lines of force generated by various miniplate fixation points, using araldite models to simulate mandible fractures. Using this approach, Champy was able to define the areas for miniplate fixation along the so-called ideal osteosynthesis line[5] (Fig. 57–4). This line corresponds to the line of tension along the mandibular body. From parasymphysis to parasymphysis, two miniplates are required to overcome the torsional forces affecting this area. Posteriorly, a single miniplate along the oblique line or below it was thought to be effective; however, Kroon[6] has shown that the forces in this area vary from positive to negative during function, necessitating the use of a second plate inferior to the first if dependable stabilization and healing are to be achieved. Whether to use one or two miniplates when repairing a fracture at the mandibular angle remains controversial. Levy et al[7] have shown that the complication rate when repairing mandibular angle fractures with miniplates drops from 26% when a single plate is utilized to 3% when a second plate is added. This is consistent with the findings of Kroon.[6] Ellis and Walker,[8] on the other hand, found a single plate not only to be adequate but to yield better results. However, he encountered a 16% complication rate in this group (compared to 28% when he used two miniplates), which is not as good as the 3% rate of Levy et al when two miniplates were used. Until this controversy is resolved, the author recommends the use of two plates if a miniplate technique is utilized to repair a fracture of the mandibular angle region.

With the ideal plate position identified, the osteosynthesis line overlying the inferior alveolar nerve and tooth roots remains a problem. The solution is the monocortical screw. A monocortical screw penetrates only the lateral cortex of the mandible, and great care is exercised to avoid deeper penetration into the alveolar nerve and tooth roots. When performing these procedures, the surgeon must be aware of the location of the tooth roots and of the inferior alveolar nerves. It should also be clear that the use of monocortical screws precludes the application of compression because compression plating puts pressure on the screw shaft at its entry point into the bone; the thin monocortical fixation of the screw to the bone will likely be inadequate to prevent shifting of the screw, which would lead to loosening and failure. Nonetheless, the plates and screws used must be strong enough to resist the distracting forces that occur in function. Two-millimeter mandibular miniplates are designed to overcome these forces, and, when properly applied, fixation failure is uncommon. However, many failures have resulted from the use of inadequate fixation, as may be seen when weaker plates designed for midfacial applications are applied to the mandible. The facial plastic surgeon must be familiar with the systems and must be sure to select implants designed for the particular indications for which they are being used. Similarly, the screws must be of appropriate size, strength, and number, and they must hold tightly in the bone. If a screw

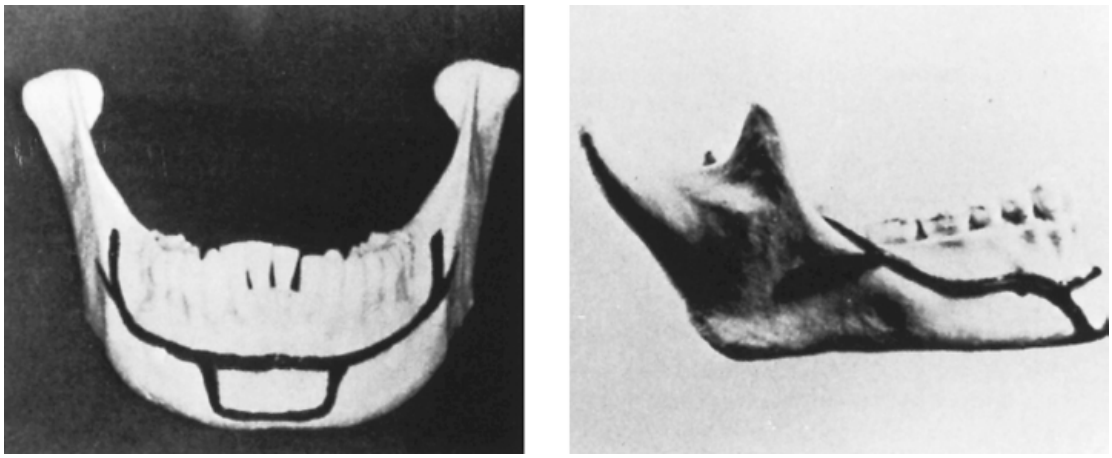


Figure 57–4 Ideal osteosynthesis line for mandibular body. (From Champy M, et al. The Strasbourg miniplate osteosynthesis. In: Kruger E, Schilli W, Worthington P (eds). *Oral and maxillofacial traumatology*. Vol 2. Chicago: Quintessence Publishing, 1985.)

hole strips during screw tightening, it must be abandoned, as it will not provide fixation. A larger ("emergency") screw may be utilized or the plate must be moved and new holes used. A variation of the miniplate technique is the use of the "3-D plate" applied along the line of tension as described by Farmand.[9] The 3-D plate is actually a miniplate that has been strengthened by being produced in geometric assemblies of squares and rectangles (Fig. 57–5). Although the plates are slightly more difficult to bend, the results using them have been excellent.

Compression Osteosynthesis

As the name implies, compression osteosynthesis involves the application of a force across the fracture such that the fractured fragments are compressed together by the fixation. Thus, at the time of fixation there is a compressive force between the fragments at rest. This is in contrast to miniplate fixation, in which case the bone fragments are held together without compression, so that compressive forces are only seen across the fracture during function (if the plate has been properly positioned and applied). Whereas it was originally believed by the proponents of compression plating that the compressive forces were necessary for direct bone healing, it is now clear that healing takes place quite dependably when neutral fixation is properly applied. However, compression certainly increases the area of bone-to-bone contact as well as the frictional forces between the fragments, so that the likelihood of successful healing, particularly in a complex and unstable fracture, is probably increased. Compression fixation may also be accomplished with lag screws, as will be described below. Note that when compression is applied across a fracture, the bone remodels under the stress to eliminate the force until the plate and/or screws are ultimately exerting no force on the bone. However, this remodeling is occurring during healing, so that a complete bony union has resulted by the time the force exerted by the fixation appliance has dissipated.

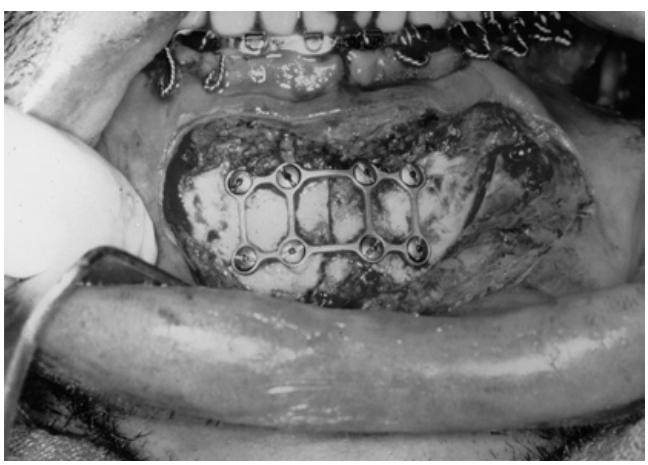


Figure 57–5 A mandibular symphyseal fracture repaired using a 2.0-mm geometrical plate. Note the similarity to two miniplates that are connected together, thereby creating greater fixation strength.

Compression Using a Plate

The technique for compression using a plate is described at the end of this chapter. As noted above, compression plate stability requires the use of bicortical screws (to prevent motion of the screws in the bone and failure of the fixation). Since the presence of the tooth roots and the inferior alveolar nerve prevents the placement of bicortical screws in the biomechanically correct position along the line of tension, compression plates are placed along the basal border of the mandible (below the inferior alveolar nerve). Despite the use of strong plates and large screws, this biomechanically incorrect positioning is frequently inadequate to overcome the distracting forces that develop across the fracture during function (Fig. 57–6), and, in fact, early experiences using this technique resulted in unacceptably high failure rates and frequent condemnation of the technique.

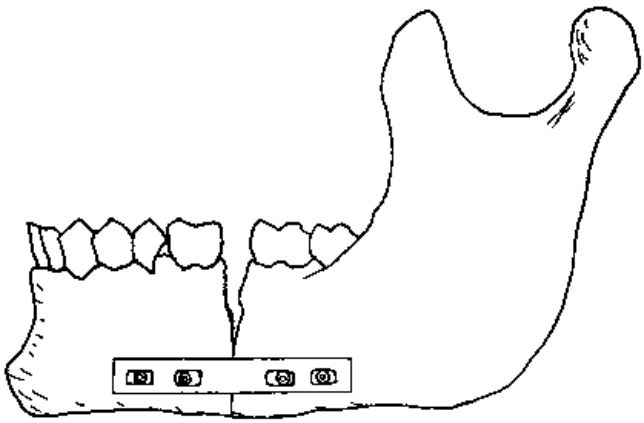


Figure 57–6 Diagrammatic representation of the effect of placing a compression plate across the basal border (compression side) of the mandible in the presence of a fracture. In the absence of a tension band across the traction side of the fracture, functional forces overcome the weak compressive forces applied by the plate, resulting in an unstable fixation and gapping of the alveolar portion of the fracture.

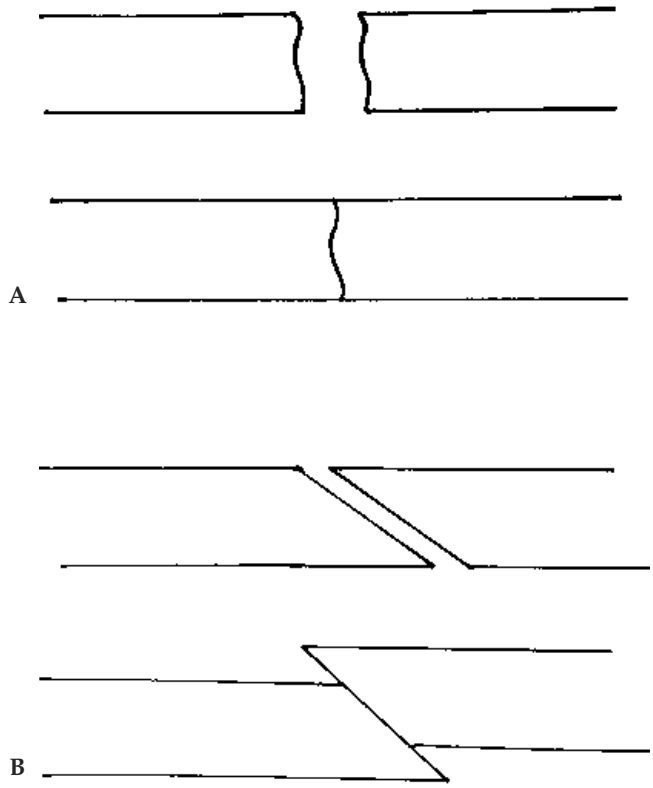


Figure 57–7 This shows why a compression plate is ineffective and harmful in the presence of an oblique or overlapping fracture. **(A)** The ends of the fractured bones abut each other and compression will be accomplished by a compression plate. **(B)** The oblique fragments overlap, and if an attempt is made to compress them, they will glide over each other, resulting in a malposition.

However, this problem was overcome by Spiessl with the use of tension banding.[2,10] A tension band is applied to hold the traction side of a fracture together. This is analogous to the miniplate applied along the ideal osteosynthesis line. Compression can then be applied to the pressure side without distracting the traction side. Furthermore, the compressive force applied will be distributed along the full length of the fracture. This compressive force increases the friction and contact between the fragments, thereby increasing the rigidity of fixation and the likelihood that bone healing will occur.

A tension band can be applied in several ways. When a fracture occurs in a dentulous area of the mandible, an arch bar attached to the teeth across the fracture line can serve as a tension band. This must be tightly applied so that distraction does not occur along the alveolar segment when compression is applied at the basal border. Behind the dentition, a plate can be placed above the level of the inferior alveolar nerve to serve as a tension band, and a compression plate can then be placed at the basal border. This is similar to the miniplate approach, and, in fact, a miniplate can also serve as a tension band for use in conjunction with a basally positioned compression plate for any mandibular fracture.

Compression Using a Lag Screw

The technique for using a lag screw is described at the end of the chapter. When fragments overlap (e.g., in an oblique fracture or sagittal split osteotomy), a compression plate tends to cause the fragments to glide past each other and override each other (Fig. 57–7). A lag screw, on the other hand, is placed through both overlapping fragments, thereby bringing the damaged surfaces together. Properly applied, a lag screw compresses these surfaces together, resulting in rigid fixation.

The key to the lag screw is that its threads bypass the first fragment and engage the second fragment. As the screw is tightened, the head of the screw cannot pass through the first fragment, so it pushes against the first fragment, thereby compressing it against the second fragment (Fig. 57–8). Compression fixation is thus achieved. If the screw engages the first fragment, fixation will occur without compression (Fig. 57–8A). When the screw exits the first fragment, the tip initially pushes the second fragment away slightly and then engages it. As the screw is tightened further, the threads hold in both pieces of bone, maintaining the gap between them unchanged. Tightening is complete when the head of the screw becomes firmly fixed in the first fragment, and thus compression is precluded. As the two fragments are held in a fixed relationship to each other, this is termed a "positioning screw." Positioning screws are sometimes used in sagittal split osteotomies to maintain a fixed relationship between the fragments and thereby avoid a shift in the position of the condylar head in the joint.

A single lag screw will not prevent rotation of the fragments around its axis. Therefore, when the lag screw is the only fixation device, two or three lag screws should be placed when feasible.[11] Note also that a lag screw can be used through a plate, but when this is done, any screws through overlapping fragments must be lagged, and all other screws must be neutrally applied (i.e., without compression) (Fig. 57–9).

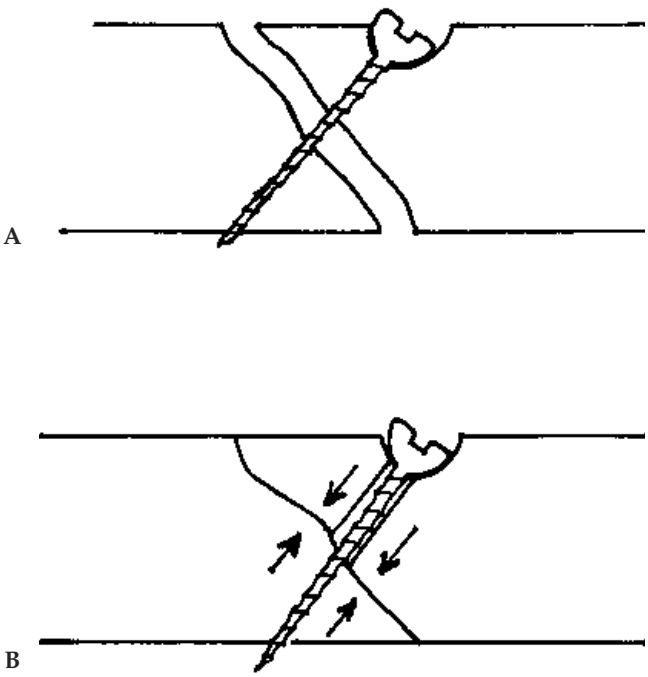


Figure 57–8 **(A)** The screw catches in both fragments of bone. The screw first passes through the first fragment and encounters the second fragment. Initially, it pushes the second fragment away and then the thread catches. The screw can then be tightened until the head is firmly positioned in the first fragment and can no longer progress. Because the screw threads are holding tightly in both fragments of bone, the gap between the two fragments will never be closed. **(B)** In this case, the threads will not catch in the first piece of bone because the hole has been overdrilled. When the screw passes through the first piece of bone, it will similarly hit the second piece of bone and push it away, and then the thread will catch. However, the screw continues to tighten until its head is compressed firmly against the first piece of bone. As the first piece of bone will not catch the threads of the screw, tightening results in compression of the first fragment between the head of the screw and the second fragment. Compression is thus achieved.

Use of a Mandibular Reconstruction Plate

Mandibular reconstruction plates (MRPs) are designed for reconstruction of mandibular defects. Unlike miniplates and compression plates, they do not rely on the intrinsic integrity of the mandible to stabilize the defective area. On the contrary, these plates are designed to replace the structural integrity of a defective area of the mandible. They must be compact enough and strong enough for use in mandibular reconstruction, and they must contain many holes so that numerous fixation points can be applied. The strength of the repair is increased by the placement of additional screws for fixation. Generally speaking, when a gap is being bridged with an MRP, at least three and preferably four or five screws on either side of the defect are preferred.

As MRPs are strong enough to bridge defect areas, they are obviously strong enough to be used to repair fractures or relative defect areas. Whenever a fracture cannot be properly stabilized with a miniplate or compression plate (e.g., because of comminution or technical difficulty), the MRP can be used. Therefore, it provides a fall-back technique whenever difficulty is encountered. It provides rigid fixation without tension banding or compression. Areas of comminution often behave like areas of bone loss, lacking the structural integrity for compression plating. The MRP also provides stability for thin and biomechanically complex areas such as the mandibular angle and in atrophic mandibles. The MRP is particularly useful in the pencil-thin mandible, in which the weakened, poorly vascularized bone has a high propensity for nonunion after fracture. A reconstruction plate can be applied with minimal devascularization (periosteum is not stripped), and the functional stress is removed from the fractured areas, resulting in a high rate of healing.

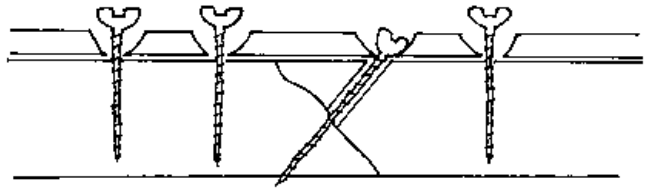


Figure 57–9 A lag screw can be placed through a plate hole. The lag screw principle is followed and the first hole is overdrilled so that the screw thread will not catch in the first fragment of bone. All the remaining screws are placed neutrally in their holes so that there is no interaction between the screwheads and the plate.

The MRP is excellent for reconstructing areas of osteomyelitis. The area can be aggressively debrided, and the plate can be applied during the same procedure, or application can be delayed until the infection has cleared. It is important to place all screws in healthy bone at a distance from the osteitic area. Sometimes cancellous bone is placed in the defect during the same procedure.

For extensive traumatic defects with both soft-tissue and bone loss (e.g., shotgun injuries), the MRP allows for the immediate reconstitution of the skeletal framework. The MRP seems to be stable enough to tolerate prolonged exposure without screw loosening and plate failure. It is therefore possible to provide a framework for later reconstruction, whether soft-tissue reconstitution (e.g., pedicle or free flaps) is carried out initially or not. The ease and simplicity of reconstruction plate placement make this possible even when the patient is too unstable to tolerate a lengthy reconstructive procedure.

For the reconstruction of oncologic mandibular defects, the MRP allows for the maintenance of the precise pre-resection relationship of the mandibular stumps. In most instances, the plate can be preapplied before the mandibular resection. The plate is then removed, carefully noting the screw and hole positions. After the resection and soft-tissue reconstruction has been completed, the MRP can be reapplied using the previously drilled holes. The pre-resection relationship of the stumps is thus maintained. Bony reconstruction can be accomplished primarily or secondarily depending on individual circumstances.

Recent advances in design have made the mandibular reconstruction plate more dependable and easier to use. With the traditional design, precise bending of the plate to

match the bone was critical because the plate was stabilized only by its fixation to the bone by tightening of the screws. In more recent designs, the screw heads are fixed directly to the plate, so that as long as the screw threads are firmly held by the bone, the screw and plate are tightly fixed in place. This not only serves to make the plate more stable when the bend is less precise but keeps the screw stable if there is any bone resorption around the thread, thereby decreasing the likelihood of foreign-body reaction and infection (and thus fixation failure), so long as some of the screws remain fixed. Various designs include screws with expandable heads that are fixed to the plate by the insertion of expansion bolts and plates with threaded holes in which the threaded screw head tightens directly into the plate itself.

REPAIR OF SPECIFIC MANDIBULAR FRACTURES

Nonoverlapping Fractures

Occlusion should first be established. If an arch bar serves as a tension band, a single compression plate with at least two screws on either side of the fracture can be used anywhere along the symphysis and body of the mandible, so long as the alveolar portion of the fracture is held together by the tension band. At the mandibular angle, two plates should be used: a tension band plate above the nerve and a compression plate below. When inadequate dentition prevents the use of an arch bar as a tension band, a tension band plate can be used. Otherwise, an alternative technique should be utilized. When a tension band plate cannot be applied, a mandibular reconstruction plate is a good alternative. [Note that the eccentric dynamic compression plate (EDCP) is rarely used today and so it is not discussed.] These plates can be placed from an intraoral or an extraoral approach.

If miniplate osteosynthesis is preferred, two plates are necessary in the symphysis and parasymphysis, whereas a single plate is adequate along the mandibular body. At the mandibular angle, a single plate should be placed intraorally along the oblique line, with care taken to ensure that at least two well-held screws are fixed to the bone on each side of the fracture. A second miniplate is recommended on the buccal surface of the mandible, generally positioned above the inferior alveolar nerve. 3-D plates are placed similarly to miniplates. Note that most miniplates can be easily applied via the transoral approach, whereas larger plates may require an external incision, particularly in the region of the mandibular angle.

Lag screws may be applied to the solid bone in the symphyseal and parasymphyseal regions of the mandible. At least two screws should be placed, and to minimize the risk of microfracture between the screws, it may be helpful to bring them in from opposite directions (Fig. 57–10). A lag screw may also be used to fix selected mandibular angle fractures as described by Niederdellmann[12] (Fig. 57–11). The screw must be placed transbuccally through the lower cheek, and it must pass in a superior, medial, and posterior direction while carefully avoiding the inferior alveolar nerve. This is a technically challenging technique.

Figure 57–10 Repair of a parasymphyseal fracture of the mandible using two lag screws. Note that the screws are placed in opposite directions to minimize the risk of microfracture of the bone between the two screws. Note also the countersinking of the hole to allow for insetting of the screwhead in the bone.

Overlapping Fractures

As noted above, when bone fragments overlap, a lag screw can be placed through the fragments. Because the lag screw is only threaded in the second fragment, tightening the screw compresses the fragments together by compressing the first fragment between the second fragment and the head of the screw. Generally speaking, at least two and preferably three lag screws best stabilize the bones together. Alternatively, a lag screw technique may be combined with plate fixation (see Fig. 57–9).

Mandibular Angle

The mandibular angle is singled out because of the high complication rates seen when repairing fractures in this region.[7,8] The ideal repair remains quite controversial. Champy et al[4] and Ellis and Walker[8] recommend using a single miniplate along the oblique line. Kroon[6] and Levy et al[7] recommend the use of two miniplates. If a compression plate approach is preferred, a smaller tension band plate should be used above the inferior alveolar nerve and a larger plate below. Due to the thinning of the bone posteriorly, it is probably wise to use an angled reconstruction plate in this region, with at least three bicortical screws on each side of the fracture.

Subcondylar Fractures

The treatment of subcondylar fractures of the mandible remains controversial. Thus far, most surgeons continue to advocate a conservative, (i.e., closed) approach to most fractures. However, with the advent of endoscopically assisted, minimally invasive techniques, the reluctance to open subcondylar fractures may diminish. Various new instruments have been designed to facilitate the endoscopic approach, which can be performed transorally or via a small incision below the angle of the mandible or by combination of these two approaches. Sleeves on the endoscope enlarge the optical cavity, and specially designed retractors allow for easier sta-

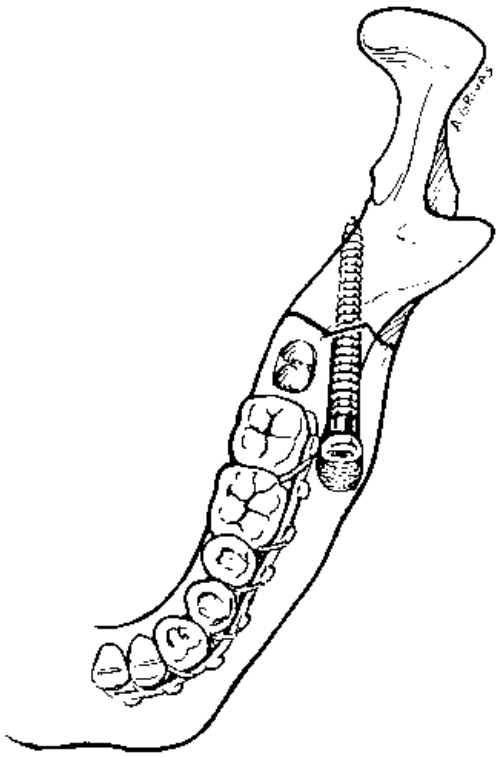


Figure 57–11 View of a mandible from above with the bone transparent for visualization of a lag screw repairing a fracture of the mandibular angle. Note the positioning of the screw from buccal to lingual as it traverses the bone from the anterior to posterior direction. The screw was also directed somewhat superiorly, which cannot be seen from this view. When properly positioned, this screw provides compressive forces that bring the two fractured fragments directly together. (From Kellman RM, Marentette LJ. *Atlas of craniomaxillofacial fixation*. New York: Raven Press, 1995.)

bilization of the fragments prior to fixation. Devices that stabilize and advance the plate into position allow for easier placement of the screws through the transbuccal trochar (Fig. 57–12). One or two small (2.0-mm) plates are applied; the position of the bones should be checked radiographically to assure proper repositioning.

Severe Comminution, Bone Loss, and Atrophic Mandibles

Miniplates, compression plates, and lag screws all rely on the structural integrity of the underlying bone; by taking proper advantage of biomechanics, the fixation devices force the bones together so they can heal. When the bone is severely comminuted or missing, it cannot be adequately supported by these methods. The strength of the bone must be replaced with bone (e.g., via microvascular free-tissue transfer) or with an implant strong enough to support the defective area. Mandibular reconstruction plates are designed to replace the structural integrity of the defective bone. When used to repair an area of comminution, the area should be treated as a defect and at least four screws should be placed into the solid bone on either side of the involved area. Small fragments can be pieced together

Figure 57–12 Photo of an endoscopic retractor designed for forehead lifts that has served effectively for creating the optical cavity during the endoscopic repair of subcondylar fractures of the mandible. (Note that retractors designed specifically for this purpose are currently being developed.) The device below the retractor is a plate advancer designed to deliver the plate into position during the endoscopic procedure. The plate position can be rotated left to right by moving the sliding plastic handpiece sides against each other. Also note that a rotating rivet holds the plate in the holder. A half turn of the screw releases the plate so that it stays in the wound and the introducer can be removed.

with wires or small plates, or they may be discarded, depending on the circumstances (Fig. 57–13). An MRP works well for the repair of fractures of the severely atrophic mandible, which is not only difficult to stabilize but, due to the paucity of bone-to-bone contact and the poor blood supply, is very prone to nonunion. Use of the MRP for these injuries has minimized the occurrence of nonunions in these difficult situations.

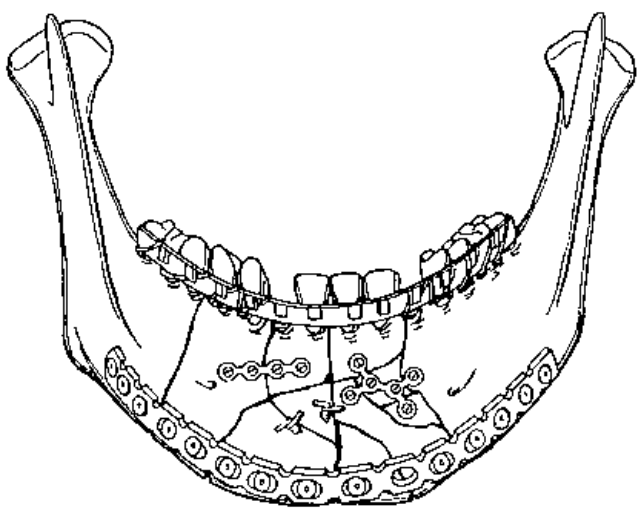


Figure 57–13 Artist's depiction of a comminuted mandible fracture. Note that a single large reconstruction plate bridges the comminuted area fixing the solid, stable fragments to each other. Screws from the plate in essence lag the smaller fragments to the plate. Smaller monocortical miniplates and/or wires can be used to fix small fragments in place. (From Kellman RM and Marentette LJ. *Atlas of craniomaxillofacial fixation*. New York: Raven Press, 1995.)

APPLICATION OF RIGID-FIXATION TECHNIQUES TO FRACTURES OF THE MID- AND UPPER FACE

Occlusion

As noted above, recreating the proper (premorbid) occlusal relationship is a primary functional concern. This is as true for maxillary fractures as it is for mandibular fractures. Of course, it is not an issue for fractures that do not in any way involve the maxilla or mandible.

Biomechanics

Like mandibular fractures, midfacial fractures and osteotomies can be repaired reliably using plate fixation. However, many of the bones are thinner, the shapes are more variable, and the areas for application are smaller, with thinner overlying skin in most areas as well. Therefore, much smaller and more variously shaped plates have been developed for middle and upper facial repairs. Compression plates and neutral plates are available.

Generally speaking, even the thinnest bones can be held in place with screw fixation. It has been demonstrated that stable fixation can be accomplished in bone as thin as 2 mm,[13] which is available in most facial areas. However, plate fixation should not be used until the correct bone positions have been reestablished because rigid fixation will be maintained despite malpositioning.[14] Once exact repositioning has been accomplished, rigid fixation allows for the removal of MMF. Furthermore, craniofacial suspension and the associated risks of facial foreshortening and rotation can be avoided.[15]

Unlike the mandible, areas of tension and compression do not seem to be a major factor, and biomechanical concerns relate to proper fixation and stabilization. Skeletal position must be carefully reconstructed in three dimensions, and enough fixation must be applied to assure stability and immobility in function. The vertical buttresses are reestablished to define facial height.[16] The anteroposterior dimension is defined along the zygomatic arches, and the lateral dimension is determined from zygoma to zygoma across the infraorbital rims and nose and across the palate.

Zygomatic Arch Fractures

Although rigid fixation of the isolated arch fracture is currently rare, the introduction of endoscopic techniques has led some people to attempt fixation of this injury. While the technology is not yet state-of-the-art, as the equipment improves we may expect to see this area treated more frequently.

Zygomatico–Maxillary–Orbital Fractures

The so-called tripod fracture centers around the solid malar eminence, and the name "tripod" comes from the junctional supports between the zygoma and the temporal bone, frontal bone, and maxilla. It has also been referred to as a quadrapod fracture, separating the maxillary fracture into its orbital rim and maxillary buttress components. In fact, it is far more complex than that, frequently with significant orbital floor and lateral orbital wall components. Manson has classified these fractures by severity into low-energy, middle-energy, and high-energy injuries.[17] Obviously, the more displaced and comminuted the fracture, the more extensive the repair will be. For low-energy injuries, displacement may be so minimal that no repair is indicated. Still, the key to repair of even the simple zygomatic fracture is proper anatomical repositioning before rigid fixation. Minimally displaced fractures sometimes require minimal exposure; in fact, a bone hook under the eminence may occasionally be adequate and fixation may be unnecessary. However, before any plate fixation is contemplated, care should be taken to ascertain that the positioning is optimal. Sublabial exposure of the zygomaticomaxillary area often reveals malpositions that are frequently ignored when only lateral orbital rim exposures have been used. Once exposed, this area can be plated along with the frontozygomatic area, providing solid two-point fixation. Some have advocated single-point fixation at the frontozygomatic area,[15,18] whereas others have advocated single-plate fixation at the zygomaticomaxillary buttress. However, these approaches remain controversial because the strong masseter pull on the zygomatic arch makes single-point fixation less dependable. It is not clear whether failures of single-point fixation are due to inadequate fixation or improper positioning. The recent work of Davidson et al[19] suggests that single-point miniplate fixation at the frontozygomatic suture should provide acceptable stability. It is therefore recommended that whether one- or two-point fixation is planned, the zygomaticomaxillary area should be visualized to ensure that the alignment is correct. With the wide variety of plate and screw sizes now available, it is still unclear what constitutes adequate fixation. As three-point fixation with wires seems to stabilize a zygomatic fracture,[19] certainly the smallest plates could be adequate if three points are fixated (assuming no bone loss). What is unclear is the size of the implant(s) required if one- or two-point fixation is to be used, particularly for a middle-energy injury. If after what appears to be adequate reduction the malar eminence still appears flattened, it may be posteriorly displaced. Proper reduction may then require exposure of the zygomatic arch via a coronal incision, so that its proper shape and alignment can be reconstituted.

For high-energy injuries, severe displacement and comminution mandate wide exposures and multiple fixation points. A comminuted arch must be exposed via a coronal approach. It may be repaired with microplates, though even the smallest plates may alter the facial contour. Sometimes the shape of the arch can be reconstituted with multiple interosseous wires, and, after rigid stabilization of the remainder of the zygoma via reconstruction of the frontozygomatic continuity, the infraorbital rim, and the zygomaticomaxillary buttress, the wired arch will maintain its shape. The infraorbital rim should be repaired with the smallest implants possible, though great attention should be paid to assuring solid bony fixation along the lateral orbital rim (and frontal bone) and the zygomaticomaxillary buttress. If this buttress is deficient, a bone graft should be utilized to reconstruct it.

The orbital walls should be directly approached and repaired. The lateral orbital wall can sometimes prove very helpful when the alignment of the zygoma is difficult to determine. While some have placed small bone plates across the intraorbital lateral wall, this is not a common technique. The orbital floor should be reconstructed, and a deficient medial wall should not be ignored (see orbital repair).

LE FORT FRACTURES

Le Fort I

The Le Fort I or horizontal maxillary fracture separates the lower maxillae and palate from the upper face. It traverses the pyriform apertures and nasal septum and is completed posteriorly across the lower portion of the pterygoid plates, thereby separating the upper teeth and the bones holding them from the remainder of the craniofacial skeleton. Repair requires reattachment of the lower face to the upper face, with care taken to assure proper reestablishment of the occlusion. Rigid fixation must be accomplished along the four vertical buttresses that support the face with exposure via the sublabial approach. These are the bones on either side of the pyriform apertures and the solid zygomaticomaxillary buttress regions. Significant bone loss along these buttresses should be replaced with grafts (Fig. 57–14). The 1.5-mm or 2.0-mm plates are commonly used to prevent shifting of the bones, though 1.3-mm and 1.0-mm plates, particularly those with the 3-D geometrical designs, have been used as well. Careful attention must be paid to avoiding the tooth roots when placing screws. After adequate fixation, MMF may be released.

Split Palate

A split palate must be repaired to maintain the horizontal width of the lower midface and to prevent rotation of the maxillary dentition either lingually or buccally. Proper MMF is critical when these are adequately available, and a maxillary dental splint can also function well to maintain the relationship of the dental arches (alveoli). A plate across the anterior maxilla may stabilize these fragments. Rarely, it is possible to microplate or wire the palate itself.

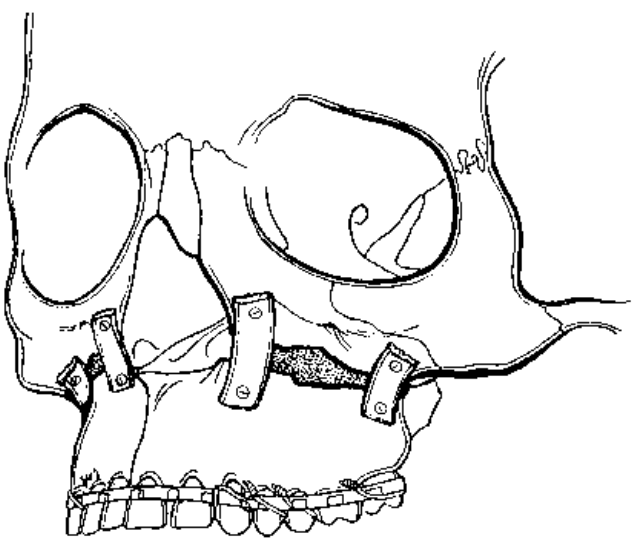


Figure 57–14 Artist's depiction of a Le Fort I fracture with bone loss repaired using bone grafts as plates. When the buttresses are deficient, bone grafts should be used. Otherwise the same areas can be fixed directly with plates. (From Kellman RM and Marentette LJ. *Atlas of Craniomaxillofacial Fixation*. New York: Raven Press, 1995.)

Le Fort II

This fracture starts at the zygomaticomaxillary buttress and continues on a diagonal through the orbital floor and medial orbit, then crosses the nasal root before continuing down the contralateral orbit and maxilla. As in all Le Fort fractures, the proper occlusion must first be established. Stabilization requires repositioning of the nasal root if it is displaced and fixation to the frontal bone if it is unstable. This is generally accomplished via small plates placed on either side of the nasal root, though "x" plates and even single nasofrontal plates have been used. The zygomaticomaxillary buttresses are then plated via the sublabial approach, along with horizontal repair of the fractured maxillae. The orbital floors and medial walls are explored as needed, generally utilizing a transconjunctival approach. Bone defects are repaired with bone grafts. Once fixation is satisfactory, MMF may be released.

Le Fort III

The true Le Fort III fracture or craniofacial separation crosses the zygomatic arch; traverses the orbit through the lateral wall, floor, and medial wall; separates the nose from the frontal bone; crosses the upper septum; includes similar fractures on the contralateral side; and is completed posteriorly by crossing the top of the pterygoid plates, essentially separating the face anteriorly from the frontal bone and posteriorly from the sphenoid, leading to a complete craniofacial separation. In practice, most Le Fort III fractures are complex and include components of Le Fort I and II fractures. These are best approached by working from stable to unstable[20] or, as Champy et al state it, from the periphery toward the center.[21] When possible, mandibular stabilization should be completed first because the mandible can provide an excellent template for midfacial repair. Occlusion must be established at the outset using MMF. When necessary, subcondylar fractures are opened and repaired to help reestablish the vertical dimension.[16,22]

An important aspect of skeletal repair is adequate exposure. The bicoronal approach provides access to the frontal area, the nasofrontal junction, the lateral orbital rims, the malar eminences, and the zygomatic arches. Exact repositioning of multiply fractured bones is difficult, and the fragments are often first loosely approximated with wires. When anatomical alignment is satisfactory, plates are used to fix the bones rigidly in position. The thick lateral orbital rims can be fixed with mini-compression plates or neutral plates as desired, with care taken to place at least two screws in each fragment. The nasofrontal area can be fixed with wires or plates; a single midline plate or two plates on either side of the nasal root will prevent facial rotation and loss of the nasal dorsum. The zygomatic arch is repaired with lag screws, plates, or wires as needed, thereby reestablishing the anteroposterior facial shape. At this point, the Le Fort III fracture has been converted to a Le Fort II fracture and can be fixated as outlined above. In fact, with adequate exposure, the key to facial skeletal repair is the careful and painstaking reapproximation of all of the skeletal structures using the smallest plates and screws that can adequately stabilize each fracture area. All defect areas are reconstituted with bone grafts, and once complete stabilization has been accomplished, MMF should no longer be necessary (assuming adequate stabilization of the fragments has been achieved) (Fig. 57–15).

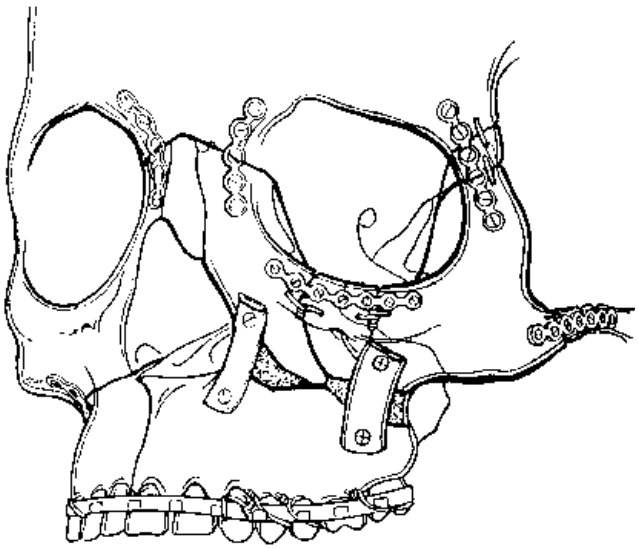


Figure 57–15 Artist's rendering of a Le Fort III fracture repaired using a combination of wires, plates, and bone grafts. Note that fixation is necessary at the buttresses using plates or, when the bone is deficient, bone grafts that function as plates when lagged to the more solid bone above and below. (From Kellman RM, Marentette LJ. *Atlas of craniomaxillofacial fixation*. New York: Raven Press, 1995.)

Figure 57–16 Orbital floor plate.

Note that with complex skeletal injuries, visualization of the repair may sometimes prove inadequate. The addition of intraoperative computed tomography has been shown to enhance the ability of the facial plastic surgeon to assess the correctness of the repair at the time of surgery and to correct any malpositions during the initial procedure.[23]

Orbital Fractures

Rigid fixation has enhanced our ability to reconstruct the orbit as well. Fractures of the orbital floor and medial walls are generally explored via the transconjunctival approach, although subciliary incisions are still used as well. Defects are generally bone grafted, though many surgeons use a variety of alloplastic materials. The orbital floor plate (Fig. 57–16) or various forms of titanium mesh have been used to support bone grafts during reconstruction of extensive defects. Another alternative is to fix a microplate to a bone graft so that the plate will extend over the infraorbital rim. Fixing the plate to the rim with screws then stabilizes the graft. Microplates can also be used to fix pieces of calvarial bone together and thereby create a curved graft using the quite unmalleable calvarial bone.

Frontal Fractures

Rigid fixation has proved helpful for managing comminuted frontal sinus fractures. Severely comminuted areas can be reconstructed on the back table and then reimplanted into the defect. The smallest plates possible should be utilized to minimize the potential for later prominence of the implants through the skin. Management of the sinus will be discussed in Chapter 59, but it is worth mentioning that the recent development of calcium phosphate bone cements has simultaneously provided what appears to be an excellent material for frontal sinus obliteration while also providing contour for anterior frontal sinus wall defects (Fig. 57–17 and Fig. 57–18).

Naso-orbital Ethmoid Fractures

Naso-orbital ethmoid fractures involve the nasal bones, lacrimal bones, and ethmoid lamina, with displacement of the medial canthal attachments and posterior telescoping of the nasal dorsum. There are numerous classifications of these fractures, but most significantly, if there is a single large central fragment with the medial canthal ligament still attached, then fixation of this fragment superiorly to the frontal bone and inferiorly to the maxilla will restabilize the medial canthus. When there is marked comminution, or when the medial canthus is detached, direct repair of the canthus is required. Transcanthal wiring is possible, though so-called centripetal suspension, as described by Raveh et al,[24] allows controlled positioning of the misplaced ligaments. In this approach, the medial canthus is sutured to the contralateral frontal bone, with the suture passing posteriorly behind the nasal bone and through the nasal septum. It is important to replace missing bone in the anterior medial orbit so that there is bone to which the repositioned ligament can adhere. When present and reducible, the nasal root is fixed to the frontal bone. Typically, in severe injuries, bone grafts are lag-screwed to the depressed nasal bone or plated to the frontal bone to provide adequate nasal projection.

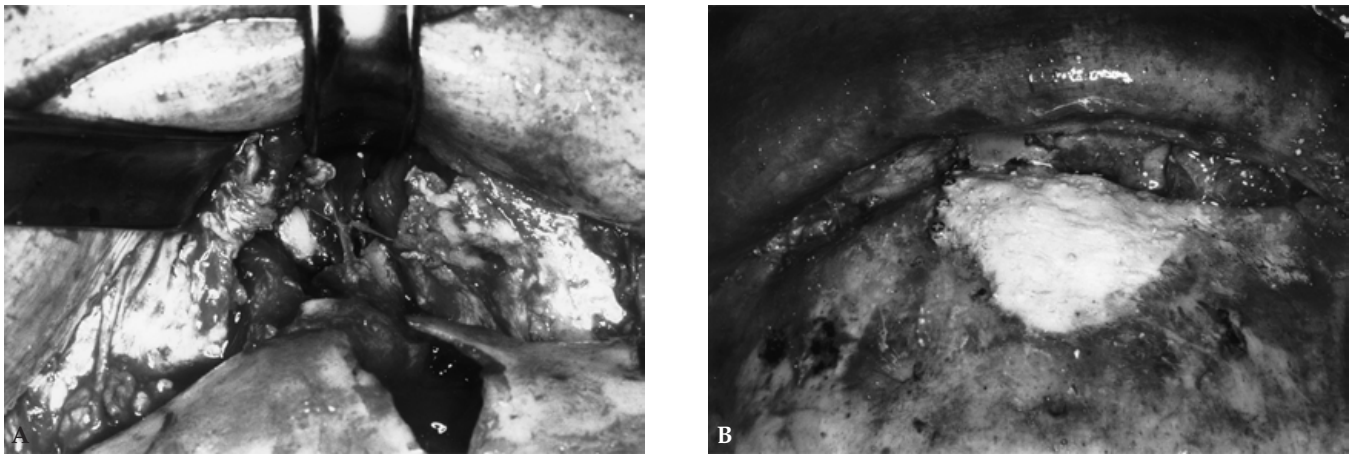


Figure 57–17 Naso-orbital ethmoid (nasoethmoid complex) and frontal sinus fractures. **(A)** The losses of the structural integrity of the nasal bone as well as a portion of the frontal sinus are demonstrated. **(B)** After repair of the medial orbits and medial canthal ligaments and reconstruction of the nasal bone with a bone graft, the frontal sinus was obliterated and the frontal contour recreated using bone cement.

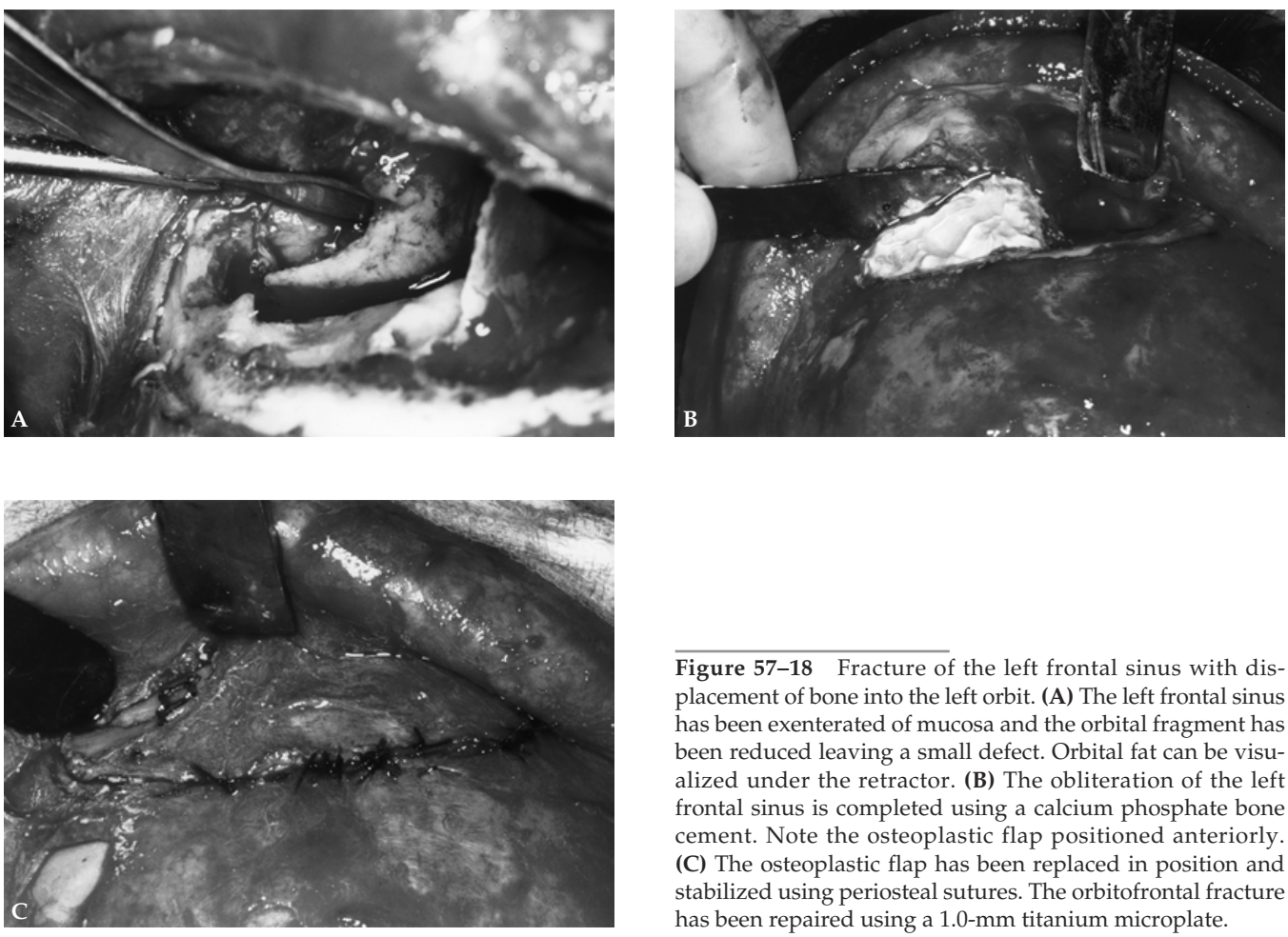


Figure 57–18 Fracture of the left frontal sinus with displacement of bone into the left orbit. **(A)** The left frontal sinus has been exenterated of mucosa and the orbital fragment has been reduced leaving a small defect. Orbital fat can be visualized under the retractor. **(B)** The obliteration of the left frontal sinus is completed using a calcium phosphate bone cement. Note the osteoplastic flap positioned anteriorly. **(C)** The osteoplastic flap has been replaced in position and stabilized using periosteal sutures. The orbitofrontal fracture has been repaired using a 1.0-mm titanium microplate.

GRAFTS AND IMPLANTS

Small areas of bone loss in the midface can be bridged with plates. However, when defects occur in the buttress areas, these should be reconstructed with bone grafts. Bone grafts are also necessary when deficient bone results in cosmetic and/or functional deformities. This is seen in the orbit, where significant structural loss results in cosmetically deforming enophthalmos and, often, a limitation in extraocular motion as well. The deformity from a naso-orbital ethmoid fracture can be severely exaggerated by a loss of nasal dorsal height. Bone grafting of the nasal dorsum corrects this deformity and also minimizes the tendency toward epicanthus formation. Bone grafts are also frequently necessary to bridge the defects created by secondary repair of facial fractures via osteotomies.

Split calvarium is readily accessible when a coronal approach is used for facial repair. Studies have shown that the membranous calvarial bone persists for years with minimal resorption when it is rigidly fixed, as compared with much higher resorption rates when rigid fixation is not utilized. Onlay grafts are best fixed with lag screws to the underlying bone. At least two lag screws should be used whenever possible. This not only provides rigid fixation but also compresses the graft against the underlying bone. Note that this is not the same as using a plate and screws in the bone graft because the lag screw through the graft is not dependent on the thread of the screw holding in the graft. An onlay implant, such as a malar implant, can be handled in the same manner, with lag screws preventing motion or displacement of the implant.

When a graft is spanning a defect, it can be carved to fit snugly into the defect and then held in place with a plate across the area. Unlike a bone flap, the graft is dead, and therefore screws in the graft are likely to loosen. It is therefore unwise to fix a graft with a plate that depends on the screws in the graft for stability. This is in contrast to a living bone flap (see below). When possible, the graft can be designed to overlap the native bone on each side of the defect, and lag screws can then be used to fix the graft in place at each end. In this situation, the graft doubles as a graft and a fixation device, bridging the defect like a plate made of bone.

Bone Flaps

When live bone is placed in a defect, as in a microvascular free flap, the repair sites behave like fractures rather than graft sites because the bone is alive. These can therefore be repaired with small plates at each osteotomy site or with larger, bridging reconstruction plates according to the surgeon's preference. Contrast this with fixation of a bone graft (see above).

Distraction

Although beyond the scope of this chapter because distractors are considered variants of rigid-fixation appliances, they will be mentioned here. A distractor is generally applied across an area of bone to be lengthened with either pins or screws, after a corticotomy has been made at the site to be distracted. The corticotomy is then extended into an osteotomy. Distraction of the bone is then performed by advancing the space between the osteotomy at a rate of 1 mm/day (usually 0.5 mm bid, though new programmed distractors can work continuously). After distraction is complete, the distractor serves as a rigid-fixation appliance to allow the completion of bony healing. Defects can be repaired by moving one or more transport disks of bone from one or both ends of the osseous defect. Multivector distractors allow for both vertical and horizontal lengthening of the mandible. Midfacial distractors can be utilized instead of extensive mobilization and repositioning of the midfacial skeleton. As the devices become smaller and more completely implantable, they will be used more commonly because the major drawback currently is distraction of the scar when distractors are placed using transcutaneous pin fixation.

Exposure for Fracture Fixation

Generally speaking, to avoid making visible scars, most facial fractures are repaired using incisions that are often not directly overlying the fracture to be repaired. Intraoral incisions are used whenever possible to expose mandibular and maxillary fractures. When exposing the mandibular body, care should be taken to avoid injury to the inferior alveolar nerve. The sublabial incision provides wide access to the maxilla. When elevating the mucoperiosteum, care should be used to avoid lifting bone fragments with the flap as well as to protect the infraorbital nerves. Nasal penetration should be avoided when possible. The orbit is now commonly approached transconjunctivally. Therefore, it is important for the facial plastic surgeon to understand the anatomy of the skin and lid retractors so as to avoid injury to these structures, which could lead to lower lid malpositions. Upper facial structures as well as the nasal root, nasoethmoid complex, and zygomas are often approached via coronal scalp incisions. The surgeon should understand the anatomy of the deep temporal fascia and its relationship to the frontal branch of the facial nerve. Dissection between the superficial and deep layers of the deep temporal fascia will minimize injury to the temporalis muscle (and, hopefully, minimize temporal wasting) while simultaneously protecting the frontal branch of the facial nerve. Great care should also be used to protect the supraorbital and supratrochlear nerves, which may have to be dissected from their bony foramina in the supraorbital rim. The coronal flap provides not only wide access to the upper midface and upper face but allows the surgeon to utilize a pericranial or galeal/pericranial flap to repair defects in the floor of the anterior fossa. Finally, it is important to pay attention to the repositioning of the soft tissues once the repair has been completed. Otherwise, a bony malposition may be replaced by a soft-tissue anomaly. The facial soft tissues must be resuspended, particularly with reattachment of the severed portion of the temporalis fascia.

If the lateral canthal ligament has been detached, it should be reattached in its natural position inside the lateral orbital rims (Whitnall's tubercle). A Frost stitch left for 24 to

72 hours from the lower lid taped to the forehead will stretch the lower lid upward and hopefully decrease the likelihood of later malpositions.

COMPLICATIONS OF RIGID FIXATION

A brief list of complications specifically related to rigid fixation is included. First is a rigid fixation without proper reduction. Rigid fixation is considered an "unforgiving" technique, so that improper reduction that is rigidly fixed will result in a permanent malunion. If fragments of bone carrying teeth are involved, this will result in a malocclusion. Implant failure is usually a result of selecting too small a device for the indication, though occasional plate fractures, particularly when defects have been bridged by mandibular reconstruction plates, have been encountered. Screw loosening can occur, and this is most likely if a stripped screw is left in place or if the fixation is unstable. Some patients complain of persistent pain at the site of plate fixation, particularly in cold climates. Removal of the plates generally resolves this problem.

Infection and nonunion are the most serious complications. A localized abscess can sometimes be drained, at which time the fixation can be evaluated; if it is solid, it may tolerate drainage and antibiotic treatment. However, if infection persists, the implant may be serving as a colonized foreign body and should be removed. Unstable appliances must be removed. Infection may lead to osteomyelitis, which requires prolonged antibiotic treatment along with aggressive surgical debridement. Finally, there are iatrogenic injuries, such as injury to sensory and motor nerves, as well as soft-tissue injuries.

FUTURE DEVELOPMENTS

As noted above, minimally invasive techniques are currently being utilized with endoscopic assistance. With ongoing advances in endoscopic technology, intraoperative imaging and computer-driven image-guided systems, it is likely that less invasive approaches will be applied to more anatomical regions and more complex fractures. The development of better implant technologies will allow placement of rigid fixation through smaller incisions as well.

Absorbable technology is progressing as well, and many facial fractures and osteotomies are now being repaired with biodegradable plates and screws. Development will continue in the area of bone replacement materials, along with growth-stimulating proteins that will affect the rate and quality of bone healing and possibly eliminate the need for bone grafts and flaps.

APPENDIX

Mechanism of Compression Plate Function and Application

When screws are placed though a plate into bone across a fracture or osteotomy, a certain degree of stability is imparted. A two-hole plate prevents axial distraction at the plate site but does not prevent rotation. A four-hole plate prevents distraction and rotation when placed along the traction side. No compressive force is imparted, only neutral fixation.

A compression plate creates axial compression across a fracture or osteotomy. It is designed so that proper positioning of screws in the plate holes produces compressive forces simply and maintains them during the healing process.

The key to this device is a planned interaction between the screw head and the plate that results in a predictable relative movement between the screw and the plate. The plate hole and screw head are therefore designed so that the screw head does not rest on the plate but rather slides into the plate hole. If a curved (spherical) or slanted (conical) plate hole is used, then as the screw is tightened, the screw head will slide into its seated position in the plate hole, resulting in a relative motion between the screw and the plate. This predictable relative motion results in axial compression.

Axial compression occurs because as it moves relative to the plate, the screw carries the bone with it. Before drilling any holes, the plate has been placed over the site to be compressed. Once the screw is screwed into the bone, any movement of the screw will bring the bone with it; thus, a "screw–bone unit" has been formed. The screw is placed in the plate hole so that the shaft of the screw rests against the plate as far away from the fracture site as possible but is not tightened (Fig. 57–19). The opposite screw is similarly placed away from the fracture site on the other side of the fracture. At this point two screw–bone units have been formed, and each is in contact with the plate so that they cannot possibly move apart. When a screw is tightened, the interaction between the screw head and the plate forces the screw head toward the fracture site, thereby bringing the bone with it. Because the opposite fragment cannot move away, compression is accomplished. When the second screw is tightened, it is similarly forced by the plate to move toward the fracture site, bringing its bony counterpart with it, which results in further compression at the fracture site.

Lag Screw Function and Application

Lag screw placement is fairly straightforward. The fragments are reduced and compressed together (frequently with a towel clip), and the site for screw placement is determined. An oversized gliding hold is drilled in the outer fragment (usually the size of the outside diameter of the screw thread), and a smaller diameter hole is drilled through both fragments. This is the key to lag screw fixation. The larger hole in the first fragment prevents the screw from holding in it. The smaller hole in the second fragment catches the screw thread. As the screw is tightened, it only holds in the second fragment. Thus, the first fragment is compressed between the head of the screw and the second bone fragment (see Fig. 57–8). Thus the two bones are forced tightly together. The first fragment can be an overlapping fracture segment, a bone graft or even an alloplastic implant. When available, drill guides are used for drilling the holes. The outer hole is then enlarged with a countersink. The screw is placed and tightened, and additional lag screws are similarly placed as needed.

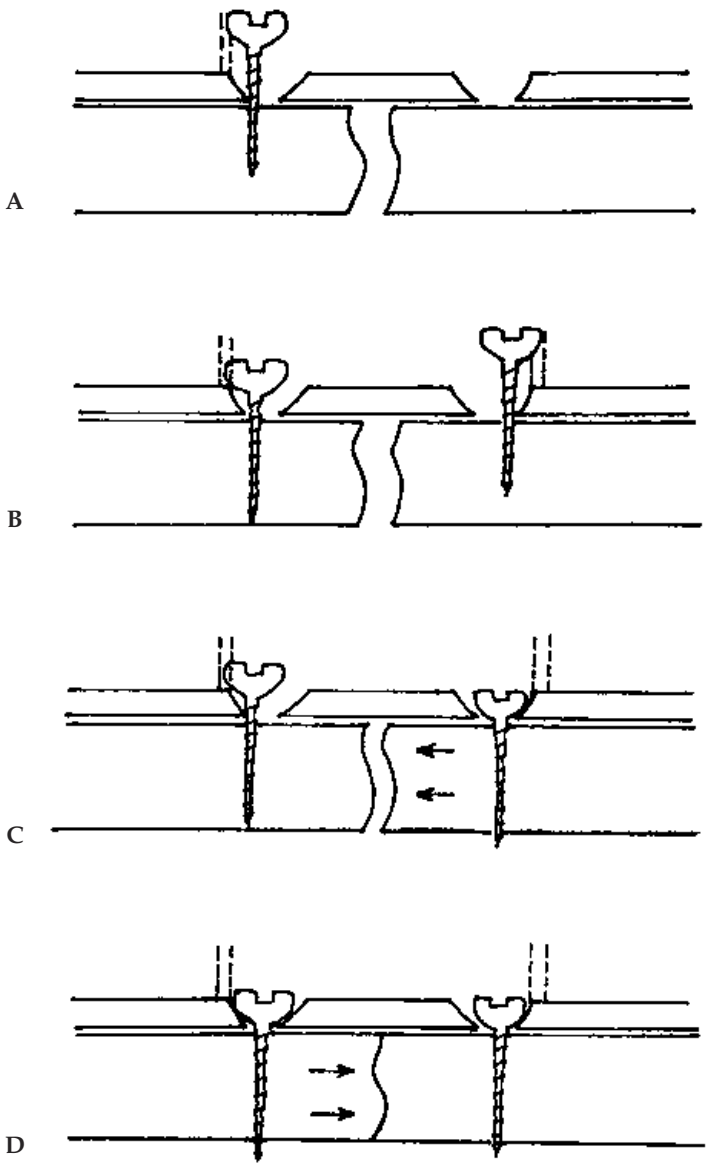


Figure 57–19 Mechanism of action of a compression plate. **(A)** The screwhead overlaps the plate when the shaft of the screw is positioned in the hole so that it is as far away as possible from the fracture. **(B)** The first screw is screwed in until the head reaches the plate, but no compression is obtained. The second screw (*right*) is placed eccentrically in the plate hole similarly to the first screw (i.e., so that the shaft is positioned in the hole so that it is as far away from the fracture as possible). No compression has been accomplished. **(C)** The second screw is tightened, and the interaction between the head of the screw and the plate forces the screw (and the bone to which it is attached) to move to the left. When the bone fragments make contact, the piece of bone on the left cannot move away from the piece of bone on the right because the screw shaft in this fragment is up against the plate on the left side. **(D)** The first (*left*) screw is now tightened, and as the screwhead slides against the plate, it moves to the right bringing the bone with it. Again, the interaction between the screw and bone on the right with the plate prevents it from moving away. Thus, compression is accomplished.

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Chapter 58

Treatment of Orbitozygomatic Fractures

Robert B. Stanley, Jr.

Traditionally, fractures of the facial skeleton resulting from trauma in the orbital and cheek areas have been evaluated and treated in a segmentalized fashion. Fractures were classified simply as being zygomatic arch, malar or tripod, or orbital blow-out fractures. This simplistic approach produced acceptable results in most injuries that were due to suburban-based or low-velocity impact causes, such as sports injuries or fistfights. However, acceptable results were often not achieved in victims of urban-based or high-velocity impact injuries seen with high-speed motor vehicle deceleration crashes, interpersonal violence involving blunt instruments other than fists, and gunshot wounds. Unfortunately, in modern society, the ratio of urban- to suburban-type injuries seen in both community hospitals and inner-city trauma centers has been increasing steadily. Experienced maxillofacial trauma surgeons have shown that suboptimal results often cannot be attributed to the severity of the injury but rather to a segmentalized approach to the injury. Therefore, all fractures of the facial skeleton resulting from trauma in the orbital and cheek areas should be evaluated as potential orbitozygomatic or even cranioorbitozygomatic fractures, and repair of the injury must be directed to restoration of an anatomically correct skeletal unit.

Evaluation of the patient with periorbital trauma has been greatly enhanced with the use of computed tomography (CT). Axial and coronal CT scans can be used to demonstrate in graphic detail the location and complexity of fracture lines throughout the entire orbitozygomatic complex. Perhaps more importantly, they also demonstrate displacement of the malar eminence and displacement of any of the four walls that might cause volume changes in the orbit. All information necessary to evaluate an injury can be seen on standard axial and coronal views. Three-dimensional reconstructions provide no additional useful information, and their value in patients who cannot be positioned for a true coronal CT has been eliminated by the availability of excellent coronal reformations that can be generated from fine-cut axial scans. Even in this time of cost-consciousness in health care, the expense of CT evaluation of almost all orbital trauma patients appears justified. It is now recognized that the information gained from CT scans is of much greater value than that gained from a combination of clinical examination and routine roentgenograms in predicting flattening of the malar eminence and malposition of the globe. It is no longer acceptable to adopt a wait-and-see attitude regarding possible delayed sequelae, such as enophthalmos.[6,9] It also is no longer acceptable to perform orbital explorations through an incision that violates the lower eyelid in order to evaluate the status of the orbital floor, thus placing the patient at risk for the iatrogenic complications of lid retraction or eversion.[5]

Accompanying the advances in roentgenographic evaluation of orbitozygomatic injuries has been the development of extended access approaches that have allowed maxillofacial surgeons to obtain more accurate reduction of fracture displacements. The inferior orbital rim and orbital floor can be approached through a transconjunctival incision, which greatly reduces the risk of increased scleral show or gross ectroption so often seen with the standard subciliary incision. The addition of a lateral cantholysis provides complete exposure of the rim and floor, as well as the lower half of the medial orbital wall (lamina papyracea). A coronal incision can be used for access to the lateral, superior, and upper half of the medial wall of the orbit and the entire length of the zygomatic arch. An upper buccal incision can be used to expose the important zygomaticomaxillary (ZM) buttress inferiorly. In addition, exploration of the orbital floor can no longer be limited to the safe concave area immediately behind the orbital rim but must be extended deeply into the orbit to allow for repair of the convex posteromedial floor that slopes gently upward into the medial orbital wall. A surgeon may be hesitant to perform these extended-access approaches in favor of a more limited approach in the hope that any facial asymmetry resulting from incomplete fracture reduction will be imperceptible. However, the range of imperceptible asymmetry is small, and the surgeon cannot rely on it to hide suboptimal results that may have been improved with a more extensive reconstruction. The surgeon must realize that to safely perform these advanced procedures a complete understanding of the anatomy of the orbit and zygoma and all contiguous bony and soft tissue structures is required. Also of importance is an understanding of the pathophysiology of fractures and fracture dislocations of the orbitozygomatic complex.

ANATOMY AND FRACTURE CHARACTERISTICS

Zygoma and Malar Prominence

The zygoma is a relatively sturdy bone that provides the aesthetically important malar prominence. It is related to the surrounding craniofacial skeleton through four superficial and two deep projections. Superficially, the projections contribute to two critical external arcs of contour (Fig. 58–1). The vertical arc runs from the zygomatic process of the frontal bone over the zygoma to the ZM buttress area of the lateral wall of the maxillary antrum above the first molar. The longer horizontal arc runs from the maxilla in the area of the lacrimal fossa around the zygoma to the root of the zygomatic process of the temporal bone. It is parallel to, but slightly below, the Frankfort horizontal plane. Because the height of contour of the malar prominence is also just at or slightly inferior to the Frankfort plane,[10] the point of intersection of these arcs of contour defines the position of the malar prominence (Fig. 58–1). The two deep projections are the sphenoid projection that articulates along the lateral orbital wall with the orbital plate of the sphenoid bone and the orbital projection that articulates with the orbital surface of the maxilla in the extreme lateral aspect of the orbital floor. The sphenoid and orbital projections lie beneath and perpendicular to the external arcs of contour in the area of the inferolateral orbital rim, thus greatly strengthening this portion of the rim.

The zygoma is the main buttress between the maxilla and the cranium and is also the principal component of the superficial lateral pillar of a buttress system of platforms and pillars that surround and protect the orbit.[13] Because its convex outer surface provides the prominent contour of the cheek, it is highly susceptible to injury. Strong impact forces directed to the zygoma are usually absorbed by the weaker bones with which the zygoma articulates, resulting in fragmentation of these bones. The exception to this is the stout zygomatic process of the frontal bone. Typically, the zygomaticofrontal (ZF) suture suffers a clean separation, whereas the ZM buttress area and the medial aspect of the inferior orbital rim will be comminuted. The zygomatic arch will suffer either a single telescoped fracture near its midpoint or a double fracture that produces a displaced and possibly rotated central fragment. Therefore, fracture dislocations of the zygoma may fragment both ends of the horizontal arc of contour and the lower end of the vertical arc. The degree of this disruption and the amount of displacement of the zygoma determine the severity of the injury and thus the complexity of the needed repair. Reconstruction of the horizontal arc restores anterior and lateral projection of the cheek, and reconstruction of the vertical arc restores the height of the malar prominence in relation to the Frankfort plane.

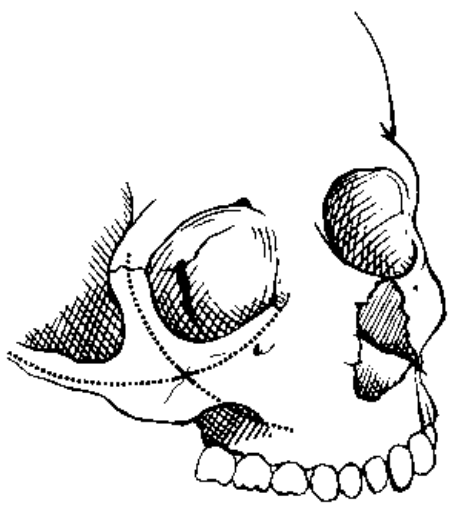

Figure 58–1 Vertical and horizontal external arcs of contour of the zygomatic complex. Intersection at *X* marks the position of the malar prominence. (From Stanley RB. The zygomatic arch as a guide to reconstruction of comminuted malar fractures. *Arch Otolaryngol Head Neck Surg* 1989;115:1459. With permission.)

Orbit

Within the orbit, impact forces are transmitted to the deeper structures through the zygoma by way of the sphenoidal and orbital processes. Any impact centered over the lateral orbital rim must be absorbed by a relatively weak sphenotemporal buttress that is formed by the zygoma, the orbital plate of the greater wing sphenoid, and the squamous portion of the temporal bone. If the capacity of this buttress to absorb an impact force is exceeded, fracture dislocations of the lateral orbital wall will result and, at a minimum, comminution will occur at the zygomaticosphenoid suture line (Fig. 58–2A). The orbital plate of the sphenoid bone may be impacted into the orbital apex or even into the middle cranial fossa (Fig. 58–2B). This impaction may cause injuries to structures in the orbit, superior orbital fissure, or optic canal. Reduction of the bony injuries may therefore be necessitated not only by the need to restore the volume of the orbit and the contour of the orbital rim but also by the need to remove bony impingement on vital neurologic structures.[2]

Impact forces centered over the body of the zygoma are transmitted inferiorly through the ZM buttress to the anterolateral wall of the antrum and medially through the orbital process to the inferior orbital rim and the floor of the orbit. The antral wall and the inferior rim suffer a comminuted injury that may result in multiple delicate fragments lying between the ZM suture line and the lacrimal fossa. Similarly, the floor of the orbit almost always suffers a comminuted injury, the severity of which varies with the strength of the impact force. This injury usually involves the concave central portion of the floor. The bone in this area lies 3 mm below the inferior orbital rim and may be as thin as 0.5 mm or less.[1] Posteriorly the floor is convex and posteromedially it slopes upward into the medial orbital wall without a sharp demarcation (Fig. 58–3). High-velocity periorbital impact forces may be transmitted to the convex posterior floor and even to the medial wall, causing serious displacement of the bone in these areas. Although the globe itself rests anterior to the convexity, evaluation and reconstruction of this area and the adjacent medial wall are as important as repair of the more accessible concave anterior portion of the floor.

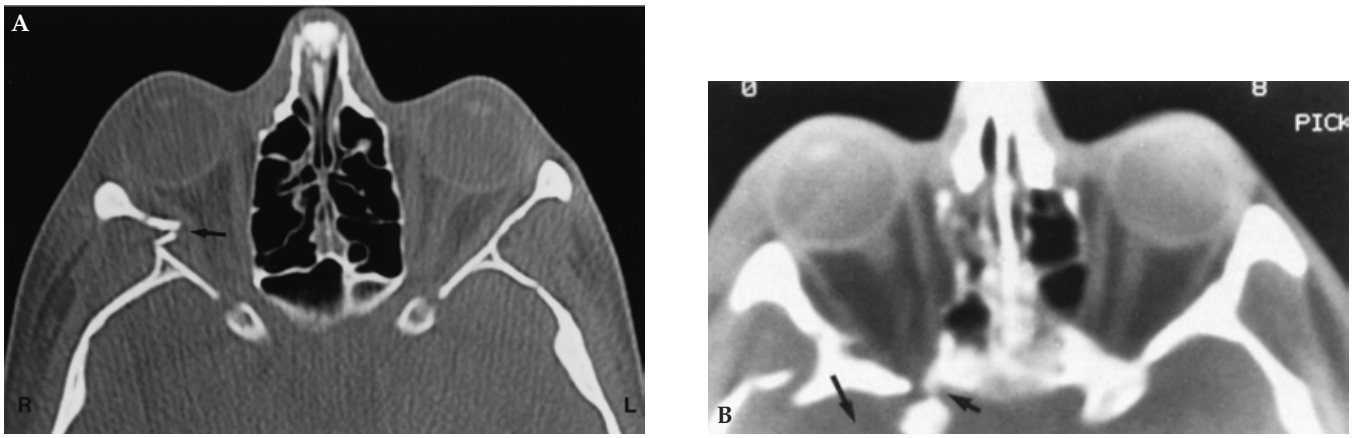

Figure 58–2 **(A)** Comminution of the zygomaticosphenoid suture line (*arrow*), making this an unreliable landmark for overall realignment of an orbitozygomatic fracture. (From Stanley RB. Use of intraoperative computed tomography (CT) during repair of orbitozygomatic fractures. *Arch Fac Plast Surg* 1999;1:19. With permission.) **(B)** CT scan of impacted lateral orbital wall fracture with compromise of both the optic canal (*small arrow*) and middle cranial fossa (*large arrow*). (From Stanley RB. The temporal approach to impacted lateral orbital wall fractures. *Arch Otolaryngol Head Neck Surg* 1988;114:552. With permission.)

Globe Position

The position of the globe is determined by the integrity of the orbital walls and the extensive network of ligaments that suspend it.[4] Recession or depression of the globe within the orbit results from any injury that pushes one or more orbital walls outward and also damages the network of suspensory ligaments. The orbital soft tissues are then displaced by both gravitational forces and the remodeling forces of fibrous scar contracture. This usually changes the shape of the orbital soft tissues from a modified cone to a sphere, and the globe sinks backward and downward.[5] Probably the most common cause of this posttraumatic enophthalmos is the incomplete repair of a defect in the normally convex posterior aspect of the floor or failure to recognize and correct a medial wall component of the injury[12] (Fig. 58–4).

Fractures of the orbital roof usually occur as part of a severe frontobasilar fracture caused by impact forces centered above the orbit. However, patients may have associated panfacial fractures, including unilateral or bilateral orbitozygomatic fractures. The stepwise repair of these craniofacial injuries begins with an accurate anatomic reconstruction of the frontal bar that includes the zygomatic processes of the frontal bone, the supraorbital rims, and the

Figure 58–3 *Arrow* in right orbit points to convex posterior orbital floor. Although the globe rests anterior to this convexity, reconstruction of this area and the adjacent medial wall is essential (see Fig. 58–4).

Figure 58–4 Computed tomography scan shows altered orbital shape and volume resulting from displaced posterior convex floor and adjacent medial wall. Failure to correct both defects will lead to enophthalmos.

glabellar region.[7] After this has been accomplished, the orbitozygomatic complexes can be reattached to the lateral ends of the bar and reconstruction continued. A description of orbital roof reconstruction is best included in a chapter on frontobasilar injuries other than to identify one key difference regarding positioning of bone fragments or bone grafts during the repair of large roof defects. Whereas the goal for reconstruction of the lateral, inferior, and medial walls of the orbit is an exact reconstruction of contour and position, the goal for reconstruction of the roof is to position it higher than its pretrauma level. The normal upward convexity of the roof is difficult to duplicate, and a reconstructed roof that appears to be at the correct level often is too flat, thus pushing the globe inferiorly. This problem is avoided if the rebuilt roof is purposefully attached to the frontal bar slightly above its normal level.

RADIOGRAPHIC EVALUATION

The preoperative choice of the appropriate surgical approach for all but the most minimally displaced orbitozygomatic fractures can be made only if the external and vertical arcs of contour and the lateral, inferior, and medial orbital walls are evaluated by CT. In particular, the horizontal arc must be evaluated with axial CT for comminution of the maxillary component of its medial end and fracture dislocations of the zygomatic arch component of its posterior end. If these injuries are found and the maxillary component of the lower end of the vertical arc is also noted to be comminuted, an exact reconstruction of the orbitozygomatic complex can be achieved only if the zygomatic arch is completely exposed and reduced. Although axial CT provides valuable information concerning the lateral and medial walls of the orbit, coronal CT is essential for evaluation of the orbital floor. This is especially true for the convex posterior floor and the area of sloping of the floor into the medial wall. Fracture dislocations in these areas can be studied in detail and decisions made regarding the need for orbital exploration and repair to prevent delayed enophthalmos. Orbital injuries that can be identified as likely to produce enophthalmos are those in which orbital floor disruption exceeds 2 cm^2, where the bone volume change exceeds 1.5 mL (5% of orbital volume), and where significant fat and soft tissue displacement occurs.[6] In addition, 3 mm of displacement of either the inferior or medial wall will cause an orbital volume change of 7 to 12%. These changes can produce from 2.5 to 4.0 mm of globe displacement if no change in orbital contents occurs.[9]

The surgeon must keep in mind that acute enophthalmos may not be seen in association with severe orbitozygomatic fractures. If the body of the zygoma has remained intact, it may be impacted medially to compensate for the increased orbital volume caused by blow-out fractures of other walls, and the globe may appear to have normal anterior projection and vertical position, or even be proptotic. However, reduction of the zygomatic component of the injury to restore the malar prominence unmasks the traumatic increase in orbital volume and leads to delayed-onset enophthalmos if the other fractures are not treated. Careful review of the axial and coronal CT scans will prevent this error.

SURGICAL TECHNIQUE

Restoration of the External Arcs of Contour

The precise relocation of the displaced zygoma can be greatly simplified if the surgeon concentrates on reconstruction of the two main external arcs of contour. Restoration of the horizontal arc reestablishes anterior and lateral projection of the cheek, and restoration of the vertical arc reestablishes the height of the malar eminence in relation to the middle third of the face. The repositioned zygoma can then be used as a framework for repair of any associated orbital wall fractures. Treatment required to attain multidimensional restoration of the position of the zygoma becomes increasingly complex as the injury to each arc of contour worsens. Together, comminution of the bones with which the zygoma articulates (i.e., the lateral and medial ends of the horizontal arc and the inferior end of the vertical arc) and the amount of displacement of the zygoma itself determine the complexity of the injury and therefore the complexity of the needed repair.

Simple Fractures

Only rare cases involving no comminution of any of the projections of the arcs of contour should be managed with closed-reduction techniques, such as the Gilles method with or without transzygomatic Steinmann pin fixation. If the adequacy of reduction of this type of injury is in doubt because of difficulty in palpating the zygomatic arch and lateral antral wall, a small gingivobuccal sulcus incision may be used for direct visualization of the lateral wall. If this is done, a single 26-gauge interosseous wire can be placed across the reduced fracture line in lieu of the transzygomatic pin to stabilize the zygoma against the downward pull of the musculus masseter. Because any type of limited-access technique relies heavily on palpation and external visualization of the position of the zygoma and its projections, these procedures should be delayed for at least 7 days to allow for maximal resolution of edema. In addition, preoperative steroids may reduce intraoperative edema to further facilitate evaluation of the reduction. The repair should not be delayed more than 10 days, however, because the musculus masseter begins to shorten after this time, making elevation of the zygoma more difficult.

Frequently, the lateral wall of the maxillary antrum is comminuted even when the other projections of the arcs of contour suffer simple fractures or separation of a suture line. In such cases, reconstruction of the lateral wall with wire fixation will be inadequate to resist the pull of the musculus masseter. However, a single rigid craniofacial miniadaptation plate attached across the comminuted area will be sufficient (Fig. 58–5). Because the fixation device is not resisting heavy occlusal forces, as would be the case with a Le Fort fracture, only insertion of two screws into the body of the zygoma above and at the maxilla below is required for stability. In addition, a prebent L-shaped plate may be used to facilitate placement of screws below the fracture lines if there is concern for the root tips of the maxillary teeth.

If the adequacy of reduction is in doubt, another projection of the zygoma can be directly visualized by means of a tunnel dissection superior to the inferior rim, with identification

Figure 58–5 L-shaped miniadaptation plate positioned across the comminuted lower end of the zygomaticomaxillary buttress. In this location, it can serve as the sole means of fixation for the body of the zygoma.

and protection of the infraorbital nerve, or laterally over the malar eminence to expose the zygomatic arch. Adequate reduction can then be confirmed with palpation of the lateral orbital rim and direct visualization of the inferior rim or arch fracture. Thus, the position of the zygoma after less severe injuries can be restored and fixation obtained without violating the lower eyelid, assuming that no serious floor component is present. This avoids the potential iatrogenic injuries most often associated with open reduction of zygomatic fractures, lower lid retraction, and eversion. Even the experienced operator notes occasional increased scleral show or even gross ectropion in a patient who underwent a transconjunctival incision for exposure of the inferior orbital rim, a step that can often be avoided with thorough preoperative CT evaluation.

Complex Fractures

The progression to more complex fractures usually involves comminution of one end or both ends of the horizontal arc of contour (i.e., the inferior orbital rim and zygomatic arch). Traditional three-point reduction restores the entire vertical arc of contour and the medial end of the horizontal arc. Severe comminution of the ZM buttress and the medial aspect of the inferior orbital rim may make this technique inadequate for accurate restoration of the position of the malar prominence. Approximation of the relatively intact bones at the ZF suture moves the point of intersection of the arcs superiorly along the vertical arc to restore the height of contour of the malar prominence to a more normal relationship to the Frankfort plane. However, comminution at the two other points of alignment prevents accurate restoration of the normal anterior and lateral projections of the prominence. Typically, the prominence will be displaced posterior and lateral to its normal location (Fig. 58–6A), and failure to recognize the extent and direction of the displacement at the time of reduction will leave a flattened cheek and a widened face. In these situations, the fourth point of alignment, the zygomatic arch, must be used to reposition the point of intersection of the arcs.[11] The external arcs of contour are geometrically imperfect arcs, most notably the zygomatic arch portion of the horizontal arc. The bone of the middle portion of the arch is actually straight and must be reconstructed as such to properly reestablish anterior projection of the malar prominence (Fig. 58–6B).

Reduction begins with exposure of the ZF suture through a lateral brow or extended upper lid blepharoplasty-type incision or by way of a coronal or hemicoronal incision if the severity of the injury indicates that exposure of the entire length of

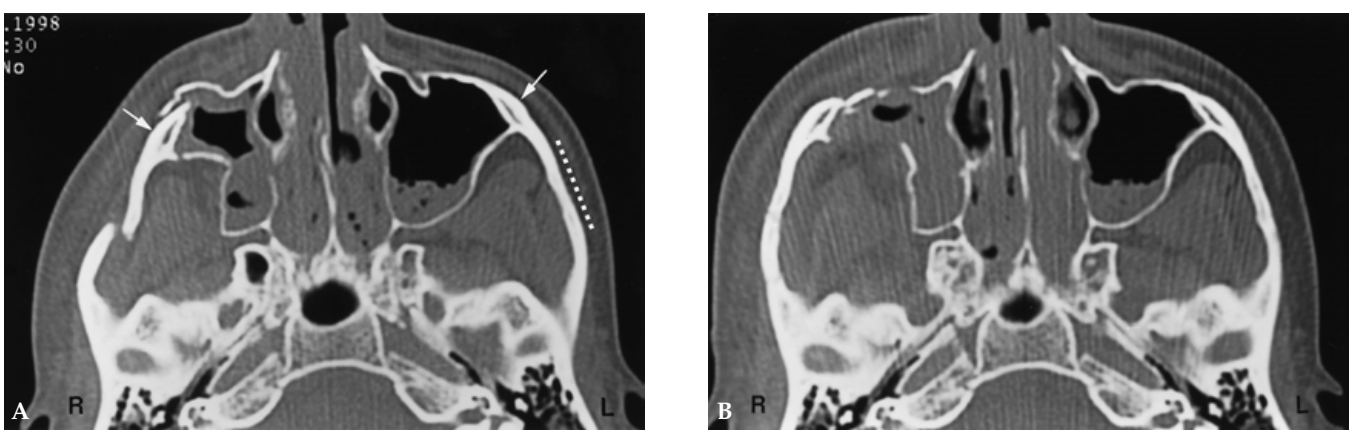

Figure 58–6 **(A)** Correctly positioned axial CT scan showing fracture dislocation of right zygoma with comminution of the medial inferior orbital rim and double fracture of the zygomatic arch. *Dotted white line* on normal side indicates the straight central segment of the arch that must be reconstructed to accurately reposition the malar prominence (*arrow*). **(B)** Postreduction scar of the same patient, showing that the right arch has a contour that now corresponds to the normal left arch. This automatically restores anterior projection of the malar prominence. (From Stanley RB. Use of intraoperative computed tomography during repair of orbitozygomatic fractures. *Arch Fac Plast Surg* 1999;1:19. With permission.)

the zygomatic arch is required. The ZM buttress is exposed through a gingivobuccal sulcus incision, and initial reduction is accomplished by placement of a Dingman elevator deep to the anterior arch and lifting upward and outward. This initial reduction often facilitates placement of the transconjunctival incision for exposure of the inferior rim by bringing the rim fragments into better alignment before incision of the overlying periosteum. In the case of the inferior rim, simple fractures usually cross it in the region of the infraorbital canal, and thus transcutaneous palpation can be used to confirm reduction. However, comminuted rim fractures usually have a component through the medialmost aspect of the rim in the area of the lacrimal fossa. The free-floating central rim fragment is usually depressed and frequently associated with a serious medial orbital floor injury, thus requiring an approach through the lower lid for repair. The transconjunctival incision is the preferred incision for this, and the cornea can be adequately protected during dissection of the deep orbit and placement of large alloplastic or autogenous grafts by the use of traction sutures that pull the bulbar conjunctiva over the globe.

Initial realignment of the zygoma is performed at the ZF suture line. This realignment is held in place temporarily with a single stainless steel wire through holes placed well away from the thick portion of the rim that will later be used for a rigid-fixation implant. Because this temporary wire allows for rotational movement of the zygoma, the point of intersection of the arcs can be appropriately adjusted in the lateral and anterior dimensions. This adjustment is accomplished by realignment of the orbital rim and lateral antral wall fragments. Resistance to the pull of the masseter muscle is again accomplished with a miniadaptation plate positioned over the lower end of the ZM buttress. Additional stability can be obtained with microadaptation (very low profile) plates placed on the inferior rim and across the ZF suture line. Thicker plates at these sites may gradually become visible through the thin overlying skin.

If the inferior rim and lateral wall fragments are too small to manipulate or are missing, the fourth point of alignment, the zygomatic arch, must be used to reposition the point of intersection of the arcs of contour. If the arch has been noted on CT scan to have a single displaced fracture or two green-stick fractures with bending of the arch, dissection may be carried out over the malar eminence through the transconjunctival incision to expose the fractures. If the arch has been noted to have a displaced central segment, then access to the full length of the horizontal arc will be required, and a coronal, hemicoronal, or extended pretragal incision will be necessary in addition to the transconjunctival incision[3,8] (Fig. 58–7). Dissection toward the lateral orbital rim and the zygomatic arch should be in a plane

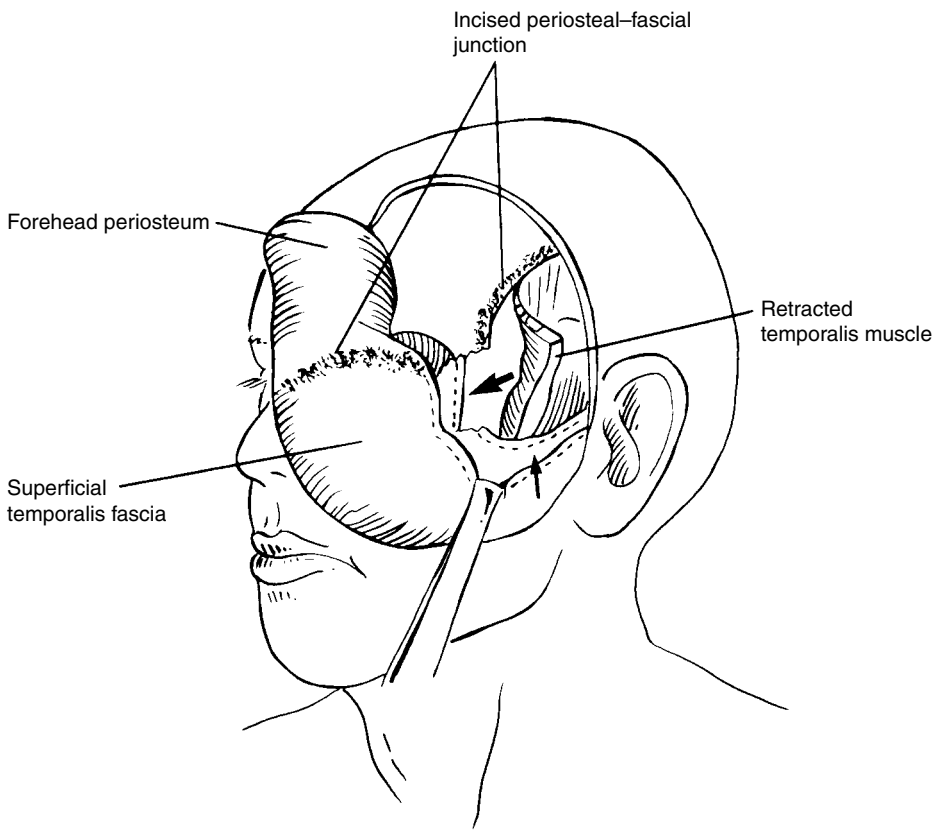

Figure 58–7 Temporal approach to the lateral orbital wall (*large arrow*) and entire length of zygomatic arch (*small arrow*), using a hemicoronal incision and a frontotemporal flap. Elevation of the superficial layer of the two-layered fascia that overlies the m. temporalis protects all branches of the facial nerve. Use of a full bicoronal incision reduces the amount of flap retraction needed for full exposure and further reduces the chances of postoperative neuropraxia of the frontal branch of the nerve. *Dashed line* corresponds to incision of the fascial and periosteal attachments along the orbital rim and zygomatic arch. (From Stanley RB. The temporal approach to impacted lateral orbital wall fractures. *Arch Otolaryngol Head Neck Surg* 1988;114:551. With permission.)

deep to the superficial layer of the deep temporal fascia so that the frontal and orbital branches of the facial nerve are automatically elevated with the flap. The periosteum is then incised along the orbital rim and along the arch fragments deep to the attachment of the superficial layer of this fascia. A subperiosteal dissection is carried over the body of the zygoma to connect with the anterior dissection, and all of the components of the zygomatic arch are exposed.

The zygomatic arch components are elevated and realigned, with emphasis placed on proper realignment of the straight middle portion of the arch. Surprisingly, although the bone of the arch is thin, an accurate end-to-end realignment can usually be obtained to reconstruct the true length of the arch and thus the anterior projection of the malar prominence. Fixation is accomplished with miniscrews and low-profile, multihole miniadaptation plates (Fig. 58–8). Final bending and attachment of the plates are done after the lateral projection of the prominence has been established by realignment of the inferior rim fragments. In the event that these fragments are too small to manipulate or are missing, lateral projection can usually be established by realignment of the ZM buttress. If the bone fragments of the lateral antral wall are also too small or missing, restoration of the lateral projection of the prominence, like the anterior projection, must be based on the accurate restoration of the contour of the zygomatic arch, in particular its straight central portion. Fixation is then applied at the other three points of reduction. The soft tissues must be accurately draped over the repositioned malar prominence. This is best accomplished by simultaneous upward traction on the skin flap and the incised temporal fascia. A tight closure of the fascial incision ensures that the periosteum is held in correct position over the zygoma and arch. Large defects in the inferior orbital rim or the anterolateral wall of the maxillary antrum should be reconstructed with bone grafts to prevent collapse of the soft tissues of the lower eyelid or upper buccal sulcus area into these defects. If the defect is not corrected, subsequent scar contracture may produce a noticeable depression of the lower lid or the midcheek area.

Occasionally, the zygoma will be fractured. Fortunately, the edges of any fracture traversing the body of the zygoma will be broad and strong, making realignment a simple function. After reduction and fixation of the zygoma are accomplished, the remaining fractures of the arcs of contour can be approached as previously described. If extreme difficulty is encountered in

Figure 58–8 **(A)** Preoperative computed tomography scan showing severe comminution of the left zygomatic complex resulting from a gunshot wound. **(B)** Fragments of the lateral orbital rim (1) and zygomatic arch (2) were retrieved from the temporal fossa and parotid gland and realigned out of field. **(C)** Reconstructed segment has been reimplanted with fixation at the zygomaticofrontal suture line (*large arrow*) and the temporal root of the zygomatic arch (*small arrow*). The bony malar prominence has been restored, and the reimplanted bone will serve as a scaffolding as the surrounding soft tissue undergoes contracture invariably seen with this type of wound. This view closely approximates the schematic in Figure 58–7.

mobilizing the zygoma to its correct position even with the extended-access approaches, the musculus masseter can be detached from the zygoma and the zygomatic arch. This is often necessary in patients not treated within the recommended 7 to 10 days. This maneuver should not have long-term effects on jaw mobility or masticatory function, but the additional soft tissue trauma and subsequent scarring may cause accentuation of the prominence of the reconstructed arch, especially if a plate spans the length of the arch. Therefore, surgery for more severe injuries should be undertaken as expeditiously as possible.

Reconstruction of the Orbital Floor

The orbital floor projection of the zygoma usually remains intact and is thus restored to a normal position when the zygoma itself is repositioned. The medial floor (orbital plate of maxilla) can then be reconstructed using the intact lateral floor as a stable landmark. Reconstruction of a defect involving only the concave anterior aspect of the floor can usually be adequately accomplished with an alloplastic implant. Dissection of the floor must completely expose at least two of the opposing quadrants of the defect for stable support of the implant. Of the various alloplasts available, porous polyethylene (Medpor) has many properties that make it an ideal choice.[14] It is readily available, easily trimmable, and tends not to migrate even without fixation of the implant to the orbital rim or residual floor.

Reconstruction of defects of both the concave anterior and convex posterior floor requires an implant with rigidity greater than that offered by Medpor. This is due to the frequent lack of a ledge of residual floor to stabilize the implant posteriorly and medially, even when the orbital floor dissection is carried well into the posterior third of the orbit. Use of Medpor in these cases requires exposure of the medial orbital wall through either a medial canthal or coronal incision so that the material can be draped along the medial wall for support of the floor repair. A graft material that is ideally suited for reconstruction of these larger defects is outer-table calvarial bone. This bone is easily harvested and contoured to match most large floor defects, and its rigidity eliminates the need for medial and posterior support. The graft may be stabilized by attachment to the orbital floor projection of the zygoma with one or two lag screws or to the reconstructed orbital rim with miniplates and screws in a cantilevered fashion (Fig. 58–9). It must be noted that the calvarial bone graft will not restore accurate position of the globe if the surgeon is hesitant in floor dissection and does not venture the sometimes necessary 35 to 40 mm into the posterior third of the orbit to allow for maximal reconstruction of the convex posterior floor.[7] However, the orbital apex must not be compromised by the posterior end of a bone graft. A decrease in orbital apex volume can produce a compressive optic neuropathy with resultant blindness.

Reconstruction of defects that involve the concave anterior floor, convex posterior floor, and medial orbital wall (lamina papyracea) offer the greatest challenge. Although these severe orbital injuries are usually seen as the orbitozygomatic component of panfacial fracture, they may occur as isolated injuries. Complete exposure of the medial wall of the orbit is mandatory and is best accomplished through a coronal incision. Reconstruction is made difficult by the need to restore not only the integrity of walls themselves but the exact relationship of one wall to the other. An accurate restoration of globe position requires restoration of bony orbital volume and shape so that the soft tissues will resume their normal shape and position.[8] The medial wall may also be reconstructed with a cranial bone graft that is cantilevered from the medial superior orbital rim. In some cases, a prefabricated titanium orbital floor plate that acts as a cradle for the multiple bone grafts may be used to facilitate placement stabilization.

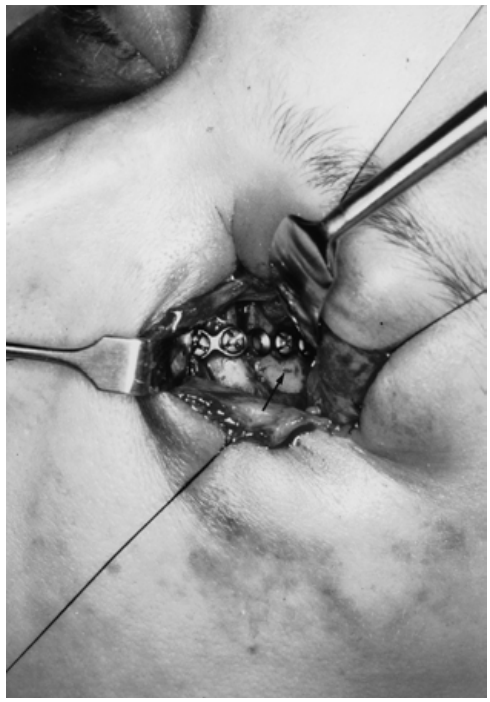

Figure 58–9 Split cranial bone graft (*arrow*) that has been cantilevered from the inferior rim to repair a large blow-out fracture of the orbital floor. Silk sutures have been placed to retract the conjunctiva inferiorly and superiorly over the cornea. (From Stanley RB. Maxillofacial trauma. In: Cummings CW (ed). *Otolaryngology head and neck surgery*. Vol 1. 3rd ed. St. Louis: CV Mosby, 1996. With permission.)

As with orbital floor projection of the zygoma, the zygomatic contribution to the lateral orbital wall almost always remains attached to the body of the zygoma and is correctly rearticulated to the greater sphenoid wing with reconstruction of the arcs of contour. The orbital plate of the sphenoid bone is often comminuted and should not be relied on as a landmark for evaluation of realignment of the zygoma. However, in the event of a displaced sphenoid wing fracture, the intact lateral wall component of the zygoma can be used as a landmark for repositioning the orbital plate of the sphenoid bone. Only rarely will an alloplastic or autogenous graft be needed to reconstruct a lateral wall defect to correct herniation of orbital soft tissues into the temporal and infratemporal fossae. If a high-impact injury produces comminution and displacement of the lateral orbital wall, a split calvarial graft is the ideal graft material. Because a lateral approach must be used to safely expose these retrobulbar bone injuries, the calvarial donor site is already in the surgical field. In addition, a relatively flat area of skull can usually be found to produce a graft that closely matches the contour of the lateral orbital wall.

The use of a transconjunctival incision rather than a subciliary incision has eliminated the need for a Frost suture

to suspend the lower eyelid from the forehead during early healing. However, when the soft tissues overlying the inferior orbital rim, malar prominence, and anterior maxillary wall have been completely elevated during reconstruction, slow-absorbing suspension sutures should be placed from the periosteum of the cheek tissues to the reconstructed rim. This pulls the elevated tissues superiorly to ensure that the infraorbital soft tissues redrape appropriately over the underlying skeleton. Periosteum that is incised during orbital floor exploration is not sutured so that the chance of tethering the orbital septum to the reconstructed rim is reduced.

Low-profile (1.0- or 1.3-mm) titanium plates should not be visible under the skin of the lateral orbital rim and zygomatic arch. Therefore, these fixation devices can be left in place permanently. A plate positioned on the inferior rim may, however, produce an irregular contour visible through the thin skin of the lower eyelid. Therefore, it is preferable not to use rigid fixation devices on the inferior orbital rim unless absolutely necessary for stability of the reconstruction. If such a plate is placed and is visible after healing is complete, a second surgical violation of this lower lid to remove the plate exposes the patient to an even higher risk for lid complication.

Evaluation of Ocular Injuries

Obtaining a complete preoperative ophthalmologic evaluation of every victim of an orbitozygomatic fracture is an unrealistic expectation and by no means mandatory. However, the reconstructive surgeon must be sensitive to the possibility of direct ocular trauma and obtain proper consultation when indicated. A minimal preoperative examination should include testing of visual acuity (subjective and objective in both eyes), pupillary function, and ocular motility; inspection of the anterior chamber for hyphema; and visualization of the fundus for gross disruptions. A decrease in visual acuity or abnormality noted on the other phases of this screening examination warrants a more detailed examination by an ophthalmologist before reconstruction of the bony injuries is undertaken. Occasionally, an ocular injury may prevent treatment of the bony injuries if any manipulation of the globe might worsen the ocular injury and precipitate total loss of vision in the eye. The potential hazards of orbital reconstruction around an only-seeing eye must be recognized by the surgeon and explained in detail to the patient. In general, reconstruction should be limited to returning the globe to a functional position in cases involving severe disruption of the orbit and marked displacement of the globe. Bone grafting should be directed to providing basic support for the globe rather than to total reconstruction of the orbital volume and shape. Intraoperative tonometry and funduscopic examination should be considered in these cases and in all other cases in which large implants are placed in the posterior orbit. Occasionally, forward positioning of the globe by an oversized implant causes an acute increase in intraocular pressure, and the implant must be removed and reduced in size.

SUMMARY

Fractures of the bones that provide support for the globe and the soft tissue contours of the cheek must be evaluated thoroughly and treated aggressively if posttraumatic deformities are to be avoided. The trauma surgeon should use detailed preoperative CT to formulate a complete treatment plan before beginning the reconstruction. Reduction and fixation of each fracture line or fracture dislocation should not be viewed in a segmentalized fashion but rather as a progressive step in reconstruction of the entire orbitozygomatic complex as a single unit. However, the surgeon should not attempt these procedures without a thorough understanding of the anatomy of the bony and soft tissue structures of the orbital and periorbital areas and also the ability to three-dimensionally conceptualize the reconstruction while it is in progress.

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Chapter 59

Frontal Sinus and Nasoorbitoethmoid Complex Fractures

E. Bradley Strong and Jonathan M. Sykes

The anterior wall of the frontal sinus is extremely resilient to injury. Incidents involving high-velocity impact, such as motor vehicle accidents, gunshots, and sports injuries, may result in frontal sinus (FS) and nasoorbitoethmoid (NOE) complex fractures. The anatomy and surgical treatments for FS and NOE fractures are distinct; however, the surgical proximity of these two areas warrants a combined discussion. Patients with FS and NOE complex fractures often have multiple associated injuries. The initial evaluation should be focused on airway maintenance and hemodynamic stability. After the patient is stabilized, the brain, spine, orbits, and facial skeleton should be evaluated. This requires a team approach involving the facial plastic surgeon, neurosurgeon, and ophthalmologist. The goal of FS and NOE complex fracture treatment is avoidance of short- and long-term complications as well as the return of normal sinus function and aesthetic facial contour. A treatment algorithm for FS injuries will be presented, and the surgical technique for repair of both FS and NOE complex fractures will be reviewed.

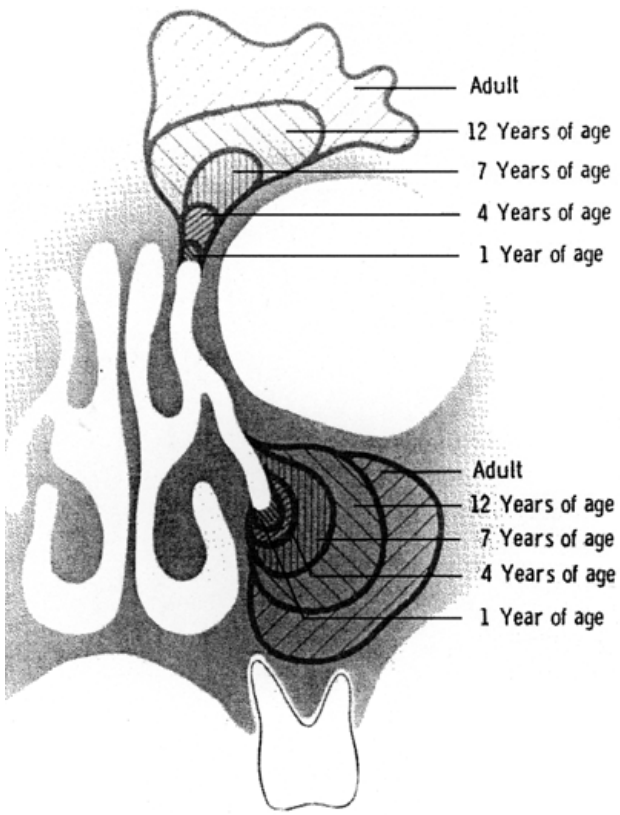

Figure 59–1 Frontal sinus development. (From Nauman HH. Development of the frontal sinus. In: Nauman HH (ed). *Head and neck: indications, techniques, and pitfalls*. Vol 1. Philadelphia: WB Saunders, 1980. With permission.)

FRONTAL SINUS

Embryology/Anatomy

The FS is absent at birth. At 2 years of age, the anterior ethmoid cells invade the frontal bone to form a rudimentary cavity. By 6 years of age, the FS can be detected radiographically. At 15 years of age, the FS is adult-sized (Fig. 59–1). The FS is pyramidal in shape with the base located inferiorly and the apex superiorly. The floor of the sinus forms the medial portion of the orbital roof. The posterior table forms a portion of the anterior cranial fossa. The anterior table forms part of the forehead, brow, and glabella[1,2] (Fig. 59–2). The FS is most commonly bilateral, asymmetrical, and divided by one or more intersinus septations. However, the size and shape of the adult FS is highly variable. Ten percent of individuals have only a unilateral sinus, 5% have a rudimentary cavity, and 4% have no sinus at all.[3] The average dimensions are as follows: height 30 mm, width 25 mm, depth 19 mm, and volume 10 cm^3. The anterior table thickness may be as great as 12 mm (average 4 mm), whereas the posterior table ranges in thickness from 0.1 to 4.8 mm.[4]

The nasofrontal recess (NFR) is the sole drainage site for the FS. Each ostium is approximately 3 × 4 mm in diameter and located on the posterior inferior aspect of the sinus floor. The ostium lies anterior to the anterior ethmoid air cells, medial to the orbit, lateral to the intersinus septum, and posterior to the frontal bone. The true ostium represents the narrowest point of an hour-glass configuration. The FS infundibulum narrows down to the true ostia, and the NFR widens out below the ostia.[5] The drainage pathway from the frontal sinus to the hiatus semilunaris is short in 85% of individuals. It is therefore most accurately described as a recess rather than a true duct.

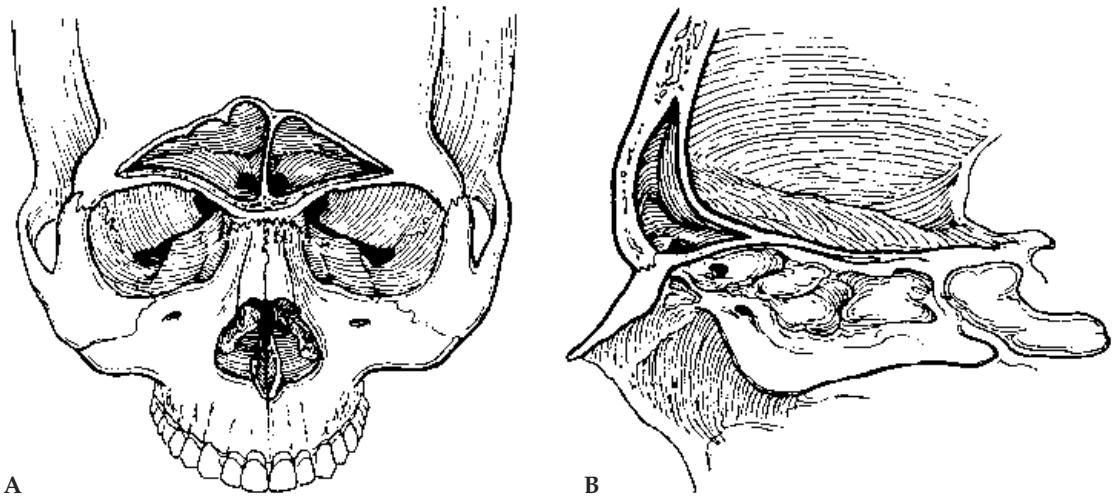

Figure 59–2 Anterior **(A)** and lateral **(B)** views of the frontal sinus demonstrating the relative thickness of the anterior and posterior tables, as well as the relationship of the frontal sinus to the orbits, ethmoid sinuses, and anterior cranial fossa. (From Donald PJ. *Maxillofacial trauma: management of the difficult case*. Philadelphia: WB Saunders, 1984. With permission.)

The vascular supply to the FS is from the supraorbital and supratrochlear arteries via the internal carotid system. Venous drainage occurs through three pathways: the facial vein, the ophthalmic vein (to the cavernous sinus), and the foramina of Breschet (to the subarachnoid space).[6] The ophthalmic branch of the trigeminal nerve provides sensory innervation to the FS.

Frontal Sinus Fractures

The FS is protected by thick cortical bone and is more resistant to fracture than any other facial bone[7] (Fig. 59–3). FS fractures account for only 5 to 15% of maxillofacial injuries and are most commonly associated with motor vehicle accidents, sporting events, and assaults.[8] The extreme force required to fracture the anterior table of the FS results in serious associated injuries in 75% of patients.[9] Sixty-six percent of patients have associated facial fractures.[10] Mortality rates as high as 25% have been reported with severe through-and-through injuries.[10] Isolated anterior table fractures occur in approximately 33% of these injuries. Combined fractures of the anterior table, posterior table, or the NFR account for approximately 67% of frontal sinus injuries.[11] Isolated posterior table injuries are uncommon.

The accurate diagnosis of FS fractures and NFR injuries is crucial to the appropriate treatment. Improper management can result in aesthetic deformity, chronic sinusitis, pneumocephalus, mucopyocele, meningitis, and brain abscess. Unfortunately, treatment of FS fractures remains one of the more controversial areas of maxillofacial trauma. Complications can occur years after the injury, and long-term follow-up is often difficult. Consequently, a surgeon may be proficient in a particular surgical technique and have few known complications. However, the same surgeon may have a long list of cases handled "elsewhere" that ultimately result in mucocele formation. Surgeons must continue to be diligent and emphasize long-term follow-up of FS injuries.

Pathophysiology

The FS is lined with pseudostratified, ciliated columnar epithelium. When injured, the FS mucosa has a unique propensity to become entrapped and form mucoceles. Muco-

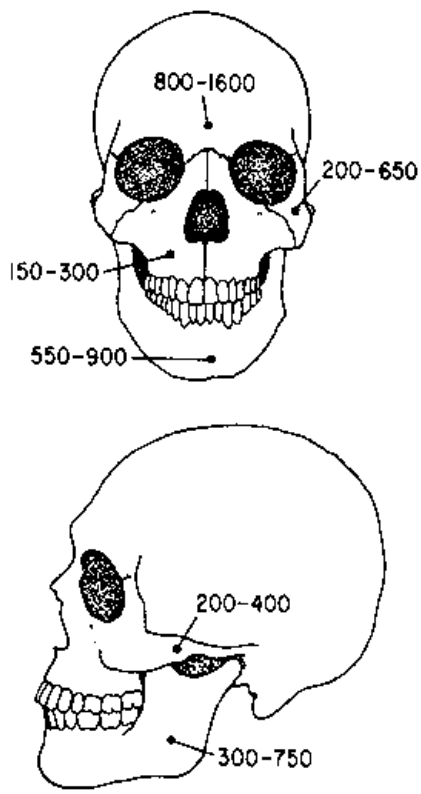

Figure 59–3 Force (pounds) necessary to fracture different facial bones. (From Nahum AM. The biomechanics of maxillofacial trauma. *Clin Plast Surg* 1975;2:63. With permission.)

celes enlarge, erode bone, and may progress to osteomyelitis, meningitis, or brain abscess. When surgically treating FS fractures with frontal sinus abliteration cutting and diamond burrs must be used to meticulously remove all mucosal remnants. The mucosa must also be removed from all free-bone fragments prior to reduction. Mucosa trapped within the foramina of Breschet may result in mucocele formation years later. The need for long-term follow-up cannot be overemphasized.

Diagnosis

After the patient has been stabilized and any associated injuries have been diagnosed and treated, a thorough head and neck examination should be performed. Patients with FS fractures often complain of forehead pain and swelling. Forehead lacerations should be examined under sterile conditions to assess the integrity of the anterior table, posterior table, and dura. Through-and-through injuries of the FS carry a grave prognosis, and prompt surgical debridement is indicated. Other findings that may suggest a FS injury include supratrochlear and supraorbital paresthesias, epistaxis, diplopia, forehead abrasions, and forehead hematoma. The patient must be questioned regarding the presence of clear rhinorrhea or salty postnasal drainage. Fluid suspicious for cerebrospinal fluid (CSF) rhinorrhea can be grossly evaluated with a "halo test." The bloody fluid is allowed to drip onto filter paper. If CSF is present, it will diffuse faster than blood, resulting in a clear halo around the blood. The fluid may also be sent for routine chemistry analysis. An elevated glucose content is consistent with CSF. The definitive test for CSF is β_2-transferrin. The presence of β_2-transferrin is very specific for CSF. The only other locations β_2-transferrin is found is the vitreous humor of the eye and perilymph of the inner ear.

Radiography

A thin-cut (1.5-mm) axial and coronal computed tomography (CT) scan is the gold standard for diagnosis of FS fractures. The axial images accurately localize the location and severity of both anterior and posterior table fractures. Gross assessment of dural integrity can be inferred from the presence or absence of pneumocephalus. The coronal cuts provide a detailed image of the FS floor and orbital roof. Unfortunately, the compact anatomy of the NFR makes accurate fracture diagnosis in this area difficult. Midline fractures that track toward the sinus floor may require surgical exploration for accurate diagnosis.

Treatment

The management goals for FS fractures include (in decreasing order of importance): protection of intracranial contents, prevention of early and late complications, restoration of aesthetic forehead contour, and return of normal FS function. Accomplishing all of these goals is not always possible. However, reconstruction of a "safe" sinus is imperative. After this has been accomplished, the aesthetic and functional repair can be addressed. Specific treatment options include observation, open reduction and internal fixation, sinus obliteration, sinus exenteration (Riedel procedure), and sinus cranialization.

TABLE 59–1 Frontal Sinus Fracture Evaluation: Anatomical Parameters

Anterior table fracture
Nasofrontal recess fracture
Posterior table fracture
Dural tear (cerebrospinal fluid leak)
Fracture displacement/comminution

Fracture Classification

FS fractures can be classified by anatomic sight, severity of injury, and presence of CSF leak. Appropriate treatment decisions can be made by the assessment of ***five anatomic parameters*** (Table 59–1). In the clinical setting, these parameters are most easily remembered by conceptually moving through the sinus from anterior to posterior. The parameters include the presence of (1) an anterior table fracture, (2) a nasofrontal recess fracture, (3) a posterior table fracture, (4) a dural tear (cerebrospinal fluid leak), and (5) degree of fracture displacement/comminution.

Nasofrontal Recess Fractures (Fig. 59–4)

The compact structure of the NFR makes accurate diagnosis of isolated NFR fractures difficult. A thorough physical examination with nasal endoscopy should be done and a thin-cut CT scan obtained. Fractures involving the floor of the FS or the anterior ethmoid region should raise suspicion for NFR injury.[12] In the absence of fracture displacement or associated FS injuries, close observation and a repeat CT scan at 4 to 6 weeks may reveal sinus opacification indicating outflow obstruction. If associated fractures track toward the NFR or the suspicion for a significant NFR injury is high, a frontal sinusotomy and endoscopic evaluation should be performed.

Displaced NFR fractures usually require FS obliteration. Some authors have advocated more conservative approaches, including NFR reconstruction with mucoperiosteal flaps (Sewell-Boyden). An intersinus septectomy has also been described for unilateral injuries. This theoretically allows the injured sinus cavity to drain into the uninjured NFR.[13,14] These techniques have not been proven efficacious or gained significant popularity.

Frontal Sinusotomy and Endoscopy: Technique

After infiltration of local anesthesia, a 1.0- to 1.5-cm skin incision is placed midway between the medial canthus and the glabella, approximately 1 cm inferior to the brow (Fig. 59–5). The incision is well hidden if placed inferior and deep to the curve of the brow. A guarded needlepoint monopolar electrocautery is used to expose the periosteum. Care is taken to avoid the supratrochlear neurovascular pedicle. The location of the FS is confirmed on the CT scan, and a large cutting burr is used to open a 4- to 5-mm frontal sinusotomy approximately 1 cm medial and inferior to the medial brow. The mucosa is incised sharply, and oxymetazoline may be instilled for decongestion if necessary. Direct visualization of the NFR can usually be performed with a nasal endoscope.

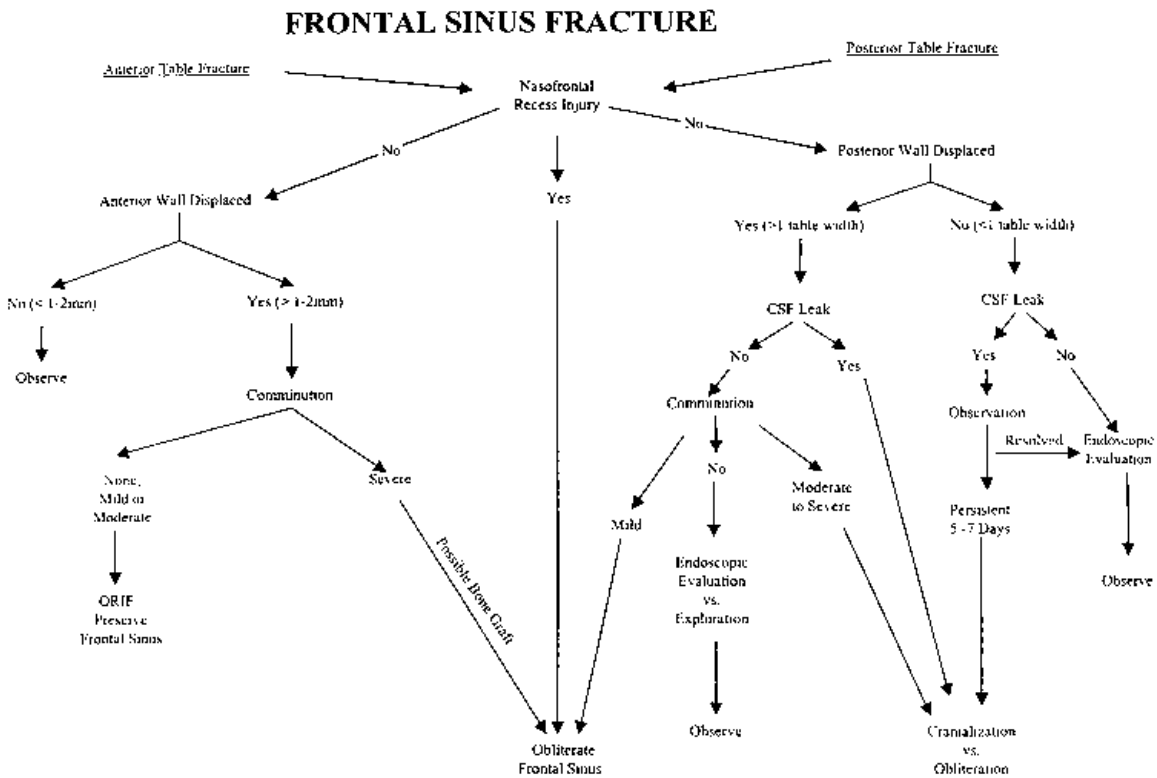

Figure 59–4 Algorithm for treatment of frontal sinus fractures.

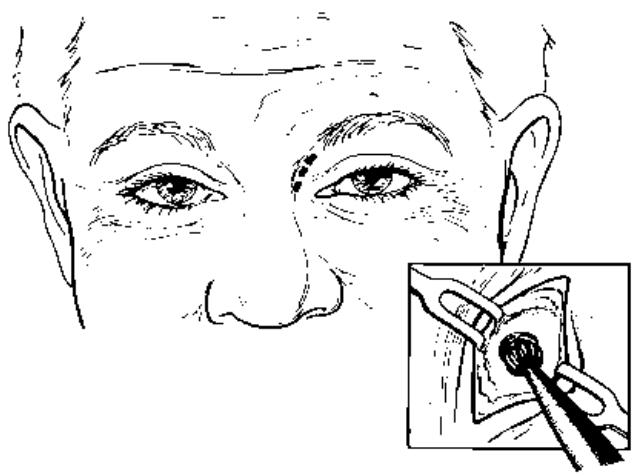

Figure 59–5 Illustration of frontal sinus trephination.

Nasofrontal recess instrumentation should be avoided because it could result in NFR stenosis. Methylene blue or fluorescein can also be instilled into the FS to confirm patency of the drainage pathway. Intranasal endoscopy will reveal the presence of dye if the NFR is patent.[15] A meticulous layered closure is then performed. The procedure can be performed bilaterally if necessary.

Anterior Table Fractures (Fig. 59–4)

Nondisplaced Fractures

Isolated, nondisplaced fractures of the anterior table pose little risk of mucocele formation and rarely result in aesthetic or functional deficit. These injuries are best managed nonoperatively. The small risk of external deformity should be discussed with the patient. If minor contour irregularities occur, they can often be repaired endoscopically after complete resolution of forehead edema.

Displaced Fractures

Displaced fractures of the anterior table may not be apparent immediately after the injury because of soft tissue swelling or hematoma. However, significant displacement of the anterior table (greater than 1 to 2 mm) places the patient at an increased risk for aesthetic deformity. If the decision is made to repair these injuries, they should be explored within 7 to 10 days and repaired with open reduction and internal fixation.[16] Anterior table fractures with minimal or mild comminution can be repaired with preservation of FS function. Injuries with severe comminution and marked mucosal injury may require bone grafting and FS obliteration.

Open Reduction and Internal Fixation: Technique

The patient is counseled regarding the risks of bleeding, infection, paresthesia, CSF leak, meningitis, external deformity, and

Figure 59–6 Coronal scalp incision placed 4 to 6 cm behind the hairline.

late mucocele formation. The coronal incision must be described in detail, particularly in patients with male pattern baldness. In the operating room, the bed is turned 180 degrees away from anesthesia and a coronal flap is designed by parting the hair in a "widow's peak" pattern at least 4 to 6 cm behind the anterior hairline (Fig. 59–6). A 1- to 2-cm strip of hair can be shaved along the incision site, but this is not necessary. Brow incisions should be avoided due to the prominent scar and associated forehead anesthesia. If large lacerations are already present on the forehead, they should be explored and used for fracture repair if possible. However, forehead lacerations are often inadequate for exposure, diagnosis, and repair of FS fractures. Extension of lacerations on the forehead should generally be avoided.

After injection of local anesthetic, the scalp is incised and elevated in a subgaleal plane with scissors, scalpel, or finger dissection. Lateral dissection of the flap must be meticulously performed between the temporoparietal fascia (superficial temporal fascia) and the temporalis muscle fascia (deep temporal fascia) (Fig. 59–7). The temporoparietal fascia and frontal branch of the facial nerve are elevated with the flap. As the dissection nears the superior orbital rims, the supraorbital and supratrochlear neurovascular pedicles should be identified and protected. The pericranium is then incised 1 to 2 cm above the sinus and elevated below the fracture. If there is any concern about a posterior table injury or dural tear, the entire pericranial flap should be elevated from the coronal incision. The vascularized pericranial flap may then be used for a dural repair if necessary.

The frontal sinus has an intrinsic convex shape. As a perpendicular traumatic force is applied to the frontal sinus, the convex shape is flattened. The bone is horizontally compressed until it fractures, whereupon it releases into a concave shape (Fig. 59–8). Reduction of these concave, compressed fractures can be difficult. If the segments overlap at the fracture site, a bone hook can be insinuated between the fragments and pulled forward. If the bone fragments do not overlap, reduction can be accomplished by placing a 1.5- to 2.0-mm screw in the depressed segment, grasping the screw with a hemostat, and pulling the segment anteriorly (Fig. 59–9). It is often necessary to carefully remove a fragment of bone along the fracture line to release the tension and make room to reduce the remaining bone fragments. An attempt should be made to keep the majority of fragments in place. This will allow a more accurate bony reduction. Missing bone is uncommon. However, high-velocity injuries may result in small, comminuted fragments, which cannot be reapproximated. Gaps larger than 5 mm are reconstructed with split calvarial bone grafts and bone paté harvested from the frontal bone with a cutting burr. Other techniques for anterior table reconstruction include titanium or resorbable mesh.

After the fracture is reduced, any torn mucosa should be removed from fracture lines to avoid entrapment. The FS infundibulum should be inspected endoscopically if necessary.

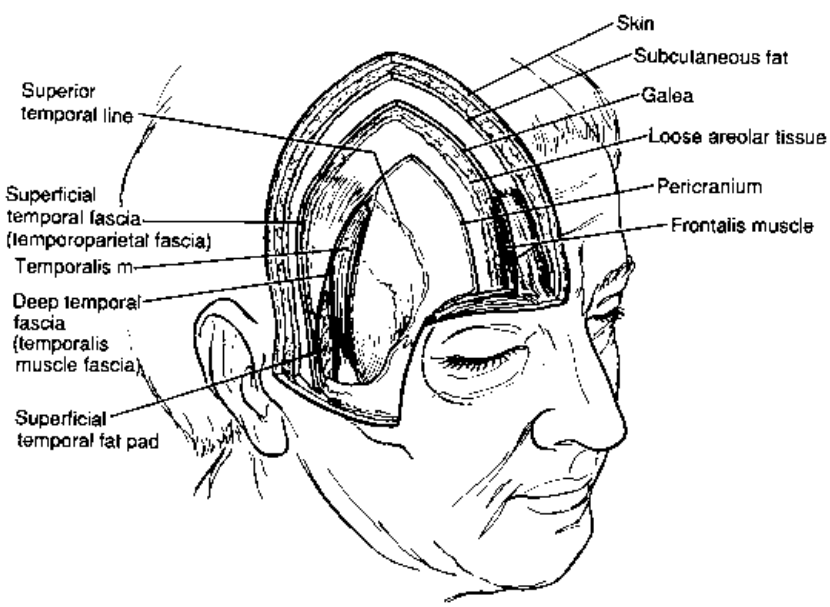

Figure 59–7 Illustration depicting the fascial planes of the forehead and temple. The temporal branch of the facial nerve runs within the superficial temporal fascia (temporoparietal fascia). (From Sykes JM. Applied Anatomy of the Forehead and Brow. *Fac Plast Surg Clin North Am* 1997;5:111.)

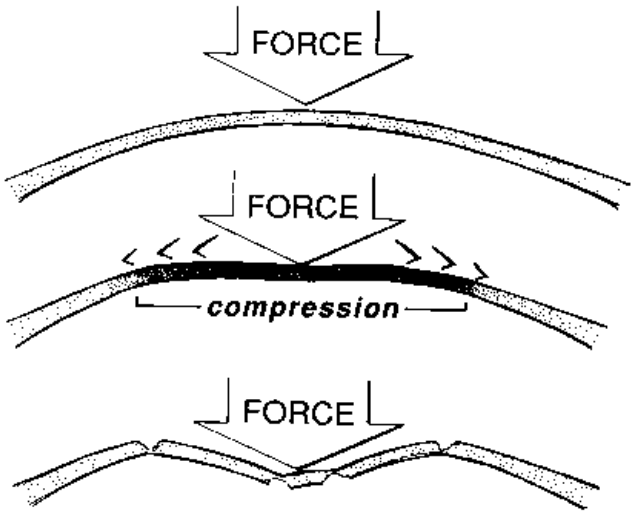

Figure 59–8 Illustration of the compressive forces on frontal sinus bone as it is deformed from a convex shape to a concave shape.

Figure 59–9 Intraoperative photo of a single miniscrew placed in the anterior table bone and used to reduce/stabilize the fracture fragments while rigid fixation was applied.

The reduced fragments are then plated with 1.0- to 1.3-mm microplates. The pericranium is sutured closed, followed by the galea aponeurosis and skin. Careful attention is paid to the galeal closure to obtain hemostasis and avoid hematoma. Bilateral Penrose drains are placed beneath the scalp, exiting the coronal incision above each ear. A pressure dressing is applied. Care should be taken to assure that the ears are not rolled forward under the pressure dressing. The Penrose drains are removed at 24 hours, the pressure dressing discontinued at 3 days, and the skin sutures and staples removed at 10 days.

Posterior Table Fractures (Fig. 59–4)

Treatment of posterior table fractures remains controversial.[9,10,15] There are no prospective, randomized studies to corroborate the different approaches and techniques. A review of the literature reveals articles that support exploration of all posterior table fractures,[17] as well as those that recommend observation of even displaced posterior table fractures.[14] An algorithm is shown that incorporates minimally invasive endoscopic evaluation with traditional sinus obliteration when indicated.

Nondisplaced Fractures

Nondisplaced posterior table fractures (less than one table width) are felt to have a reduced risk of complications (dural tears, CSF leak, meningitis, and mucocele formation), when compared with displaced posterior table fractures.[16] Therefore, nondisplaced fractures can be managed more conservatively. The patient should be questioned for the presence of clear, watery drainage from the nose or salty-tasting drainage into the nasopharynx. Patients with no evidence of CSF leak but with a confirmed central posterior table fracture can undergo frontal sinusotomy and endoscopic evaluation. Sinus endoscopy will help to rule out mucosal injury, dural tear, CSF leak, or NFR injury. If the results of the examination are negative, the patient is observed. Peripheral frontal sinus fractures may be difficult to visualize endoscopically due to intersinus septations. Most patients are observed; however, a lower threshold for surgical exploration should be maintained if the fracture cannot be examined endoscopically.

Nondisplaced fractures with a confirmed CSF leak may be observed for 5 to 7 days. Approximately half of these patients will have spontaneous resolution of the CSF leak.[3,14] Endoscopic confirmation of the leak closure and assessment of the posterior table, dura, and NFR should be considered prior to discharge. If the CSF leak is persistent, a cranialization or obliteration procedure is indicated, depending on the degree of injury noted at the time of surgery.

Displaced Fractures

Displaced fractures (Fig. 59–10) require a more aggressive approach because the risk of long-term complications is high. The presence of a CSF leak should be carefully evaluated.

No CSF Leak

Patients without a CSF leak should be categorized by the severity of posterior table comminution. Centrally located noncomminuted fractures can undergo sinusotomy and endoscopic evaluation to confirm the extent of mucosal injury, bony disruption, and NFR involvement. The patient should consent for an osteoplastic flap with possible obliteration or cranialization in case the injury is more severe than anticipated. A lower threshold for open exploration should be maintained for injuries that cannot be inspected endoscopically. In the absence of significant mucosal lacerations, CSF leak, or NFR involvement, any associated anterior table fractures should be reduced and the sinus function preserved. Mild comminution noted on the CT scan is an indication for an osteoplastic flap and sinus obliteration. Moderate to severe comminution, involving more than 30% of the

Figure 59–10 Axial CT scan demonstrating a comminuted anterior and posterior table frontal sinus fracture.

posterior table, is an indication for cranialization of the sinus.[13] After removal of the posterior table, the intracranial contents move forward and obliterate the frontal sinus space. The external contour is maintained by reconstruction of the anterior table with bone grafts from the anterior table, posterior table, and outer-table calvarial bone grafts (when necessary). Neurosurgical consultation should be obtained for assistance with brain debridement and dural closure.

CSF Leak

Patients noted to have CSF leaks and displaced posterior table fractures should undergo open exploration with an osteoplastic flap and either obliteration or cranialization if more than 30% of the posterior table is involved.

Frontal Sinus Obliteration: Technique

The patient gives informed consent after having been apprised of the risks of bleeding, infection, paresthesia, CSF leak, meningitis, diplopia, external deformity, and late mucocele formation. Preoperatively, an anteroposterior plain radiograph (Caldwell view) of the skull is obtained. The patient should be positioned 6 feet from the film to avoid magnification of the image. Alternatively, a surgical navigation system can be used intraoperatively to localize the sinus. The patient is prepared for a coronal flap (see the section Open Reduction and Internal Fixation earlier in this chapter) and the abdomen prepped for a fat graft. While the patient is being positioned, the orientation of the Caldwell x-ray is confirmed by comparison with the CT scan. A template is then cut in the shape of the FS. Lateral "wings" paralleling the orbital rims are cut into the template to assist with orientation of the radiograph intraoperatively (Fig. 59–11). An "R" is scratched into the template on the right side to avoid incorrect orientation of the template intraoperatively. A second template is usually cut in case one copy is contaminated during the procedure. Then both templates are sterilized.

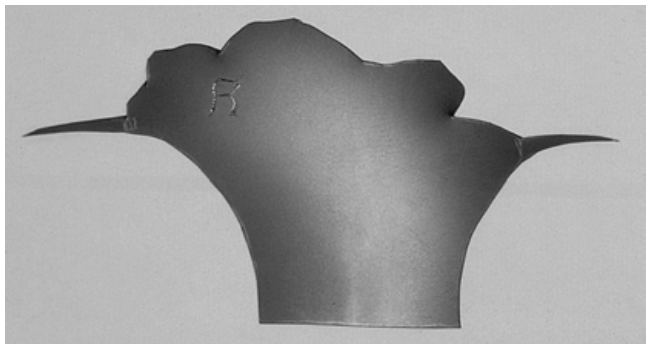

Figure 59–11 Frontal sinus template cut from "six-foot penny Caldwell" x-ray film and sterilized for intraoperative localization of the frontal sinus. Note the lateral "wings" paralleling the orbital rims, which help to correctly orient the template over the sinus.

A coronal incision is performed leaving the pericranium intact. The scalp flap is elevated to the orbital rims in a subgaleal plane. If the anterior table of the FS is not comminuted, the FS template is applied and an outline of the FS is tattooed on the bone with an 18-guage needle and methylene blue. The pericranium is then incised along the coronal scalp incision. Parallel lateral cuts are made along the temporal line and a large, inferiorly based pericranial flap is raised. Care should be taken to maintain a wide pedicle and avoid perforation of the flap because unexpected posterior table injuries may require the pericranial flap to be used for dural closure. If a significant dural tear is anticipated, the pericranial incision can be moved 4 to 5 cm posteriorly to obtain additional length. Midline pericranial flap elevation should continue to approximately 1 cm below the outline of the FS. Traditionally, a drill is used to perforate the outline of the flap. The drill should be angled toward the sinus cavity to avoid intracranial penetration and injury. The perforations are then joined with an oscillating saw. The sinusotomy can be performed more efficiently with a high-speed Midas Rex drill and a B-1 bit, obviating the need for an oscillating saw.

A 4-mm osteotome is then used to fracture the superior orbital rims and glabella at the periphery of the sinus. Care should be taken to avoid injuring the supraorbital and supratrochlear neurovascular pedicles. An osteotome is then placed through the saw kerf and the intersinus septum is fractured. This step is repeated around the periphery of the sinus with multiple osteotomes until the anterior table of the sinus is hinged open inferiorly. The use of multiple osteotomes allows the surgeon to repeatedly place a new osteotome without losing the purchase from the previous one. If the anterior table is comminuted, formal osteotomies are often unnecessary and preservation of the pericranial flap can be more difficult.

After completion of the sinusotomy, posterior table comminution is assessed and a decision made regarding sinus obliteration or cranialization. If the sinus is to be obliterated, meticulous debridement of all mucosa is accomplished with both cutting and diamond burrs. A malleable retractor should be placed behind the posterior table to protect the dura while larger posterior table fractures are being demucosalized.

The FS infundibulum mucosa is elevated inferiorly and a temporalis muscle plug is placed to occlude each ostium. The fat graft is obtained through a periumbilical incision using a sterile set of instruments. When the osteoplastic flap is replaced, the fat should meet but not extrude into the saw kerf. Other materials used for frontal sinus obliteration include cancellous bone, muscle, and pericranium. Spontaneous osteoneogenesis with auto-obliteration has also been described.[3] Bone stabilization is achieved with 1.0- to 1.3-mm plates. Bone paté is harvested from the frontal bone and collected on a wet tongue blade. The paté is used to fill the osteotomy and bony defects in the anterior table, avoiding postoperative step-off deformities. Compressed Gelfoam is then placed over the paté to avoid displacement. The pericranium and scalp are then closed in layers.

Frontal Sinus Cranialization: Technique

The surgical approach to cranialization is identical to that described for FS obliteration. These injuries are often more severe, and the pericranium is usually lacerated at the glabella. Special care should be taken to avoid further injury to the inferiorly based pedicle because the pericranial flap may be needed for closure of dural tears. Exposure of the sinus rarely requires osteotomies due to the severity of the anterior table injury. Any free-bone fragments from the posterior table are removed and the dura is inspected. Simple lacerations of the dura can be repaired with interrupted 5-0 nylon sutures. More complex injuries may require neurosurgical debridement and dural closure. The remaining portion of the posterior table bone is then removed using elevators and rongeurs. Large pieces of posterior table bone should be preserved for reconstruction of the anterior table during closure. All fragments of the anterior and posterior table are divested of mucosa with cutting and diamond burrs. Through-and-through injuries are often grossly contaminated with road dirt. In such cases, the bone fragments should be soaked in Betadine until needed for reconstruction. The posterior table bone is then drilled flush with the anterior sinus walls, floor, and anterior cranial fossa. Each FS infundibulum is drilled out, the mucosa is inverted, and the ostia are occluded with a temporalis muscle plug. The pericranial flap can then be used to repair dural tears or fill dead space. A small bony defect must be fashioned in the anterior table to allow the pericranial flap to pass intracranially without cutting off the blood supply. The preserved bone fragments are then cleaned with saline and the anterior table is reconstructed using 1.0- to 1.3-mm microplates. Outer-table calvarial bone grafts should be used as necessary to supplement native bone. The intracranial contents are then allowed to expand forward and fill the FS space (Fig. 59–12).

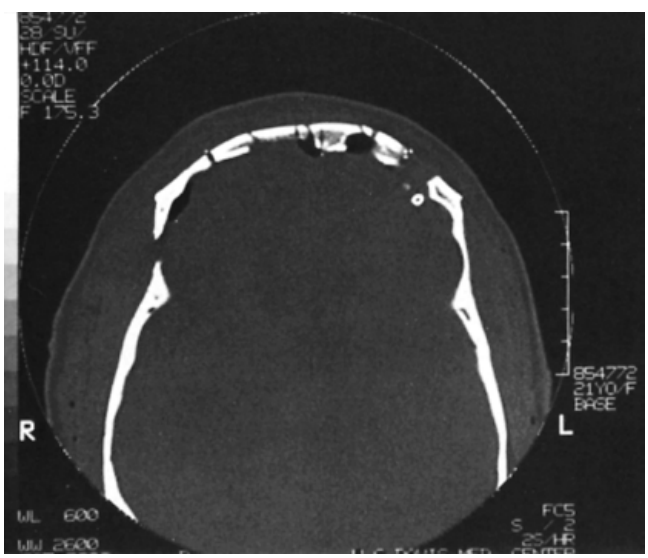

Figure 59–12 Axial CT scan demonstrating previous frontal sinus cranialization and anterior displacement of the intracranial contents to fill the frontal sinus dead space.

NASOORBITOETHMOID COMPLEX FRACTURES

Anatomy

The NOE complex represents the confluence of the nasal, lacrimal, ethmoid, maxillary, and frontal bones. The paired nasal bones attach to the frontal bone superiorly and the frontal process of the maxilla laterally. The ethmoid bone is located posterior to the nasal bones. The ethmoid labyrinth separates the orbits laterally from the nasal cavity medially. The fovea ethmoidalis forms the roof of the ethmoid sinuses laterally. The cribriform plate, which is approximately 1 cm inferior to the fovea ethmoidalis, forms the roof of the nasal cavity (Fig. 59–13). The primary vertical buttress of the NOE complex is the frontal process of the maxillary bone. The primary horizontal buttresses are the superior and inferior orbital rims. If these buttresses are violated, comminution of the entire complex may occur. Long-term consequences of NOE complex disruption include blindness, telecanthus, enophthalmos, midface retrusion, CSF fistula, anosmia, epiphora, sinusitis, and nasal deformity.

The medial canthal tendon (MCT) arises from the anterior and posterior lacrimal crests and the frontal process of the maxilla. The MCT surrounds the lacrimal sac and diverges to become the pretarsal, preseptal, and orbital orbic-

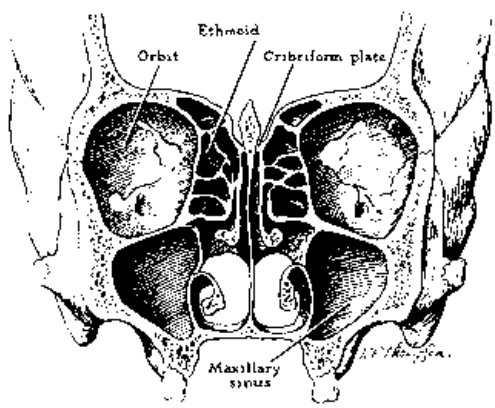

Figure 59–13 The nasoorbitoethmoid complex. Note that the cribriform plate descends approximately 1 cm below the level of the ethmoid roof (fovea ethmoidalis). (From Kazanjian VH, Converse JM (eds). *Surgical treatment of facial injuries*. 3rd ed. Baltimore: Williams & Wilkins; 1974. With permission.)

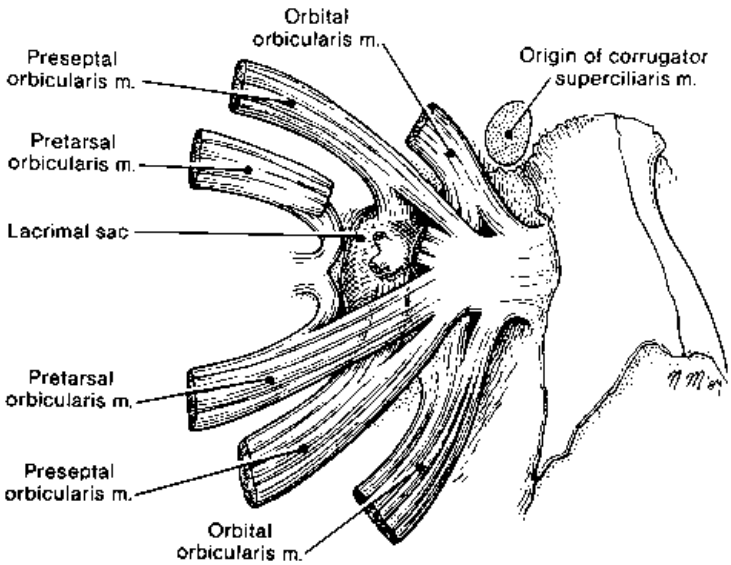

Figure 59–14 Anatomy of the medial canthal tendon. The tendon splits around the lacrimal sac and attaches to the anterior and posterior lacrimal crests, as well as the frontal process of the maxilla. The canthal tendon diverges to become the pretarsal, preseptal, and orbital orbicularis oculi muscle. (From Bergin D, McCord CD. Anatomy relevant to blepharospasm. In: Bosniak S (ed.). Advances in Opthalmic Plastic and Reconstructive Surgery: Blepharospasm. Philadelphia: Harper & Row, 1985.)

ularis oculi muscle (Fig. 59–14). Normal intercanthal distance is approximately 30 to 35 mm. Anatomically this equates to one half of the interpupillary distance or the width of the alar base (Fig. 59–15). The MCT maintains the normal intercanthal distance. Therefore, this tendon and its bony insertion become the focal point of NOE complex reconstruction.

Diagnosis

NOE complex fracture is primarily a clinical diagnosis; however, thin-cut CT scans play an important role in defining the pattern and extent of injury. A high degree of suspicion must be maintained for these injuries because failure to identify NOE complex fractures often results in deformities that are extremely difficult to repair secondarily. After associated injuries, if any, have been evaluated, a complete head and neck examination should be performed. Ophthalmologic consultation is mandatory. The nasal cavity and any facial lacerations should be cleaned and examined for a CSF fistula. The integrity of the medial canthal tendon should be evaluated by placing the thumb and index finger over the medial orbital rims and carefully applying lateral tension to each lower lid. Normally, there will be a defined end point to the maneuver, without palpable motion at the medial orbital rim. A periosteal elevator can also be inserted through the nose to apply lateral pressure in the same area. A lax MCT or medial orbital wall motion is consistent with a NOE complex fracture.

Telecanthus, enophthalmos, pupillary response, and extraocular muscle mobility should be assessed and documented. The nasal bones should be palpated for crepitus and comminution. The degree of nasal or midface retrusion should be assessed in case there is a need for surgical augmentation. A complete cranial nerve exam will rule out trigeminal or facial nerve injury. If there is gross MCT disruption or significant suspicion of lacrimal injury, the lacrimal system should be tested. Anesthesia should be placed in the eye (tetracaine) and nose (cocaine). Pledgets are then placed in the inferior meatus, and fluorescein is instilled in the eye. If the nasolacrimal system is intact, the dye will appear intranasally on the pledgets. Finally, thin-cut (1.5-mm) axial and coronal CT scans should be obtained to assess cribriform plate disruption, frontal recess/sinus involvement, orbital integrity, degree of NOE complex comminution, and associated facial fractures.

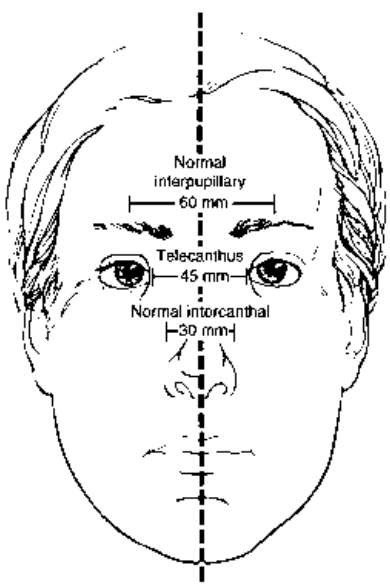

Figure 59–15 Normal intercanthal distance is 30 to 35 mm. This is approximately one-half the interpupillary distance and equivalent to the width of the nasal base. (From Holt JE and Holt GR. *Ocular and orbital trauma*. Washington DC, 1983. American Academy of Otolaryngology—Head and Neck Surgery Foundation.)

Fracture Classification

The key component of NOE complex reconstruction is the bony central fragment onto which the MCT inserts.[18] Markowitz et al devised a classification system describing the degree of bony injury[19] (Fig. 59–16). Type I fractures represent a single, noncomminuted central fragment without MCT disruption. Type II fractures involve comminution of the central fragment, but the MCT remains firmly attached to a

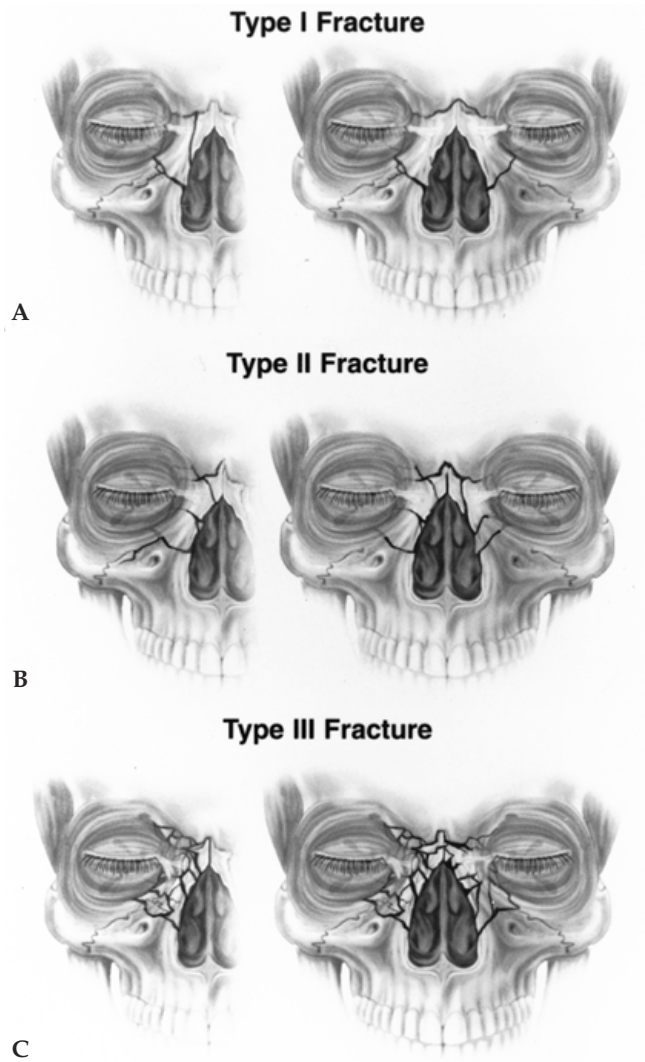

Figure 59–16 Classification of nasoorbitoethmoid complex fractures. **(A)** Type I injuries involve a single, noncomminuted central fragment without medial canthal tendon disruption (left, unilateral; right, bilateral). **(B)** Type II injuries involve comminution of the central fragment without medial canthal tendon disruption (left, unilateral; right, bilateral). **(C)** Type III injuries involve severe central fragment comminution with medial canthal tendon disruption (left, unilateral; right, bilateral.) (From Sargent LA, Rogers GF. Nasoethmoid orbital fractures: diagnosis and management. *J Craniomaxillofac Trauma* 1999;5(1):19–27. With permission.)

definable segment of bone. Type III fractures are uncommon and result in severe central fragment comminution with disruption of the MCT insertion. Each fracture type is subclassified as unilateral or bilateral.

Treatment

Surgical Exposure

NOE complex injuries are the most challenging of all facial fractures, and surgical repair is often complex and arduous. Inadequate surgical exposure, imprecise fracture reduction, or poor MCT repair will almost certainly yield suboptimal results. Proper surgical exposure can be obtained through coronal, subciliary, and sublabial incisions. Existing lacerations should be used to augment surgical access. Limiting the exposure to existing lacerations is usually inadequate. Glabellar and "open sky" incisions are generally avoided due to unfavorable external scarring. The coronal incision should be elevated in a subperiosteal plane, with care taken not to injure the supraorbital and supratrochlear nerves. Osteotomies can be placed in the supraorbital/supratrochlear foramina to release the neurovascular pedicles and increase the exposure if necessary. A subciliary incision offers the greatest exposure to the medial orbital rim; however, many surgeons find the transconjunctival exposure adequate. Finally, the sublabial incision allows access to the piriform aperture and frontal process of the maxilla. After extensive surgical exposure, care should be taken to resuspend the periosteum and soft tissues around the orbits and the zygomatic arches to avoid future ptosis.

Fracture Reduction

Most authors recommend repair of associated facial fractures prior to NOE complex repair. Reduction of maxillary and frontal sinus fractures often provides more accurate landmarks for subsequent NOE fracture repair.

Type I Fractures

Nondisplaced single-fragment injuries do not require surgical repair. Displaced type I fractures require superior (coronal) and inferior (subciliary or sublabial) exposure. Two separate microplates (1.0 to 1.3 mm) are applied from the frontal bone to the central fragment and from the maxilla to the central fragment. An accurate reduction must be maintained until both plates are placed, or the lateral pull of the MCT may result in central fragment lateralization and telecanthus. Application of a single plate from the frontal bone across the entire fragment and onto the maxilla should be avoided. Such placement requires greater elevation of the periosteum on the central fragment, which may disrupt the MCT. Plates placed in this region may also widen the nasal root. Isolated superior or inferior displacement of the central fragment may require exposure and plating from only one direction.

Type II Fractures

Comminuted fractures require more extensive surgical exposure from above and below, microplate reduction, *and* transnasal wiring. Subperiosteal dissection is used to locate but not avulse the MCT. Holes are drilled on the central fragment above and below the MCT. Stainless steel wire (26- or 28-gauge) is passed from lateral to medial, through the central fragment, and twisted tightly on the medial aspect. Holes are drilled through the medial orbital wall *posterior and superior* to the lacrimal fossa. Transnasal wires placed *anterior* to the lacrimal fossa will result in lateral rotation of the central fragment and telecanthus[20] (Fig. 59–17). The cribriform plate lies inferior to the roof of the fovea ethmoidalis (Fig. 59–13). Therefore, care should be taken to avoid drilling above the frontoethmoid suture line to decrease the risk of intracranial injury. Exit holes are drilled on the contralateral orbital wall.

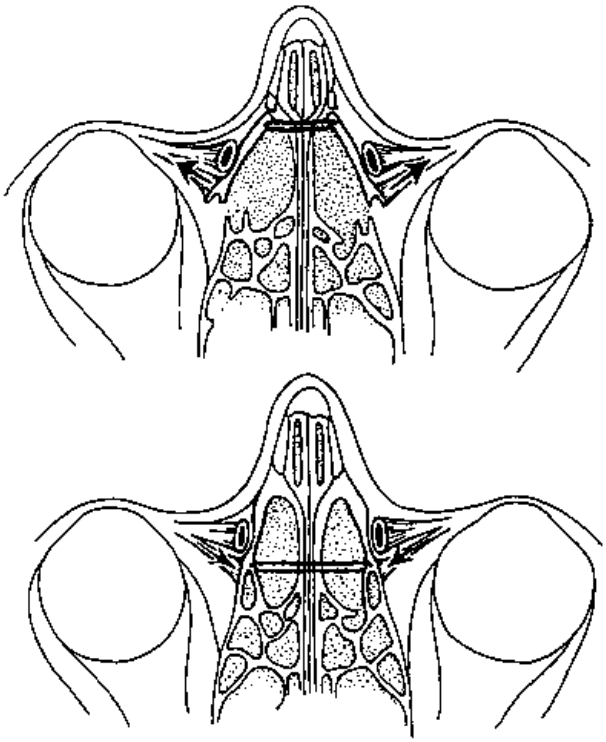

Figure 59–17 (top) Placement of transnasal wires anterior to the lacrimal fossa results in rotation of the central fragment laterally, leading to postoperative telecanthus. (bottom) Placement of transnasal wires posterior and superior to the lacrimal fossa provides adequate support for the medial canthal tendon and avoids postoperative telecanthus. (From Markowitz BL, Manson PN, Sargent L, et al. Management of the medical canthal tendon in nasoethmoid orbital fractures: the importance of the central fragment in classification and treatment. *Plast Reconstr Surg* 1991;87(5):843–853. With permission.)

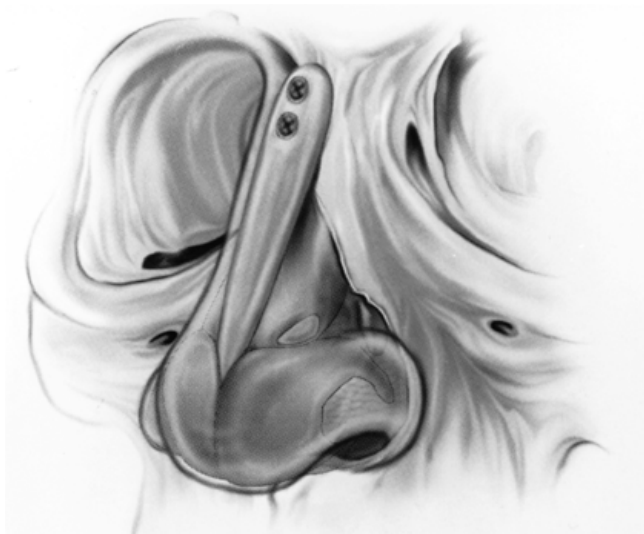

Figure 59–18 Cantilevered calvarial bone graft fixated with two position screws. A horizontal groove should be drilled into the frontal bone at the superior aspect of the graft to accept the bone graft and reproduce an aesthetic nasofrontal angle. The bone graft should extend as far as is necessary to reconstruct the preinjury contour. (From Sargent LA, Rogers GF. Nasoethmoid orbital fractures: diagnosis and management. *J Craniomaxillofac Trauma* 1999;5(1):19–27.)

A large spinal needle is then passed retrograde, through the ethmoid complex, toward the central fragment. The wires are passed through the lumen of the needle, and the needle is removed. The wires are secured to a microscrew or plate on the contralateral superior orbital rim. Slight overcorrection is helpful to avoid postoperative telecanthus. Finally, the central fragment is rigidly fixated to the frontal and maxillary bones with microplates (see Type I Fractures).

Type III Fractures

Type III fractures are associated with more severe trauma and may require primary bone grafting. There is a greater risk of lacrimal duct injury, and stenting of the duct should be considered. Wide surgical exposure is obtained and the MCT remnant is identified. A 3- to 5-mm horizontal skin incision at the medial canthus can be used to identify and secure the MCT. A 28-gauge wire suture is then passed through the stump of the MCT twice. The wire is then passed through two drill holes in the central bone fragment and twisted securely. If the central bone fragment cannot be identified, an outer-table calvarial bone graft can be used. Bone grafts must be of adequate size to fill the medial canthal defect and be secured by microplates.[12] The wires are passed transnasally and fixated to the contralateral orbital rim as described in the Type II Fractures section. Microplates are finally applied to rigidly fixate the central fragment.

Type III injuries resulting in significant loss of nasal projection should be repaired primarily with calvarial bone grafts. After MCT reconstruction is complete, an outer-table calvarial bone graft should be fashioned to augment the nasal dorsum. The graft should be positioned to reconstruct a normal nasofrontal angle and extend as far as necessary to provide a normal nasal contour. A horizontal groove should be drilled into the glabella to accept the superior aspect of the graft. A miniplate or two position screws are placed to cantilever the graft off the frontal bone[21] (Fig. 59–18).

Type III injuries may require external bolsters to prevent hematoma formation and restore a normal nasal contour. Two-millimeter-thick lead plates padded with felt can be applied to the lateral nasal sidewall. Transnasal wires are passed through the medial canthal region and back through the nose just inferior to the nasal bones.[19] The wires are twisted to apply pressure and reduce soft tissue

edema. The underlying tissue should be closely observed to avoid tissue necrosis. The bolsters are removed at 7 to 10 days.

Disruption of the delicate ethmoid complex and comminution of the nasal bones can make the repair of NOE complex fractures extremely difficult. These injuries often test the capabilities of even the most experienced surgeons. To obtain an aesthetic surgical result, the surgeon must meticulously identify, accurately reduce, and rigidly fixate the central fragment. Special attention must also be focused on the overlying soft tissue to avoid hematoma, induration, and telecanthus.

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Chapter 60

Le Fort Fractures (Maxillary Fractures)

Timothy D. Doerr and Robert H. Mathog

The management of midfacial fractures has changed dramatically over the past two decades. With computerized tomography allowing precise diagnosis, and advanced surgical approaches and plating techniques permitting stable fixation, fractures can now be managed in a single-stage reconstruction. These contemporary reconstructive techniques allow for rapid restoration of form and function with minimal treatment morbidity.

ETIOLOGIC AND EPIDEMIOLOGIC FACTORS

Maxillary fractures compose 10 to 20% of all facial fractures. These injuries usually result from motor vehicle accidents, interpersonal violence, or falls. Males predominate with fractures common in the second through fourth decades.[1] An expanding, increasingly active senior population is likely to increase facial fractures in the older age groups.[2] By comparison, children seldom sustain midface fractures. A proportionately larger mandible and frontal bone combined with a flexible facial skeleton, underdeveloped sinuses, and unerupted dentition protects against these fractures.[3]

Maxillary fractures are often associated with other bodily injuries. Serious intracranial injury is seen in 38%[4] and serious ophthalmologic injury in 28% of midface fractures.[5] Trauma involving the cardiovascular, abdominal, and orthopedic systems is also common, especially in high-energy injury mechanisms.

CLASSIFICATION AND PATHOPHYSIOLOGY

The maxilla is the principal bone of the midface. It contains a large air-filled sinus cavity and fractures with far less force than that required in the adjacent facial skeleton. The bony architecture of the midface is arranged in a latticework of vertical buttresses and horizontal beams, with the vertical buttresses transferring masticatory loads from the mandible to the skull base. This structural framework is also theorized to absorb impact forces and thereby prevent injury of the intracranial and orbital contents. Thus, impact forces directed to the midface can result in significant facial fractures with far less intracranial injury than the impact kinetics would predict.[6]

Fracture patterns of the facial skeleton are well described in the trauma literature, with the most lasting contribution from René Le Fort. In his classic 1901 work, Le Fort described a series of characteristic fracture patterns produced in cadaver skulls.[7] These "linea minoros resistentiae" remain the basis of most contemporary classification systems. Traditionally, the maxillary fractures are classified as Le Fort I, Le Fort II, Le Fort III, segmental, palatal, and medial maxillary fractures.

Although pure Le Fort fractures are rarely encountered in clinical practice, Le Fort's original work provides an excellent description of the fracture patterns, which is valuable in understanding the degree of injury. The Le Fort I, or Guérin, fracture is a low horizontal fracture between the maxilla and palate/alveolar arch complex. It is usually the result of direct anterior-posterior impacts low on the midface that produce fractures of the paired nasomaxillary and zygomaticomaxillary vertical buttresses. The fractures can continue posteriorly through the pterygoid plates or between the palate and maxilla (Fig. 60–1). It also involves the nasal floor, septum, piriform aperture, and anterolateral maxilla. A Le Fort I pattern is seen in 30 to 45%[1,8] of all Le Fort fractures.

The Le Fort II, or pyramidal, fracture is the most common Le Fort fracture pattern, seen in 30 to 60% of cases.[1,8] This injury can result from either direct horizontal forces to the midface or from impacts to the chin point that are transmitted from the mandible to the midface.[9] Classically, the fracture starts at the nasal bones and crosses the frontal process of the maxilla and lacrimal bones. Changing direction, the fracture then descends through the floor of the orbit, infraorbital rim, and lateral maxillary sinus wall. The Le Fort II often extends through the pterygoid plates (Fig. 60–1).

The Le Fort III fracture, or craniofacial disjunction, is a relatively uncommon midfacial fracture. It is usually the result of forces directed obliquely to the vertical buttresses and is frequently seen in conjunction with other facial fractures. With a high-velocity impact mechanism there is significant comminution and, often, serious intracranial injury. The Le Fort III fracture typically passes through the nasofrontal suture, frontal process of the maxilla, lacrimal bones, ethmoid sinus, and lamina papyracea before crossing the orbital floor to the inferior orbital fissure. From this point, the fracture extends in three directions: (1) across the lateral orbital wall through the zygomaticofrontal suture, (2) through the zygomatic arch, and (3) through the pterygoid plates, thereby creating a separation of the midface from the skull base (Fig. 60–1).

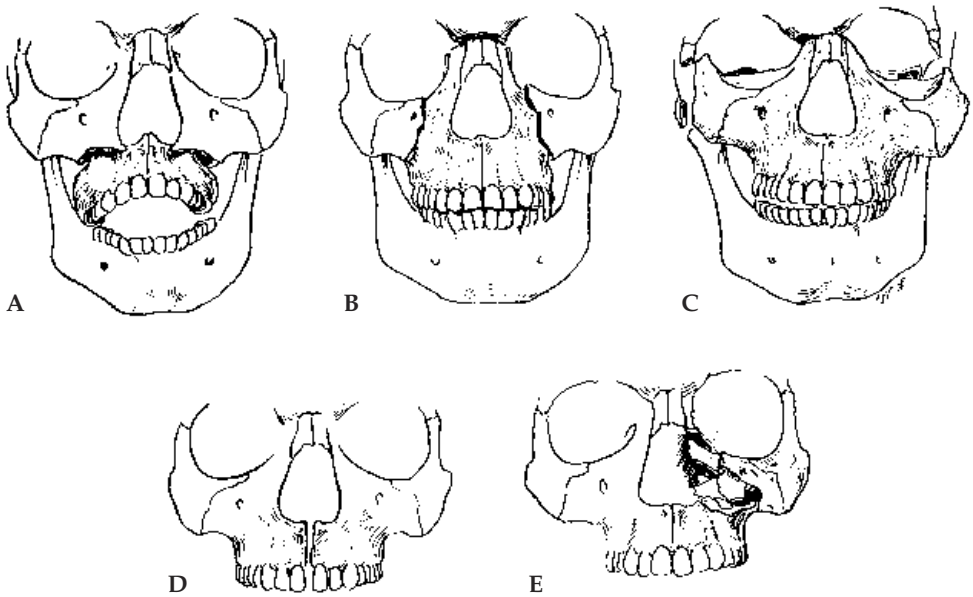

Figure 60–1 Classification of Le Fort fractures. **(A)** Le Fort I or Guérin type; **(B)** Le Fort II or pyramidal type; **(C)** Le Fort III or craniofacial dysjunction; **(D)** palatal split; **(E)** medial maxillary. (From Mathog RH, Arden RL, Marks SC. *Trauma of the nose and paranasal sinuses*. New York: Thieme Medical Publishers, 1995:54. With permission.)

Palatal split fractures begin anteriorly at the incisor space and extend posteriorly. The fractures may be either a true sagittal split, which is more common in children, or a parasagittal fracture, which is more common in adults.[10] Although palatal fractures may be isolated, they usually accompany other midfacial fractures. A segmental or alveolar fracture is a fracture of the alveolar ridge. It can be anterior, involving the incisors, or posterolateral, involving the molars. Medial maxillary fractures result from impacts of small objects to the area between the nose and the cheek. The frontal process of the maxilla and usually the nasal bones are involved (Fig. 60–1).

Despite the descriptive nature of the Le Fort classification system, most midface fractures are more complex, possessing components of several Le Fort injuries with differences in the degree of injury between sides. Furthermore, there is often comminution and displacement of the fracture that is not addressed in the Le Fort classification system. Because these complicated fractures are inadequately or inaccurately described using the Le Fort system, other authors have suggested modifications. Manson emphasized the importance of impact mechanism and fracture displacement in the classification of midfacial injuries. He stressed an accurate description of the highest level of fracture on each side as well as the status of the fragments containing maxillary dentition.[11] Others recognized the importance of the medial and lateral components of a fracture. They called for precise repair of both the horizontal and vertical fracture elements to optimize outcomes.[12]

To manage facial fractures a simplified description of the injury is essential. We now employ a new classification system that avoids the deficiencies of Le Fort's original classification. This system uses a skeletal matrix of vertical buttresses and horizontal beams to simply and precisely describe all fracture patterns (Fig. 60–2). The system allows for easy communication between diagnosticians and surgeons so that injuries can

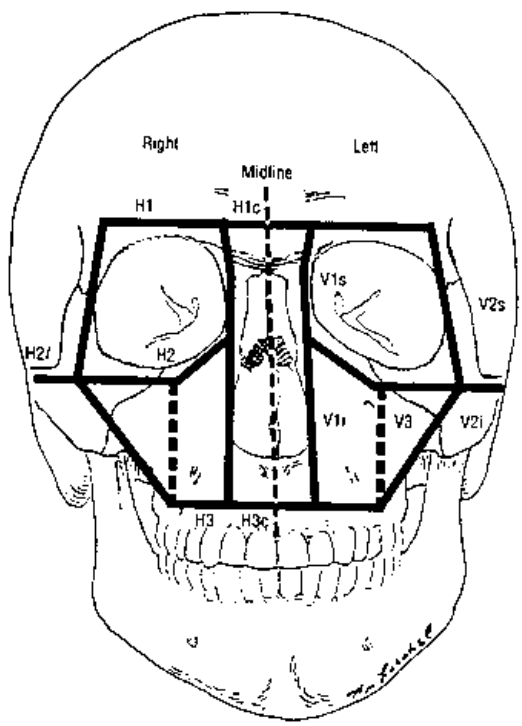

Figure 60–2 Vertical buttresses and horizontal beams of the facial skeleton. Buttresses: frontonasomaxillary (V1), frontozygomaticomaxillary (V2), pterygomaxillary (V3). Beams: supraorbital rims and glabella (H1), orbital rims and zygomatic arches (H2), alveolar process of maxilla (H3). (From Donat et al. Facial fracture classification according to skeletal support mechanisms. *Arch Otolaryngol Head Neck Surg* 1998;124:1308. With permission.)

be accurately assessed and repaired. The classification system also is easily adaptable to a database that provides treatment outcomes, so that comparable fracture patterns can be analyzed objectively.[13]

To effectively diagnose and manage fractures of the midface a thorough analysis of the buttresses and beam framework is required. The vertical supports of the midface are three paired vertical buttresses—zygomaticomaxillary (lateral), nasomaxillary (medial), and pterygomaxillary (posterior)—along with a weaker, unpaired, midline, septovomerian buttress. These vertical supports are joined by less rigid, horizontal beams. These beams—the alveolus, orbital floor and rims, and supraorbital bar—collectively reinforce the vertical buttresses as well as maintain the vertical and lateral dimensions of the face.

Blows to the midface, especially those high-energy impacts seen with more severe Le Fort fractures, result in a buckling and collapse of these midface support structures. Therefore, repair of both the vertical buttresses and horizontal beams is critical to the restoration of facial appearance and function.

CLINICAL EVALUATION AND DIAGNOSIS

Maxillofacial trauma patients present a unique set of challenges for the clinician. Frequently, these patients sustain multiple-system traumas, including intracranial injury with altered levels of consciousness. It is also common for more acute, life-threatening conditions to cause a delay in the complete evaluation of facial injury for hours or even days. Because these potentially life-threatening injuries do occur, the facial trauma patient must be managed with a standardized approach. Use of an "ABC" (airway, breathing, and circulation) algorithm prioritizes the emergency intervention that is a prerequisite for facial skeleton evaluation.

Bleeding frequently complicates midfacial injuries. The bleeding may be minor, resulting from the disruption of septal, nasal, or sinus mucosa. Alternatively, it may be profuse from skull base vessels and require nasal packing or even temporary fracture reduction to obtain control.

Although difficult in the acute setting, the examiner needs to attempt as complete a history and physical examination as possible. The premorbid dental occlusion and any history of prior trauma are of particular importance. In addition, a brief ocular history will help avoid confusion if decreased vision is noted later.

The clinical history is followed by a thorough examination, including inspection and palpation of the entire facial skeleton. Despite the excellent imaging available, assessment of the mobility and stability of facial structures is only made through a physical examination. Reliance on radiographic findings without an accurate clinical correlation will lead to treatment errors.

The examination begins with a visual inspection of the face for symmetry and proportion. Midface trauma usually produces significant soft tissue edema and ecchymoses that can distort facial appearance. The forces of midface trauma usually drive the maxilla posteroinferiorly along the slope of the skull base, creating a "flat" or "pan" face appearance. In other instances, separation at the frontozygomatic sutures or an inferiorly displaced chin gives an elongated facial appearance. An extension of the injury to the orbits produces periorbital edema and can result in abnormal globe position. Disruption of the medial canthi can produce telecanthus, whereas displacement of the zygomaticomaxillary complex can leave a malar depression.

Facial inspection is followed by palpation of the entire facial skeleton. With a lower Le Fort injury there can be gingival buccal sulcus crepitance or subcutaneous emphysema. Le Fort II fractures cause step-off deformities of the orbital rim and can produce V_2 paresthesia. Le Fort III fractures often involve a diastasis and step deformity of the frontozygomatic suture and zygomatic arch. In medial maxillary fractures, the lateral nasal and medial maxillary bone are depressed, producing a palpable deformity.

The examiner then makes a careful assessment of the mandibular and maxillary dental occlusion. A displaced maxilla will cause premature contact of the molars and an open-bite deformity. If there is lateral displacement of the fracture elements a cross-bite can be seen. Additional occlusal disturbances are apparent in alveolar fractures and palatal split fractures in which incisor teeth are loose or fractured. In an alveolar fracture there is a mobile tooth-bearing segment with two visible fracture lines. The occlusal evaluation is especially critical in nonmobile or minimally displaced fractures whereby few clinical signs are present, and a subtle malocclusion may be the only indicator of fracture.

The final step in evaluating maxillary fractures is an assessment of mobility. The mobility of the midface is best determined by using the thumb and forefinger to grasp the premaxilla while the other hand palpates the infraorbital rims. With a Le Fort I injury only the premaxilla is mobile, whereas a Le Fort II fracture separates at the infraorbital rims, which will move with the premaxilla. In a Le Fort III injury, the premaxilla, malar bones, and remainder of the facial bones are mobile at the nasofrontal and zygomaticofrontal sutures. Although clinical mobility is evidence of a maxillary fracture, nonmobile fractures are seen in 9% of Le Fort injuries.[14]

OPHTHALMOLOGIC EVALUATION

The prominent position of the orbits within the midfacial skeleton is responsible for the high incidence of ocular injuries with maxillofacial trauma. Eye injuries occur in as many as 90% of midface fracture patients, with vision-threatening injuries (including hyphema, retrobulbar hemorrhage, and traumatic optic neuropathy) seen in 12% of cases.[5] When there is concern about decreased vision an ophthalmologic evaluation is needed. The early diagnosis of a serious eye injury allows for prompt treatment that may preserve sight. In addition, early diagnosis helps avoid fracture repairs that could threaten vision. Certainly the deterioration of vision following surgical repair demands an immediate ophthalmologic evaluation.

NEUROLOGIC EVALUATION

Neurologic injuries are common in midface trauma, with as many as 90% of fracture patients having at least a mild closed-head injury.[15] Serious intracranial injury occurs in up to 38% of midface fractures and is more common in injuries caused

by motor vehicle accidents.[4] Trauma patients presenting with loss of consciousness or altered sensorium should undergo computed tomography (CT) of the head to properly evaluate for serious intracranial injury. Even with a normal head CT scan, clinical closed-head injury can produce long-term sequelae, including headache, dizziness, memory problems, and a delayed return to work. It is therefore important that these head injury patients have a neurologic evaluation and follow-up with a neurologist or neurotrauma specialist.

RADIOLOGIC EVALUATION

Computerized tomography of the facial skeleton is the examination of choice in evaluation of maxillofacial trauma. Ideally, all patients with suspected trauma should undergo scanning in both the axial and coronal planes with an appropriate bone window. This can be done with head CT without adding significant imaging time. Some patients are unable to undergo coronal scanning because of intubation, cervical spine precautions, or other injury. In these cases, available software programs can produce excellent coronal or sagittal reconstructive images.

Although thicker sections may serve as an initial screen, 2- or 3-mm slices in both the axial and coronal views are required for optimal detail of the facial bone anatomy. In analyzing the images, the vertical buttresses and horizontal beams must be carefully and systematically inspected for fractures and any displacement or comminution noted. Special attention should also be directed to the orbit and the skull base for globe or intracranial injury that may complicate repair. Use of a systematic analysis of buttresses and beams allows the radiologist and surgeon to understand the extent of injury in far greater detail than that provided by a Le Fort description. It also permits the surgeon to select the necessary exposure as well as predict the degree of bone loss and estimate the need for bone grafts or volume restoration. Further information can be obtained using three-dimensional reconstructed images and may be beneficial in very complicated cases.

TREATMENT

Objective

The reconstructive surgeon's primary objective is the restoration of form and function. In maxillary fractures it is critical to restore the projection and height of the face and to recreate the pretraumatic occlusion. In addition to treating the bony framework, the surgeon must also effectively manage the overlying soft tissue. The judicious use of incisions, careful handling of tissues, and resuspension of the midface soft tissue are all important in minimizing postoperative complications. Achieving the best outcomes in maxillary fracture repair requires a well-developed but adaptable surgical plan that encompasses anesthesia, exposure, reduction, and fixation.

Preparation

When initially seen, the maxillofacial trauma patient must be evaluated for any life-threatening process. The consistent use of the ABC algorithm will prevent the overlooking or compounding of existing injuries. Initially each patient requires a careful airway assessment. With loss of consciousness, intracranial injury, or hemorrhage, an artificial airway may be required to ensure adequate oxygen delivery. If the maxilla is pushed back and blood and secretions obstruct the pharynx, the airway can be improved with suctioning and temporary reduction of the maxilla. If this maneuver is not effective in relieving the airway problem, then an oropharyngeal or nasal airway may be required. When any injury to the cervical spine is suspected, it is critical to protect the cervical spine and maintain appropriate precautions regardless of the method used to establish the airway.

Endotracheal intubation, when necessary, should be performed by a skilled anesthetist. Although there is some concern about nasal intubation in midfacial trauma, most authors report that it can be done safely. Nasal intubation is advantageous in that occlusion can be established without interference from the tube; however, it can make reduction of nasal fractures difficult. Oral intubation is simpler and less traumatic but can interfere with occlusion. To avoid this, the tube can usually be placed behind the maxillary tuberosity and not interfere with intermaxillary fixation. When conventional intubation is not possible, there are other techniques that allow for intermaxillary fixation and avoid a tracheostomy.[16] Tracheostomy or cricothyroidotomy is a safe alternative and should be considered if there is any question of establishing or maintaining an airway.

Timing

In the last two decades the timing of midfacial fractures repair has moved toward earlier intervention. The classic dictum was to wait for the resolution of swelling, which would allow more accurate restoration of landmarks and presumably better surgical results. However, recent experience supports earlier repair. Early intervention with open reduction and direct rigid fixation enables precise repair of fractures without the bone edge resorption or fibrous ingrowth seen with delayed repair. Additionally, authors report earlier function, less infection, decreased scarring, and fewer overall complications with prompt repair. There are also significant savings in hospitalization costs if surgery is not delayed.

A number of other factors may influence the timing of surgery. Midfacial fracture patients often have concomitant intracranial and systemic trauma that can delay or interfere with plans for reconstruction. There has been considerable debate over whether early repair of fractures is safe in a patient with intracranial injury. The focus of debate concerns the general anesthesia, supine positioning, and intraoperative fluid shifts that may exacerbate cerebral edema. Derdyn and colleagues addressed this question by reviewing clinical outcomes in 49 patients with facial fractures and significant intracranial injury. They found that patients with low Glascow Coma Scale scores (less than 6), intracranial hemorrhage, or shift of midline cerebral structures did poorly. However, early surgical intervention did not negatively impact outcomes provided the preoperative intracranial pressure was less than 15 mm Hg.[17] The experiences of Brandt and colleagues[4] and Piotrowski[18] also support safe early fracture repair in head injury patients provided that they receive close general surgical and neurosurgical support. In instances when neurosurgical procedures are required, it may be safer to perform the

facial fracture repairs under the same anesthesia rather than incur the risks of a second trip to the operating room. Obviously, patients with severe intracranial injury and a poor neurologic prognosis do not gain significant functional benefit from fracture repair, but correction of an obvious deformity can have emotional value for the family and caregivers.

Under some circumstances early surgical intervention should be avoided. Any cervical spine injury must be thoroughly evaluated and stabilized before facial fracture repair can be undertaken. Likewise, any ocular injury in which vision is threatened or could be threatened by surgical manipulation must be delayed. When it is necessary to postpone surgery, a repair can be successfully completed up to 3 weeks after injury.

Exposure

The bones of the facial skeleton can be exposed through concealed surgical incisions that produce no visible facial scars. An extended bicoronal incision, a midfacial degloving, and transconjunctival incisions will allow for accurate reduction of all of the vertical buttresses and horizontal beams of the midface The choice of incisions is dictated by the degree of maxillary injury and by any extension of fractures into the zygomatic and nasoorbitalethmoid complexes. In general, a Le Fort I fracture or isolated alveolar fractures can be managed through a wide sublabial incision. A Le Fort II fracture may require a periorbital incision (subciliary, subtarsal, or transconjunctival) in addition to the sublabial approach. A bicoronal incision is usually necessary to expose the frontozygomatic and frontonasal projections in Le Fort III fractures. Although these extended-access approaches provide ample exposure to the facial skeleton, the surgeon should not ignore the traditional limited external incisions that offer direct exposure to the fracture sites. These incisions can be highly suitable for fractures where minimal plating is required.

Reduction

Maxillary fractures may be loose or impacted into the adjoining craniofacial skeleton. In many cases the fractured maxilla is pushed posteriorly along the incline of the skull base, resulting in a face that appears retruded and lengthened. This creates an open-bite occlusion from premature molar contact. If there is a lateral displacement of the maxilla, an asymmetric deformity and cross-bite are seen.

When the fracture is loose, it can be reduced with digital or hook traction. In these instances, an index finger or hooklike instrument (army–navy retractor or large bone hook) is placed behind the soft palate and used to pull the palate forward. The maxilla can then be manipulated into anatomic position.

When the maxilla is impacted into the adjacent bone, greater force is needed to disimpact the segment. The Rowe forceps are designed for this task. These forceps have a right and left handle with both a straight and a curved blade. The straight blades are placed along the nasal floor and the curved blade fits against the roof of the hard palate. With a handle in each hand, the surgeon rotates the maxilla into position vertically, then horizontally (Fig. 60–3). Brisk bleeding can accompany this maneuver but usually subsides in a few minutes. After appropriate reduction is achieved the fractures can be fixated.

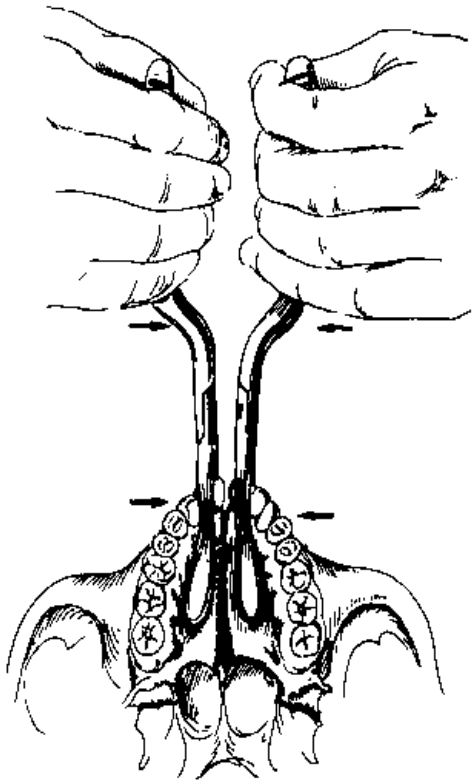

Figure 60–3 Reduction of a maxillary fracture using Rowe disimpaction forceps. (From Mathog RH. *Atlas of craniofacial trauma*. Philadelphia: WB Saunders, 1991:153. With permission.)

Fixation

Fixation of midface fractures has also changed dramatically during the last two decades. Previously the management included delayed repair through small incision with minimal exposure of fracture elements. Stabilization was done with wires or external suspension with prolonged intermaxillary fixation. Less than optimal outcomes from incorrect vectors of suspension and soft tissue shrinkage combined with the difficulties of secondary repairs led to current practice. The best results are achieved by exposing, then precisely reducing and rigidly fixing, the supporting buttresses of the midface. The use of rigid fixation provides stability with bone-to-bone contact that allows the midfacial bones to heal more rapidly with new-bone formation and a true osseous union.[19]

There are many materials available for fixing fractures of the midface. In addition to traditional stainless steel wire, there are a number of mini- and microplating systems available. Made primarily of titanium, these thin, low-profile plates range in thickness from 0.8 to 2.0 mm and provide rigid (or, more accurately, semirigid) fixation with minimal tissue reactivity. A plate-and-screw system also offers distinct biomechanical advantages over wire fixation. Plates have superior capacity to resist translation and rotation about the three principal axes. Properly positioned plates with multiple screws on each side of the fracture line also allow load sharing between the plate and the bone, resulting in less hardware

failure.[20] These mechanical advantages thereby limit the need for lengthy postoperative intermaxillary fixation.

More recently, nonmetallic plates made of bioresorbable polymers have been developed for midfacial fracture repair. Early experience suggests that these resorbable systems function as well as their metal counterparts provided there is not significant bony comminution. Although the thicker nonmetallic plates are initially palpable beneath soft tissues, they resorb over several months and do not remain as a foreign body. These properties appear to be well suited for pediatric fractures where the presence of permanent plating may interfere with facial growth.

Le Fort I Fracture

Minimally displaced Le Fort I fractures can be reduced and stabilized with intermaxillary fixation. Elastic bands provide traction that maintains proper occlusion while the fracture lines heal.

When there is displacement or mobility of the maxilla an open approach is necessary. Initially the occlusion is set with Ivy loops or arch bars and the fracture approached through a sublabial incision. The medial or lateral buttresses are then repaired using 1.2- to 1.7-mm monocortical miniplates. The plates should be oriented along the load-bearing pathways, and ideally three screws are used on each side of the fracture (Fig. 60–4). Plating reduces the need for postoperative intermaxillary fixation, thereby allowing earlier return to function.

The duration of postoperative intermaxillary fixation is dictated both by the degree of fracture and the stability achieved with repair. In most cases, the arch bars are left on and the patients followed closely for 8 to 12 weeks postoperatively. With careful follow-up, occlusal problems can be identified and corrected early. Frequent reapplication of elastic bands is sufficient to direct the patient back to proper occlusion. Failing to correct even a subtle malocclusion can lead to problems with temporomandibular joint dysfunction.

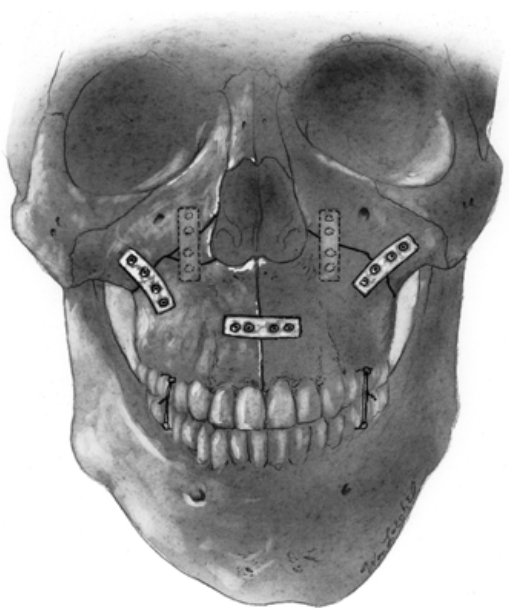

Figure 60–4 Fixation of a Le Fort I fracture. Plating of the medial and/or lateral buttresses. The palatal split is corrected by a horizontal plate in the midline.

An edentulous Le Fort I fracture presents some challenges for the surgeon, but fortunately the repair can be less precise because dentures can be modified to the new maxillary–mandibular relationship. When the edentulous fracture is minimally displaced and reasonably stable, one may elect to reduce the fracture and perform no fixation. If there is displacement or appreciable mobility, the fracture should be plated. The techniques are generally the same as those for patients with teeth, although thinner atrophic bone and reduced masticatory forces permit the use of smaller plates.

Le Fort II Fracture

Nearly all Le Fort II fractures require an open reduction and fixation of the zygomaticomaxillary, infraorbital rim, or the nasomaxillary buttress. After the proper occlusal relationship is established with arch bars or Ivy loops, the midface is degloved to expose the piriform apertures, canine fossae, and zygomaticomaxillary buttresses. Additional exposure of the nasomaxillary buttresses may be needed and can be obtained through a periorbital incision that also allows exploration of the orbital floor. After the fractures are exposed, the lateral buttresses are repaired using miniplates. If there is severe comminution or bone loss, split calvarial bone grafts may be required to support the vertical pillars. When the superior portion of the fracture remains unstable, microplate fixation or wiring of the orbital rim is necessary. In most instances, it is not necessary to plate the nasomaxillary buttress high. The guidelines for postoperative intermaxillary fixation are generally similar to those of Le Fort I injury.

In edentulous patients with Le Fort II injury, the preferred repair is an open reduction with miniplate fixation. In rare instances when the fracture involves the alveolus and accurate reduction is uncertain, dentures or occlusal splints with arch bars can be used to establish intermaxillary fixation. The splint or denture is held in place with circumzygomatic and circummandibular wires or with screw fixation to the palate.

Le Fort III Fracture

Forces producing Le Fort III fractures are great, and the resultant injury is usually a complex maxillary fracture requiring open reduction and direct fixation. Rarely is there a clean Le Fort III fracture with minimal displacement. In those very few select cases, occlusal fixation followed by plating of the buttresses through limited incisions is sufficient.

The majority of Le Fort III fractures are complex and require wide surgical exposure. A bicoronal incision is used to access the zygomaticofrontal suture, zygomatic arch, and nasofrontal projections. After establishing occlusion with an arch bar or Ivy loop, 1.0- to 1.5-mm plates are used to stabilize the buttresses (Fig. 60–5). It is important to assess the zygomatic arch and restore it when displaced because this landmark sets the horizontal position and projection of the midface. Management of Le Fort III fractures in an edentulous patient is identical to that of their dentate counterpart.

Because of the poor cosmetic and functional outcomes associated with craniofacial suspension, including loss of facial projection and maxillary retrusion, these techniques have largely been abandoned.

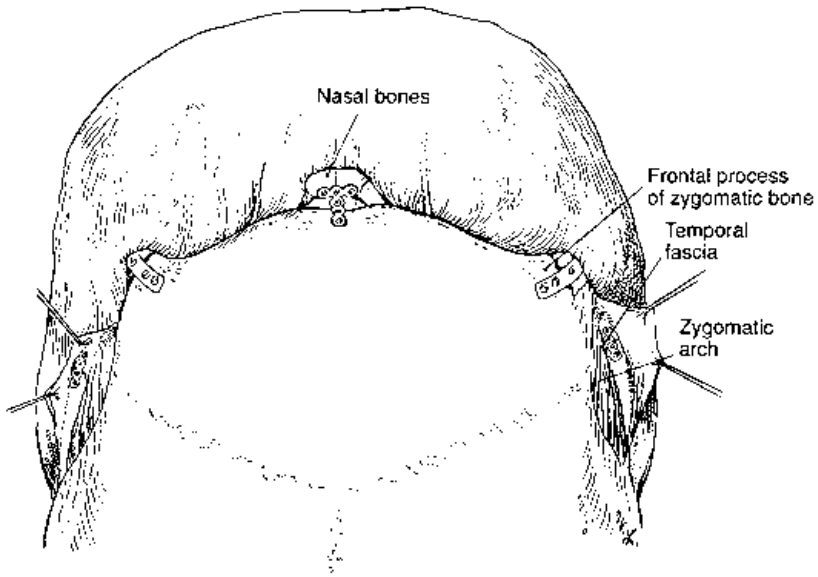

Figure 60–5 Repair of a Le Fort III fracture through a bicoronal flap with fixation of the frontozygomatic process and zygomatic arch. (From Mathog RH, Arden RL, Marks SC. *Trauma of the nose and paranasal sinuses*. New York: Thieme Medical Publishers, 1995:63. With permission.)

Segmental Fractures

In segmental fractures where teeth are present, an arch bar may be sufficient to stabilize the fracture. Alternatively, this can be managed with a horizontally placed miniplate. If stability remains in question after plating, then intermaxillary fixation should be maintained. For edentulous segmental fractures, open reduction with miniplate fixation is best.

Medial Maxillary Fractures

Fractures of the medial maxilla are best approached through a midfacial degloving. The nasomaxillary buttress should be stabilized with a low-profile miniplate. The nasal fracture will require reduction and, if severely comminuted, may require microplating or interfragmentary wiring. A periorbital incision may also be needed to repair the orbital rim or medial orbital wall. In rare circumstances when there is disruption of the medial canthus, exploration and repair are required.

Palatal Fractures

Palatal fractures deserve special consideration because they produce an irregular maxillary alveolar arch that allows rotation of the dental alveolar segments. This creates difficulty in reestablishing the occlusal relationship between the upper and lower jaw, leading to malalignment. It is therefore essential to restore the palatal arch to obtain proper occlusion.

If there is fracture without displacement of the palatal arch, the injury can be managed with intermaxillary fixation. When the palatal arch is disrupted or there is injury to the adjacent vertical buttresses, then further intervention is required. A horizontal plate placed beneath the nasal spine is used to join the two halves of the maxilla (Fig. 60–4). Intermaxillary fixation is then established and when necessary, the medial and lateral buttresses are plated to support the posterior portion of the hard palate.[21] Alternatively, sagittal and parasagittal palatal fractures can be managed by direct intraoral plating (Fig. 60–6). The direct plating of these fractures

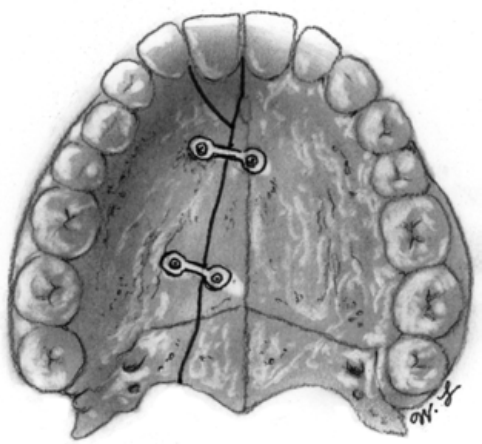

Figure 60–6 Reduction and fixation of a split palate with direct intraoral plating using a 1.7-mm miniplate.

reestablishes palatal width but is not sufficient to prevent rotation of the alveolus. It is therefore necessary that intermaxillary fixation be maintained for 4 weeks following repair. Because of the large forces encountered, a larger (1.7- or 2.0-mm) plate is required for fixation. Unfortunately, such plates often become exposed intraorally and have to be removed after the fracture has healed.[22] In complicated cases where there is bone loss or severe comminution, a dental splint can help maintain the palatal arch. In the edentulous fracture, the patient's denture secured with transpalatal screws will restore the palatal arch (Fig. 60–7).

Panfacial Fractures

Fractures that involve the upper, middle, and lower third of the facial skeleton are termed panfacial fractures. The fracture patterns are complex and affect both the vertical buttresses and horizontal beams. These complicated injuries call

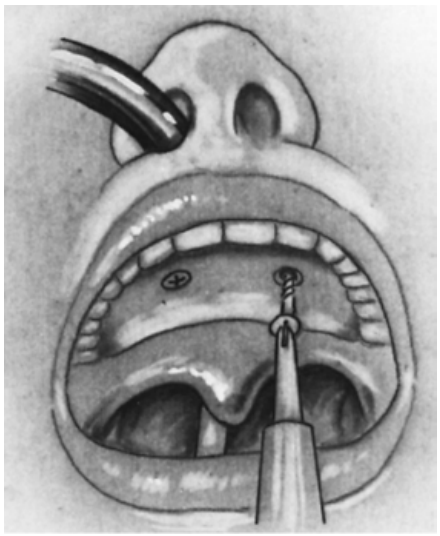

Figure 60–7 Reduction and fixation of a split palate using patient's denture and transpalatal screws. (From Mathog RH. *Atlas of craniofacial trauma*. Philadelphia: WB Saunders, 1991:200. With permission.)

for careful assessment and a logical approach to reduction and repair. To achieve optimal results the surgeon should work from a solid base using established landmarks.

Most panfacial fractures can be viewed as two areas of injury: one above and one below the Le Fort I fracture line. The lower injury zone consists of the mandible and the lower half of the midface and is reconstructed by using the mandible as the stable base. The position of the lower half of the midface is then determined through the mandibular–maxillary occlusion. The upper injury zone comprises the frontal bone and the upper half of the midface. The frontal bar acts as a solid base to establish the position of the upper half of the midface. These two upper and lower halves are then properly related to one another by accurate restoration of the vertical bony buttresses.[23]

In the panfacial fracture, the reconstruction begins by first establishing the mandibular height that may require open reduction and internal fixation of mandible fractures. The maxilla is then reduced and the maxillary–mandibular relationships are established with arch bars or Ivy loops. The repair proceeds to the upper facial skeleton where a stable frontal bone serves to reestablish the relationships between zygoma and cranial base. To properly determine the width and projection of the midface, the zygomatic arch must be reduced and fixed. The repairs can then proceed from a lateral to medial direction using both the stable upper and lower landmarks to restore the vertical buttresses and establish the correct facial height. This sequence represents a logical approach for repairs in panfacial fractures; however, it is not absolute, and the reconstructive surgeon must be able to adapt the repair to each injury.

Soft Tissue

Current approaches for midfacial fracture repair uses extensive degloving of soft tissues to gain wide exposure to the facial skeleton. Following osseous fixation, the soft tissues must also be repaired. Failure to do so can result in temporal hollowing, midface soft tissue ptosis, and eyelid malpositioning. To prevent these aesthetic complications, the periosteum and fascia of the midface must be resuspended to the bony skeleton with permanent or semipermanent suture to prohibit downward migration of the overlying soft tissues.[24] In addition, incisions must be closed in multiple layers to prevent a soft tissue diastasis. Even with exceedingly precise bone fixation, failure to adequately address the soft tissue can cause poor cosmetic outcomes.

POSTOPERATIVE CARE

Patients with maxillary fractures should be given preoperative broad-spectrum antibiotics directed against oral and sinus pathogens. The antibiotics are continued for 5 days postoperatively while oral hygiene is maintained with chlorohexadine oral rinses and pulsed irrigation. A close postoperative follow-up is important to monitor occlusion and make adjustments when necessary. Follow-up post reduction imaging, ideally with CT scans, is also valuable in confirming successful reduction and subsequent healing.

PEDIATRICS

Pediatric facial fractures are best managed using a conservative treatment approach. An aggressive approach with extensive periosteal stripping and plating should be avoided because these techniques can disrupt facial and dental growth centers. Plates are generally used only when there is considerable comminution. Because significant potential for remodeling exists, even displaced bones can remodel and assume normal position. Plates, when used, should be removed after healing to prevent any interference with bone growth. Because children exhibit rapid healing of fractures, the window for repair is only 7 to 10 days before complications from malunion are seen.

Most pediatric fractures can be managed by intermaxillary fixation with Erich arch bars. Alternatively, dental mounts or circummaxillary splints can be used to lessen the damaging forces that circumdental wires impart on short deciduous tooth roots. When an open technique is required, plates and wires should be used sparingly, and when possible, a resorbable plating system is preferable. Postoperatively, pediatric fractures heal much more rapidly with bony union in 2 to 4 weeks.

COMPLICATIONS

The complications of midface fractures can be divided into bone and soft tissue sequelae causing either functional or cosmetic problems. Bony complications in midface fracture repair include delayed union, malunion, and nonunion. These almost invariably produce malocclusion. Problems with bone healing need to be properly diagnosed and treated accordingly. With a delayed union, the patient must be reduced to the

preinjury occlusion and maintained in intermaxillary fixation for an additional 3 to 6 weeks. When a true nonunion or fibrous union occurs, the interposing fibrous tissue and any nonviable bone must be removed. Bone grafts may be required to fill in gaps so that the vertical buttresses can be restored.

Malunion resulting in a facial skeletal deformity requires careful evaluation of occlusion and facial appearance. Reconstructive CT scans and cephalometric analysis are helpful in evaluating the degree of maxillary retrodisplacement and vertical midface collapse, whereas dental models can aid in surgical planning. When midfacial retrusion develops as a result of poor fixation or improper restoration of the craniofacial buttresses, correction is necessary. Usually this requires maxillary osteotomies and midfacial advancement using fixation plates and bone grafts to achieve proper occlusion and facial dimensions.

Subtle problems of malocclusion can initially be managed with intermaxillary fixation. If the malocclusion persists after healing, dental adjustments, orthodontics, and possibly osteotomies may be necessary to avoid chronic problems in the temporomandibular joints.

Malar flattening without any deformity or dysfunction of the orbit is best treated using onlay bone grafts or alloplasts. If the malar complex is rotated, producing a disturbance in orbital volume, osteotomies and possibly bone grafts may be necessary to reestablish proper orbital volume.

Soft tissue complications also occur following midfacial injury and fracture repair. Fortunately, because of an excellent blood supply, soft tissue infections are rare despite the contamination from sinus and oral contents. Localized wound infections can usually be managed with systemic antibiotics. When an infection persists despite appropriate therapy, osteomyelitis must be considered. In these cases, removal of hardware and debridement of the underlying bone are necessary. If an oroantral fistula develops, it should be closed with excision of the fistula tract and any nidus of the infection.

Paresthesia or hypesthesia of the infraorbital nerve is often seen with midface injury and less commonly after fracture repair. These conditions are generally managed expectantly; however, in rare cases nerve ablation has been required. A few patients will experience a hypersensitivity to cold at the site of a plate, which when bothersome necessitates hardware removal. Postoperative weakness of the temporal branch of the facial nerve after repair through a coronal approach is not uncommon and is usually the result of traction during exposure. Generally, when the nerve is not transected function improves with time.

There are also a number of cosmetic complications that can occur after repair of maxillary fractures. Usually, the cosmetic complications of midfacial fractures can be avoided by careful soft tissue handling and diligent resuspension of the midface. Failure to adequately resuspend midface soft tissue may result in temporal hallowing, cheek ptosis, and eyelid malposition. When this is of significant concern, cosmetic correction is an option. Problems with eyelid position, including lower lid ectropion, can occur after surgical repair. Initially the ectropion should be treated with massage and steroid injection. If conservative measures fail, a lid elevation or shortening procedure may be necessary.

SUMMARY

Le Fort fractures are a complex group of midfacial fractures whose management requires an understanding of the structural buttress anatomy of the facial skeleton. Management of these injuries involves open exposure and precise anatomical reestablishment of the bony skeletal matrix to restore form and function. Repairs can be made through camouflaged incisions with low-profile miniplates that lessen the need for lengthy postoperative intermaxillary fixation. Restoring the proper occlusal relationship, establishing the bony buttresses, and resuspending the midfacial soft tissues optimizes outcomes and minimizes complications.

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Chapter 61

Mandibular Fractures

Jaime R. Garza

Treatment of mandibular fractures can be a challenging endeavor and, at times, a frustrating one. The presence of teeth in an arched-shaped tubular structure and the need to restore accurate interdigitation with the opposing upper teeth makes management of these types of fractures very different from that of long-bone fractures. However, the principles of fracture reduction, fixation, and bone healing are the same.

ETIOLOGIC FACTORS

Mandibular fractures most often occur as a result of blunt trauma. Motor vehicle accidents, assaults, and falls constitute an array of possibilities for fracturing the mandible. A recent study from Austria reported that athletic competition was the most common cause of mandibular fractures, accounting for 31.5% of their series of 712 patients.[1] The prominence of the chin in the mature human makes this structure susceptible to injury. In the pediatric population, the cranium is the most projecting region of the head and neck. Therefore, in children, cranial injuries are more common than mandibular injuries.[2]

ANATOMY

The mandible is an arched-shaped structure comprising vertical and horizontal components. (Fig. 61–1). The majority of bone consists of a dense outer and inner cortex surrounding an inner layer of cancellous bone. Through the cancellous bone run the inferior alveolar neurovascular bundles and lymphatics that nourish the bone and the associated teeth. The inferior alveolar artery is a branch of the internal maxillary artery and enters the lingual aspect of the mandible high on the ascending ramus through the mandibular foramen. The inferior alveolar nerve is a branch of the mandibular nerve, which in turn is a branch of the trigeminal nerve. Its course in the mandible parallels that of the artery.

There are 16 teeth in the fully developed mandible. There are two each of a central and lateral incisor; cuspids; first and second bicuspids; and first, second, and third molars. The horizontal portion of the mandible is divided into a superior or alveolar portion comprising spongy bone that surrounds and supports the roots of the teeth. The inferior or basal portion is where the inferior alveolar neurovascular bundle courses. The chin prominence at the midline of the mandible is called the *symphysis*. As the mandiblular arch continues proximally from midline, the area at the canine forms the *parasymphysis*. The horizontal region from the parasymphysis proximally is called the *body*. This horizontal body joins the vertical ascending ramus at the angle of the mandible. The ramus narrows superiorly to form the condylar neck and the coronoid process. The condylar neck flares superiorly to form the condyle, which articulates with the glenoid fossa of the temporal bone at the base of the skull. Interposed between the condylar head and the glenoid fossa is a fibrocartilaginous structure called the *meniscus*. This structure, the *temporomandibular joint (TMJ)*, is an example of a diarthroidial or ginglymoarthroidial joint. This type of joint is capable of hinge, gliding, and rotational movements.

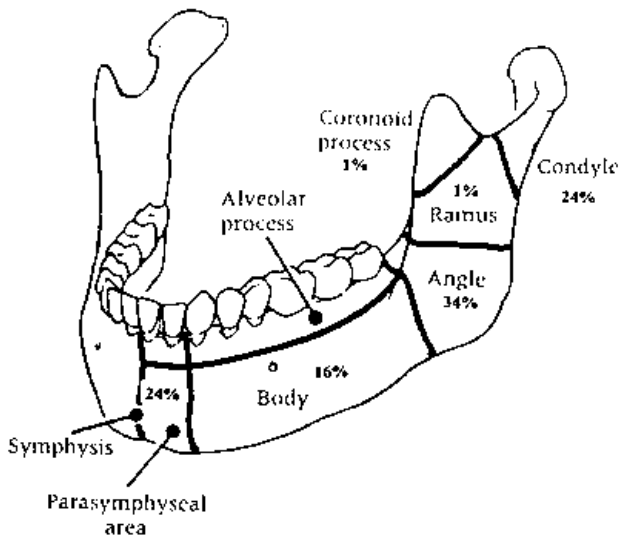

Figure 61–1 Anatomy of the mandible.

Although the mandible is a strong, dense bone, it has several areas of inherent weakness. The subcondylar region down to the angle is an area of naturally thin bone. The presence of a third molar at the angle further thins this area and makes it susceptible to fractures. The narrow portions of the condylar neck are frequently fractured when forces generated at the symphysis travel upward and overcome the compressive strength of the condylar neck, causing it to fracture. The presence of the canine tooth root and the mental foramen makes the parasymphyseal area susceptible to fractures. It is

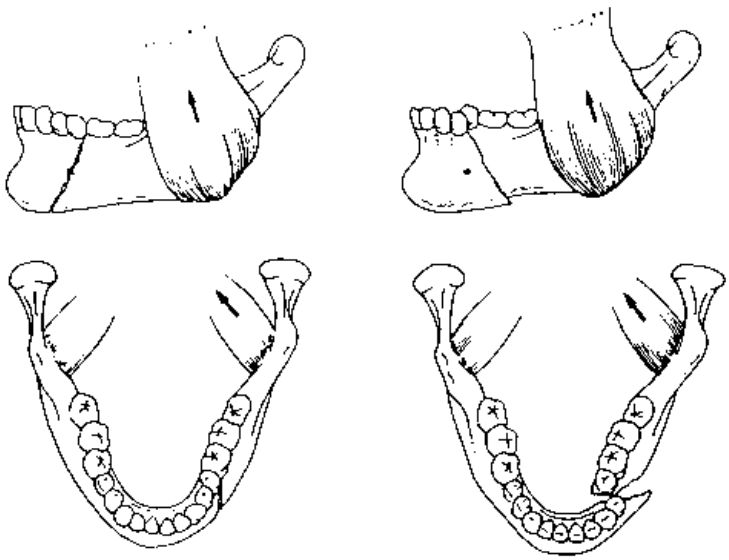

Figure 61–2 Favorable and unfavorable fractures.

not surprising that the most common areas of fracture are the subcondylar, angle, and parasymphyseal regions.[3]

The muscles of mastication are mirror images bilaterally and attach to the mandible at various sites. The elevators of the jaw are the masseter, temporalis, and medial pterygoid muscles. The depressors are the suprahyoid muscles and the lateral pterygoid muscles. When a fracture occurs through the mandible, the unopposed pull of a particular muscle or muscle group can displace the fractured segments and keep them out of alignment.

CLASSIFICATION

Similar to long-bone fractures, fractures of the mandible can be described as closed, open, simple, complex, or comminuted. Fractures of the mandible that extend through the periodontal membrane surrounding the root of the tooth and communicate with the oral cavity are considered open fractures. Fractures can also be classified as favorable or unfavorable (Fig. 61–2). The direction in which the fracture line travels, the bevel of the fracture line, and the muscular forces acting on the fractured segments can either displace the segments to a position that is unfavorable for healing or reduce the fracture line to a position that is favorable for healing. In general, mandibular fractures that are directed inferiorly and anteriorly are classified as horizontally favorable. Fractures directed inferiorly and posteriorly are classified as horizontally unfavorable. Medial displacement can occur when a fracture runs from posterior to anterior because of the medial pull of the elevator muscles of mastication, thus making this a vertically unfavorable fracture. A fracture that passes from the outer surface of the mandible, posteriorly and medially, as in a sagittal split osteotomy, is a favorable fracture because the muscle pull prevents displacement. This is considered a vertically favorable fracture.

A fracture through the body of the mandible that contains a tooth in the posterior fracture segment, even if it is coursing in an unfavorable direction, can reduce itself when the tooth in the posterior fracture segment opposes a maxillary tooth and comes into contact with the opposing fragment. In this situation the tooth should be retained and used as an occlusal stop to prevent displacement of the fracture. Mandibular fractures that involve only the alveolar bone and the associated teeth are termed *dentoalveolar fractures*. These fractures are considered open fractures and should be managed as such.

Treatment of all of these fractures must include fixation forces that are substantially greater than the displacing forces to optimize healing.

DIAGNOSIS

Diagnosis of mandibular fractures can generally be made by a thorough clinical examination. Signs and symptoms of a mandibular fracture include intraoral bleeding, pain, swelling, trismus, malocclusion, and deviation of the jaw on opening. Palpation of the mandible may reveal step-offs at the fracture site as well as pain. An intraoral examination may reveal ecchymosis of the floor of the mouth in the region of a fracture, a step-off between the teeth or bleeding (Fig. 61–3). The

Figure 61–3 Obvious step-off between the canine and first bicuspid in a parasymphyseal fracture.

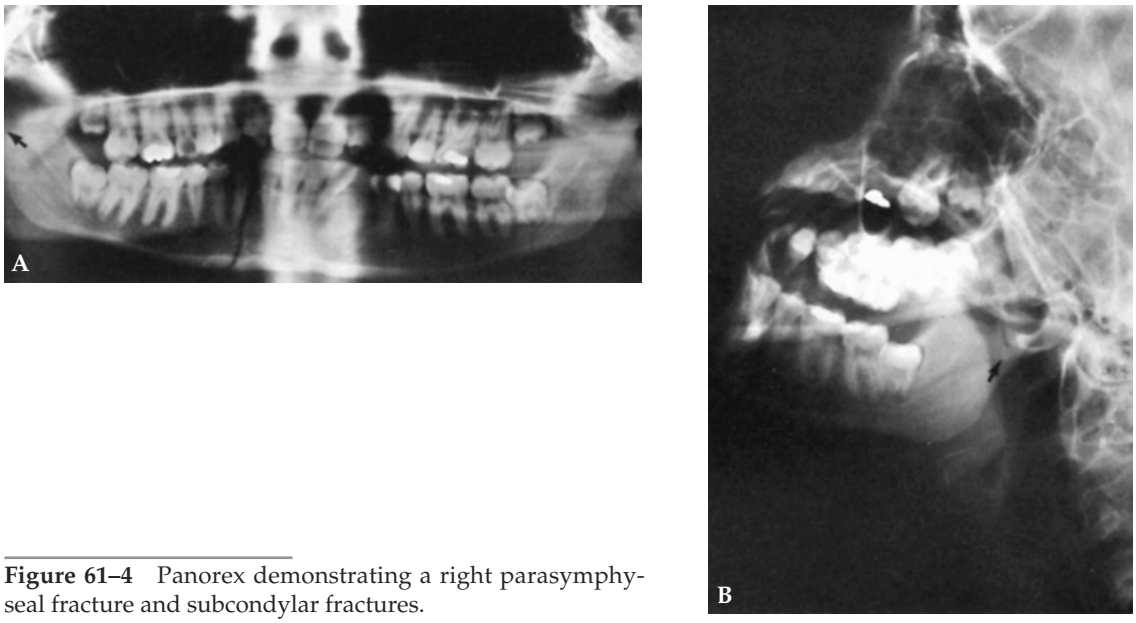

Figure 61–4 Panorex demonstrating a right parasymphyseal fracture and subcondylar fractures.

mandibular stress test can reveal subtle fractures. The stress test is performed by placing the volar pads of the examiner's thumbs on the lingual aspects of the body of the mandible and then pushing the thumbs outward. Pain elicited during this "stress" is usually indicative of a fracture at that site. This maneuver should obviously be performed only on cooperative patients.

Radiographic examinations can delineate the locations and patterns of fractures. The most information for the least expense can be obtained from a panoramic radiograph of the jaws or Panorex. A Panorex is essentially a single tomogram that reveals the entire mandible in a two-dimensional panoramic view (Fig. 61–4). Due to the overlap of the x-ray at the mandibular midline, the symphyseal region is usually blurred. However, a Panorex cannot be obtained from an uncooperative or obtunded patient, and in that situation a mandibular series is indicated. This series of radiographs includes lateral obliques, a posterior–anterior view, and a Towne's view. Towne's view gives an excellent view of the condylar regions. Studies have shown that 92% of fractures in a given patient population can be detected on a Panorex, whereas only 66% were detected in a mandibular series.[4]

Computed tomography (CT) scans can give more detailed information of fractures in the condylar regions and the lingual aspect of the mandible (Fig. 61–5). However, their use as a screening tool is costly and unnecessary.

TREATMENT PRINCIPLES

No matter what method of fixation is being considered for the repair, the principles of bone fracture management remain the same. After the appropriate diagnosis has been made, trauma to the remainder of the patient has either been ruled out or managed, and the patient is stable, several principles should be adhered to. Open fractures should be treated with systemic antibiotics. This decreases the incidence of infection. Generally, the earlier a fracture can be reduced and fixated, the better the outcome is. If fixation of the fracture will be delayed, preliminary stabilization of the segments should be performed to decrease patient discomfort. Something as simple as an elastic band suspension device from the inferior border of the mandible to the top of the head could be used to bring the muscles of mastication to resting length and help decrease the amount of muscle spasm and movement of the fracture line.

The principles of mandible fracture management include establishment of the preinjury dental occlusion, anatomic reduction of the fractures and stabilization of the fracture

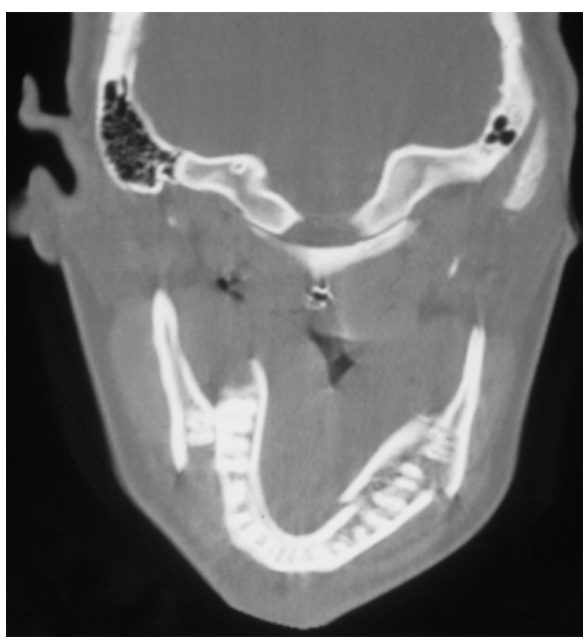

Figure 61–5 CT scan demonstrating lingual fractures and their displacement.

until bony healing has occurred. The question of how to manage teeth that are involved in the line of a mandibular fracture continues to be a point of controversy. Teeth that are fractured through the root or pulp chamber, teeth with significant amounts of carious decay, root abscesses and loose teeth with severe periodontitis should probably be extracted prior to reduction and fixation of the fracture. The extraction sockets in the alveolar bone should be thoroughly curetted and irrigated with sterile saline solution. Another controversial issue regarding teeth in the fracture line is what to do with the third molar, which is in the line of a mandibular angle fracture. Some investigators recommend leaving teeth in the line of the fracture to provide a broader area of hard tissue contact and therefore provide stability.[5] In a study by Ellis and Sinn, of nine patients in whom teeth associated with a fracture were left in place, six developed infections, for an infection rate of 67%. On the other hand, in 46 fractures when the tooth was removed, 13 infections occurred, resulting in an infection rate of 28%.[6]

FIXATION TECHNIQUES

Fixation techniques can be described as either semirigid or rigid.

Semirigid Fixation

Semirigid fixation implies that because of the elasticity of these fixation devices, some movement occurs at the fracture line. Semirigid mechanisms of fracture fixation include maxillomandibular fixation (MMF) techniques, such as placement of arch bars with interdental wiring, four-screw intermaxillary fixation, ivy loops, and external fixation devices such as the Joe Hall Morris appliance. In general, minimally displaced, favorable fractures with easily reproducible occlusion can be managed with semirigid fixation (Fig. 61–6). MMF devices are placed, and heavy elastic or wire is then used to hold the teeth in their preinjury occlusion. Interdental fixation is then maintained for periods ranging from 2 to 6 weeks. The younger and healthier the patient, the less time required for bony healing to occur.

Although there are some advantages to the use of MMF, there are also distinct disadvantages. The advantages include simplicity of fixation and no need for soft tissue dissection. Disadvantages of interdental fixation include weight loss, tooth decay, gingivitis, and immobility of the TMJ, which can lead to stiffness and limitation of range of motion. A contraindication for the use of MMF is the patient's inability or unwillingness to cooperate with interdental fixation.[7] This can be the case with the elderly, obtunded patients, mentally retarded patients, alcoholics, drug addicts, or any patient predisposed to vomiting. Such patients are at risk for aspiration and should be treated with rigid-fixation techniques.

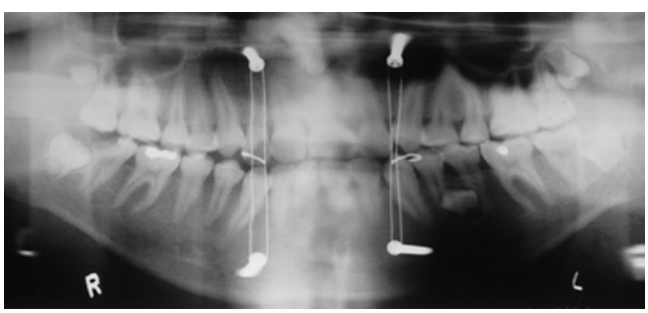

Figure 61–6 Four-screw maxillomandibular fixation for minimally displaced subcondylar fracture.

Rigid Fixation

Rigid fixation of the mandible involves the use of plates and screws for fracture fixation. Principles of rigid fixation include early anatomic reduction of the fracture segments, maintaining them in their anatomic reduction, and immobilizing the fracture segments with appropriate plates and screws or screws alone. The rigid-fixation devices should be of sufficient strength to neutralize loads that occur under normal functional requirements, such as mastication and speech. It is important not to underestimate the masticatory loading conditions because of the danger of plate fracture and nonunion or, worse, infection of the bone.

The majority of fixation plates used for the mandible are made of commercially pure titanium, which consists of titanium and oxygen. It is insoluble and therefore inert and biocompatible. Titanium has a high corrosion resistance due to the presence of a thin oxide layer that forms on the surface, which allows the material to behave passively.[7]

Techniques and principles that help to minimize complications of rigid fixation of the mandible are the same as for rigid fixation of any of the bones in the human skeleton. An extremely sharp drill bit is used at low speeds of less than 1000 rpm with constant irrigation of the drill bit with saline so that the temperature of the bone remains below 40°C. This prevents osteocyte necrosis, which can cause loosening of the screws. Loose screws are an absolute source of fixation failure and should never be left in place. The plate should be passively adapted to the underlying bone with a slight overbend of the plate just over the fracture site[8] (Fig. 61–7). This slight overbend helps to prevent lingual displacement of the fracture when the screws are placed. Accurate passive adapta-

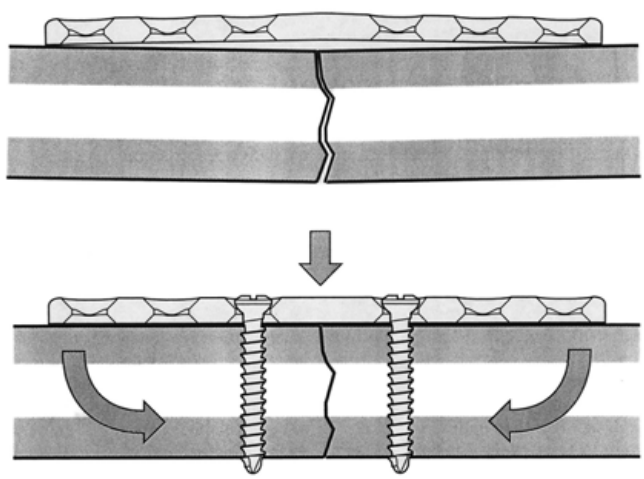

Figure 61–7 Correct passive adaptation of a plate to the mandible with a slight overbend at the fracture site allows for accurate reduction of the fracture during screw placement, as well as reduction of the lingual aspect of the fracture.

tion of the plate to the bone surface allows the fracture segments to remain in their reduced position. A poorly adapted plate forces the fracture segments out of position when the screws are placed and can lead to nonunion, malunion, and malocclusion. The screws should be placed through the bone so that at least one or two threads engage and exit the outer cortex of the bone to ensure engagement of the screws with as much cortical bone as possible. The plate must be of sufficient strength to overcome the tensile forces of the mandible.

Tension Band Principles

As described in the anatomy section, there are multiple muscles acting and exerting forces on different areas of the mandible during function. During occlusal loading a zone of tension develops at the alveolar surface of the mandible and a zone of compression develops at the inferior border.[9] The depressor muscles acting at the symphysis pulling downward and the elevator muscles pulling upward at the angle and the coronoid process help to develop these tensile and compressive forces (Fig. 61–8). When a fracture occurs in the horizontal segments of the mandible, the tensile forces act to displace the fracture at the alveolar border and compress the fracture at the inferior border. Compressive forces can also cause the fracture segments to override at the zone of compression. Multiple forces acting at the symphysis allow for the development of torsion forces in this area.

Fixation systems should ideally be located at the superior border of the mandible across the fracture site. The fixation would function as a tension band that overcomes the distracting forces at the alveolar border. This tension band should therefore be strong enough to overcome the tensile forces at the superior border of the fracture line and resist separation of the fracture. The inferior border would remain closed due to the natural compressive forces.

Several methods are used to establish a tension band. The presence of the teeth and their roots in the alveolar portion of the mandible makes the use of bicortical fixation of plates and screws impossible. The two most commonly used methods are bridging of the teeth across the fracture line with either an arch bar or direct wires (such as ivy loops) or placement of a monocortical miniplate across the fracture line (Fig. 61–9). Monocortical placement of the screws prevents damage to the tooth roots.

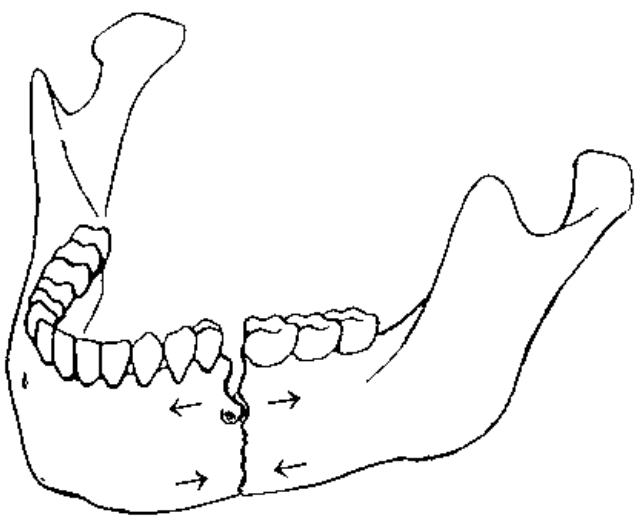

Figure 61–8 During occlusal loading, tension forces cause the alveolar surface to separate and compressive forces cause the inferior border of the mandible to close at the fracture site.

Figure 61–9 Monocortical placement of a miniplate near the superior border of the mandible functions as a tension band.

COMPRESSION

A description of compression plating is important to the understanding of mandibular fracture fixation. Basically, compression is a method for preventing interfragmentary motion of the mandible fracture. Compression plating consists of the forcing together of two surfaces to produce an axial preload force in the fracture line and also acts by increasing interfragmentary friction. Therefore, the fracture remains immobile as long as the actual axial preload that has been placed with the plate is higher than the tensile forces produced by masticatory function.

Preloading with plates and screws mechanically allows load sharing to occur between the bone and the plate.[7] Compression plates are designed so that two holes on either side of the fracture line are eccentrically placed (Fig. 61–10). These two holes are designed with an inclined and horizontal beveled surface that allows a screw that is being threaded to glide toward the medial aspect of the plate. Because the screw is engaging the bone, the bone is moved medially as the screw is tightened and the bone is compressed against the opposite fracture segment. Only two screws, one on each side of the fracture, should be placed eccentrically. The remaining screws are placed in a centric or neutral fashion. This method of fixation is useful only when you have a noncomminuted, simple transverse fracture of the mandible. Bones that are

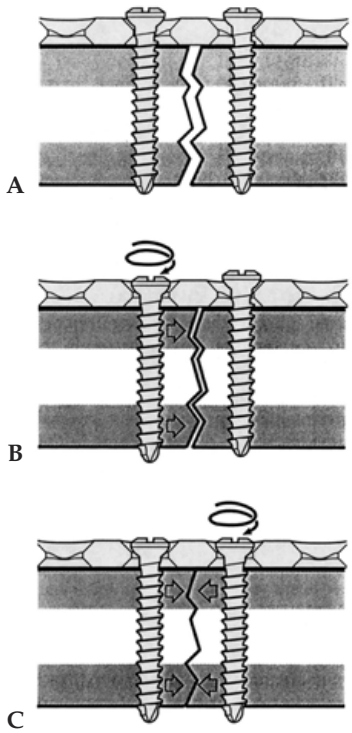

Figure 61–10 Compression with a plate. **(A)** The two innermost screws should be placed eccentrically within the DC holes. **(B)** As these screws are tightened they approximate the fragment. **(C)** With final tightening of the screws, compression is achieved.

fractured obliquely or are comminuted when compressed will override their fracture fragments, displace the comminuted segments, and lead to fracture instability and possibly malocclusion.

Compression can also be obtained with the use of a lag screw. Lag screw fixation is useful for uniting fracture segments and for fixating bone grafts.[10] The technique of lag screw fixation involves the establishment of a gliding hole in the outer cortex. This gliding hole allows the screw to pass through without engaging the bone. A second threaded hole is placed in the far or outer cortex. The first hole or the gliding hole is purposely overdrilled so that the hole is at a minimum the size of the outer diameter of the screw threads. The hole in the far cortex is drilled to the exact diameter of the size of the core of the screw. A screw is then placed through the gliding hole, and as the screw engages the threaded hole in the far cortex and is tightened, the two bone fragments are forced together and interfragmental compression is obtained. This type of compression is referred to as static interfragmental compression.[7] It is static because it does not change significantly with load. Lag screws can be used for fractures at the symphysis or oblique fractures of the body, angle, and subcondylar regions that have significant overlapping segments. (Fig. 61–11) At least three lag screws are placed in fractures of the mandible. At the symphysis, two screws may be used. Rarely should only a single lag screw be applied. A single lag screw does not provide a great deal of strength, though it does provide stability.

NEUTRALIZATION PLATES

When a fracture of the mandible is more than a simple transverse fracture and compression plates are contraindicated, then a neutralization plate should be used. A neutralization plate is a plate of sufficient length and strength to overcome the functional forces acting on the mandible. The use of noncompression holes in the plate and an adequate number of screws with a minimum of two on either side of the fracture provides sufficient rigidity to allow bony healing to occur (Fig. 61–12).

SOFT TISSUE APPROACHES TO THE MANDIBLE

A wide unobstructed view of the mandible at its fracture site is a key component of anatomic fracture reduction and fixation. With the advent of new craniofacial surgical techniques and the utilization of incisions adapted from facial aesthetic surgery, soft tissue approaches to the mandible can be chosen to minimize nerve injury and scarring of the patient.

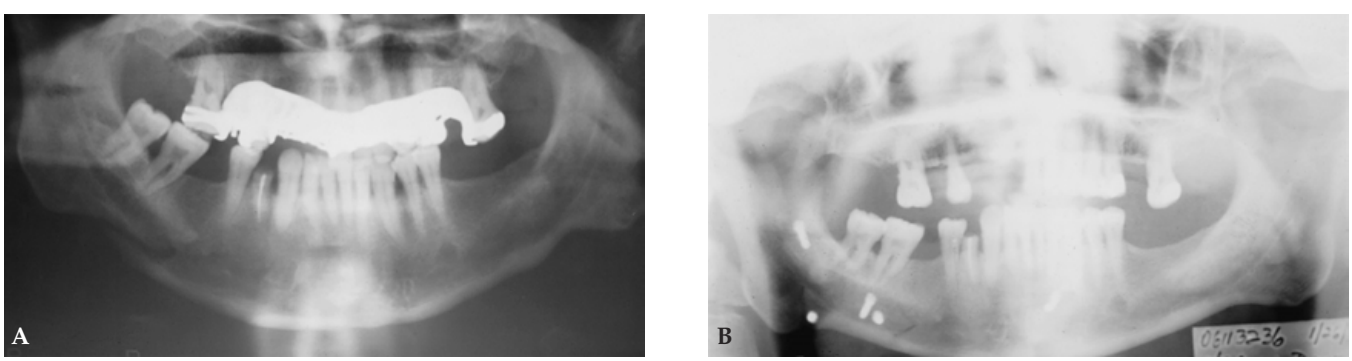

Figure 61–11 **(A)** Oblique fracture of the mandible with overlapping segments. **(B)** Three lag screws placed to rigidly fixate the oblique fracture.

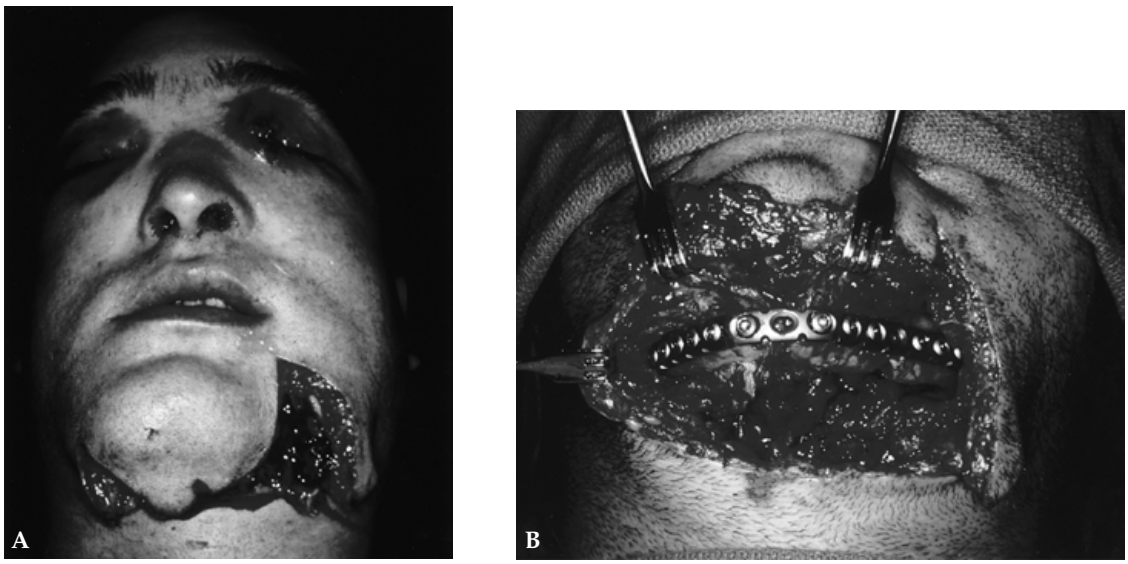

Figure 61–12 **(A)** Gunshot wound to the mandible after debridement of damaged soft tissues. **(B)** Neutralization plate used to reduce the severely comminuted mandible.

In general, intraoral incisions should be utilized whenever feasible. Intraoral incisions made in the vestibule leaving a 5- to 10-mm cuff of mobile mucosa and wide periosteal dissection of the mandible allow for excellent exposure of the mandible from the symphyseal region back to the angle and ascending ramus. Care should be taken at the level of the bicuspids. The mental nerve exits the mental foramen and travels just under the mucosa toward the skin. Blunt dissection over this area with a hemostat will expose the nerve (Fig. 61–13). With enough experience and the use of percutaneous drill and screw placement methods, low subcondylar fractures can also be approached from this direction. The intraoral approach avoids damage to the facial nerves and leaves no external scarring. Disadvantages include limited visibility of the inferior border of the mandible, particularly as the fracture lines approach the angle. In addition, there is no visualization of lingual cortical fractures. In an arched structure such as the mandible, it is important to maintain three-dimensional reduction of the fracture at the buccal cortex, the inferior border, as well as the lingual cortex. Not accurately reducing the lingual cortex can lead to widening of the mandibular arch and therefore widening of the facial plane in a transverse dimension.

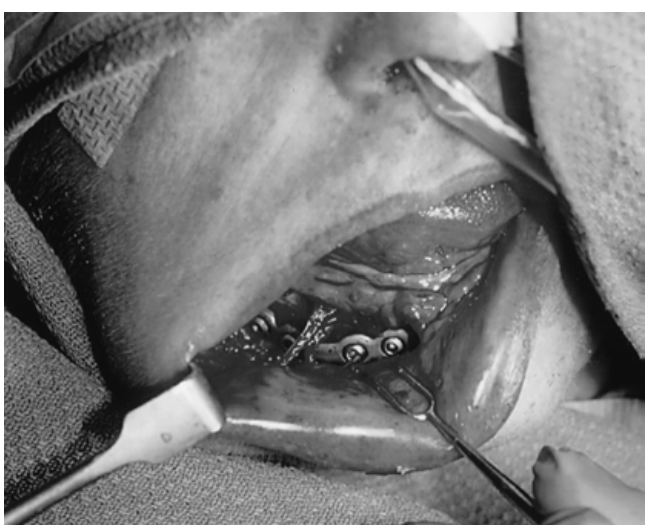

Figure 61–13 Knowledge of anatomy and careful dissection allow for preservation of the mental nerve and adequate exposure of the mandible fracture for plate and screw placement.

Extraoral approaches to the mandible are variations of standard facelift and parotidectomy incisions. The incisions in the temple region extending to the preauricular regions are useful for exposure of the condyle of the mandible as well as the glenoid fossa (Fig. 61–14). The inferior extent of the facelift incision around the lobule of the ear and extended to the neck in a horizontal crease line is called the Risdon incision. The neck incision should be placed at least one finger breadth below the angle of the mandible to avoid injuring the marginal mandibular nerve. This incision exposes the angle of the mandible, the ascending ramus, and the subcondylar regions. The temporal extension of the preauricular incision is made deep to the superficial layer of the deep temporal fascia to avoid damage to the frontal branch of the facial nerve. Retraction of these flaps can also injure these facial nerves and should be done with care.

In the edentulous patient with a thin, atrophic mandible, an intraoral approach will strip the periosteum from the mandible. This increases the risk of complications due to devascularization of this thin, atrophic bone. Therefore, an extraoral approach is usually indicated in fractures of the edentulous mandible. The plane of dissection is above the level of the periosteum. The plate is screwed directly on top of the

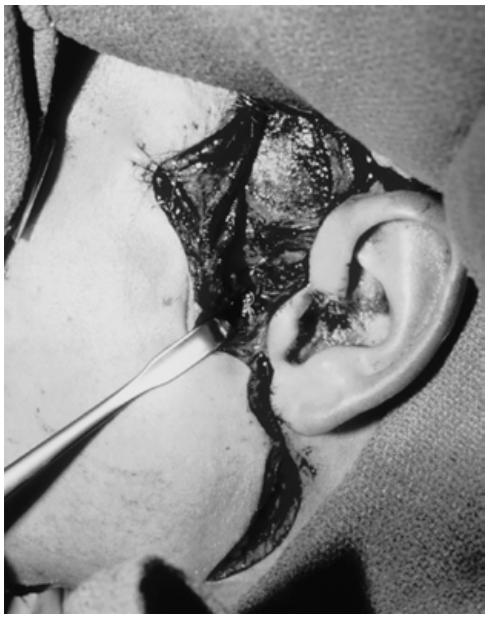

Figure 61–14 Extended facelift incision combined with a modified Risdon incision exposes the glenoid fossa, condylar head, and subcondylar regions of the mandible.

periosteum, allowing as much blood supply as possible to remain intact. In severely comminuted fractures and some bilateral fractures with displacement, a cervical smile incision has been used (Fig. 61–15). This is a transcervical incision that is made in a horizontal crease of the neck between the hyoid and the thyroid cartilage. Such dissection allows visualization of the mandibular branch of the facial nerve bilaterally with safe reflection of the nerve upward. Direct visualization of the inferior, buccal, and lingual borders of the mandibular fractures bilaterally is easily obtained.

The soft tissue approaches to the fractured mandible should be individualized to each patient and carefully chosen to optimize visualization, reduction, and fixation of the fractures and minimize facial scarring and damage to neurovascular structures.

MANAGEMENT OF SPECIFIC FRACTURE SITES

Symphysis

Fractures of the symphysis can be difficult to detect, particularly if they are nondisplaced. Because of blurring at the midline, a Panorex usually cannot delineate a nondisplaced symphysis fracture. A sublingual hematoma or ecchymosis of the anterior floor of the mouth may be the only sign of a fracture (Fig. 61–16). An intraoral approach is used for exposure of the symphysis. A large laceration at the chin, if present, may be used for the approach instead of the intraoral incision. When a symphysis fracture is identified, subcondylar fractures should be highly suspected until ruled out. In children presenting with a chin laceration because of a fall or other blunt trauma, a symphysis fracture should be sought and condylar head or subcondylar fractures ruled out (Fig. 61–17).

Figure 61–15 **(A)** A cervical incision allows for wide exposure of the mandible when extensive comminution or severe bilateral mandible fractures exist. **(B)** The "cervical smile" incision approach to severe bilateral mandible fractures. Note the excellent exposure of the lingual aspects of the mandible.

Figure 61–16 Ecchymosis of the anterior floor of the mouth can be indicative of a symphyseal fracture.

Figure 61–17 Wide exposure of the symphysis is possible through an intraoral incision.

Arch bars or their equivalent should serve as tension bands and be used to set the teeth into their preinjury occlusion. Either the arch bar may be used as a tension band, or a four-hole miniplate can be placed in a monocortical fashion at the alveolar border. A mandibular fracture plate is then placed at the midportion of the symphysis. There is no inferior alveolar neurovascular bundle coursing through this portion of the mandible, and as long as the plate is placed below the roots of the teeth this will suffice.

When a symphysis fracture is combined with subcondylar fractures a longer and stronger reconstruction plate should be considered. This stronger plate will help to overcome the torsion forces that develop at the symphysis and will also prevent widening of the mandibular arch.

Lag screws may also be used for the symphysis. A minimum of two screws should be used. As previously stated, these screws should be placed perpendicular to the fracture line and parallel to each other.

Parasymphysis

Fractures of the parasymphyseal region are managed in a similar fashion to symphyseal fractures. An intraoral approach should be used. The mental nerve courses very close to the mucosal surface in the area of the canine and first bicuspid. Careful blunt dissection of the mental nerve will preserve its function. The mental nerve should be dissected free from the surrounding tissues and gently retracted from the dissection field. A tension band should be placed and a mandibular fracture plate positioned at the inferior border of the mandible below the mental nerve (Fig. 61–18).

Body

An intraoral approach is usually employed for these fractures. It is important to remember that the inferior border and the lingual cortex cannot be visualized intraorally. Careful evaluation and diagnosis of the fractures will determine

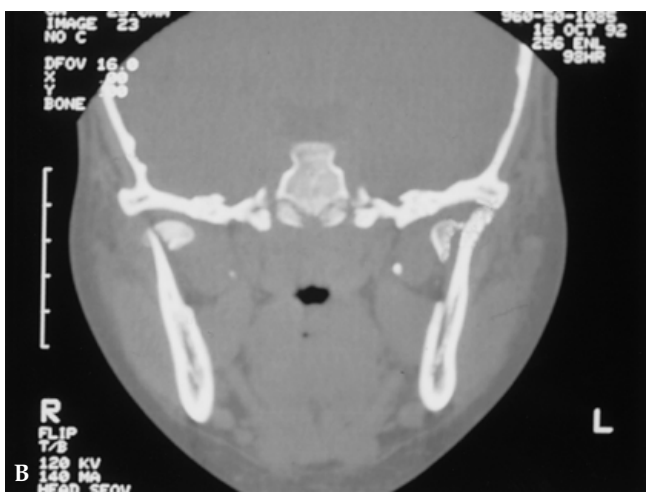

Figure 61–18 **(A)** A repaired chin laceration in a 5-year-old child who suffered a fall from a bicycle. **(B)** CT scan of the same patient demonstrating medially displaced bilateral condylar head fractures.

if an intraoral approach is adequate or if an external approach should be used. After preinjury occlusion has been reestablished a monocortical tension band can be placed. The mandibular fracture plate is then adapted to the inferior border and screwed into position. The inferior alveolar neurovascular bundle travels near the inferior border in this region and should be avoided. A Panorex is helpful in identifying the path of this structure.

When a sagittal or oblique fracture occurs through the parasymphysis or the body of the mandible, lingual tipping of the occlusal surfaces of the mandibular teeth can occur when the patient is placed in occlusion with arch bars and wires. As the MMF wires are tightened, the obliquely fractured segment can tilt lingually leading to a malocclusion. A custom acrylic splint fabricated from study casts is placed along the lingual borders of the mandibular teeth and wired into position, thus preventing lingual displacement of the fracture segment when the patient is placed in MMF.

Sagittal or oblique fractures of the body of the mandible and parasymphysis can be fixated using the lag screw technique. At least three screws should be placed to obtain sufficient fixation to allow for bony consolidation and healing.

Angle

Fractures of the angle of the mandible tend to be difficult to reduce and fixate accurately. The combination of the location of the fracture, the thinness of the proximal segment, and usually the lack of a tooth in that segment makes anatomical reduction difficult. The approach can be an intraoral incision with wide stripping of the periosteum. The difficult area to visualize is usually the inferior border. The use of a dental mirror from the intraoral approach or an endoscope can help make visible the inferior border and often the lingual border to ensure adequate reduction of the fracture. When this has been done, preinjury dental occlusion is obtained and held in place with MMF. A curved or L-shaped mandibular plate is then placed across the fracture segment at the inferior border, with care taken to avoid the inferior alveolar nerve as well as the roots of the teeth (Fig. 61–19). Fixation is performed percutaneously. It is important that at least two screws be present on either side of the fracture. In a large, muscular patient, three screws should be placed on either side of the fracture segment. A monocortical 2-0 miniplate is placed at the superior border to function as a tension band (Fig. 61–20). Ellis and colleagues have described their experience using one noncompression miniplate at the external oblique ridge for fractures of the angle of the mandible. The theory behind this is that a plate positioned across the external oblique ridge functions as a tension band to prevent displacement of the superior border during function and that the inferior border will be compressed and remain reduced. In their patient population, treatment of angle fractures with traditional methods produced a high rate of complications (approximately 17%).[11] Their study recommends an intraoral approach with an incision at the external oblique ridge. Dissection of the soft tissues over the fractures is performed, reduction is obtained, and the patient is placed in MMF. After adequate reduction of the fracture is obtained, a single noncompression miniplate is passively adapted to the external oblique ridge and a minimum of two screws are placed in a monocortical fashion on either side of the fracture line. As stated in their study, all biomechanical tests performed to date indicated that two plates are more stable than one. However, this author's clinical experience is the complete opposite. It is his belief that improved maintenance of the blood supply to the bone due to limited dissection may be a factor leading to successful use of this technique.

Condylar and Subcondylar Fractures

Perhaps no other fractures of the mandible generate as much controversy as condylar and subcondylar fractures.[12] Approaches to the fractured condyle inevitably involve areas of the face where the facial nerve is susceptible to injury. Multiple approaches are described in the literature, including preauricular, intraoral, Risdon, and a combination of a transexternal auditory canal approach and one of the above.[12] Again, the principles remain the same in treatment of condylar fractures (i.e., anatomic reduction of the fracture segments and stabilization of the reduced segments).

Figure 61–19 Monocortical tension band and mandibular fracture plate placed for a parasymphyseal fracture.

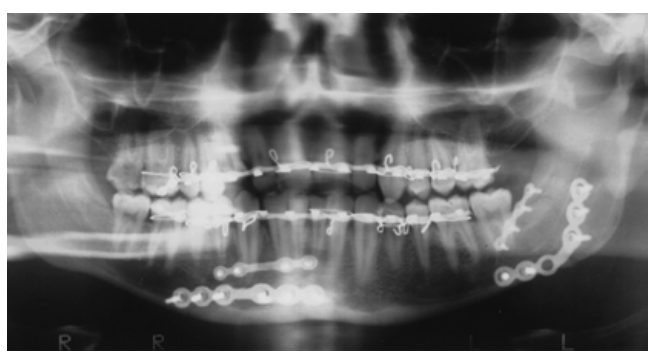

Figure 61–20 Panorex of a rigidly fixated left mandibular angle fracture and a right parasymphyseal fracture with monocortical miniplates used as tension bands.

Fractures of the condylar and subcondylar region usually occur because of the inherent weakness of the condylar neck. Forces that are generated at impact, particularly at the symphyseal and parasymphyseal regions of the mandible, travel along the body and ramus of the mandible up to the condylar neck where they usually are sufficient to overcome the compressive strength of the bone in this region, and a fracture occurs. Condylar fractures can be classified as intracapsular, referring to fracture of the condylar head itself within its surrounding ligamentous capsule, or high subcondylar or low subcondylar, referring to fractures that occur at the level of the sigmoid notch. By definition, each of these fractures affects the TMJ and, as with any joint injury, early mobilization is recommended to prevent long-term problems. If a patient has easily reproducible occlusion and a nondisplaced or minimally displaced fracture, conservative management with a soft diet alone is indicated. A patient who has difficulty achieving occlusion but has simple, minimally displaced fractures of the condylar or subcondylar region is usually treated with short-term MMF with heavy elastics for approximately 2 weeks. After release of the MMF, the patient is placed in lighter elastics to help guide the teeth into occlusion, and a postinjury physical therapy regimen is begun. Several treatment protocols are available. However, all essentially include opening and closing of the jaw and movement into lateral excursions, thus enabling the patient to open the jaws to their preexisting maximal interincisal opening.

Indications for open reduction of condylar and subcondylar fractures include (1) displacement of the proximal segment fragment of 30 degrees or more from the axis of the ascending ramus; (2) shortening of the ascending ramus with telescoping of the fragments and a resulting open bite; (3) dislocation of the condylar head from the temporomandibular fossa; and (4) inability to obtain adequate dental occlusion with closed reduction.[13] In addition, bilateral subcondylar fractures with loss of vertical height are usually an indication for open reduction and internal fixation of the condylar neck on at least one side to reestablish the posterior height of the mandible. Zide and Kent published their absolute indications for open reduction or the condylar neck fractures. These include (1) displacement of the condyle into the middle cranial fossa, (2) difficulty in obtaining adequate occlusion by closed reduction, (3) lateral capsular displacement of the condyle, or (4) invasion of the condylar neck by a foreign body, such as in a gunshot wound.[14] As previously stated, many techniques for stabilization of the condylar fracture have been described. These include traditional plate and screw fixation, direct wiring, extracorporeal removal of the proximal condylar fragment and placement of a plate and fixation to the distal fragment, lag screw placement, and replacement of the condyle with a rib graft. If the fracture occurs below the midlevel of the neck, it is often possible to perform an intraoral alignment and reduction of the fracture, stabilization with bone-holding clamps, followed by percutaneous placement of a passively adapted plate and screws. This author prefers the 2.4-mm titanium plate-and-screw system. A standard intraoral incision is made along the external oblique ridge wide dissection of the periosteum performed. Then the proximal segment is identified and reduced with bone-holding forceps. At this point, the patient is placed into preoperative dental occlusion and fixation with wires is carried out. Then a 2.4-mm plate that has been appropriately adapted is placed along the lateral surface of the fracture supported by a single K wire that was driven percutaneously into the segment, and a standard transbuccal trocar system is used to screw the plate into position. When this has been performed, the bone-holding forceps is removed, the maxillomandibular fixation released, and the occlusion checked. It is important that during fixation the proximal segment be located in the glenoid fossa. If the condyle is out of the fossa and the fracture is fixated, the patient will be left with a posterior open bite.

Recent reports have described endoscopic techniques for approaching condylar and subcondylar fractures.[15] The endoscope allows visualization of the proximal segment and therefore manipulation of the segment into position. The use of endoscopic techniques combined with percutaneous screw placement is relatively recent but shows significant promise. The use of the endoscope therefore would avoid the need for large incisions, allow visualization of the fracture segments, and prevent injury to the branches of the facial nerve. If a surgeon is skilled in the use of endoscopic techniques, the visualization is excellent and the remainder of the plating techniques remains the same.

Comminuted Fractures

Comminuted fractures of the mandible are usually the result of high-energy injuries. These types of fractures involve multiple fracture lines and small segments of free-floating bone. Gunshot wounds and motor vehicle accidents are responsible for the majority of comminuted fractures. It may be necessary and often wise to obtain preoperative study models and the fabrication of an acrylic splint to help guide establishment of the preinjury occlusion. An extraoral approach usually allows direct visualization of the fracture fragments. A stepwise anatomic reduction of the mandible fragments is then performed. Small fragments of bone are placed in their anatomic position and held there with monocortical miniplates. Wires may be used in a similar fashion. When the fracture segments have been reduced and held in position and the preinjury occlusion reestablished, a large reconstruction plate should be used to span all of the fracture fragments. Special attention should be paid to the extent of the lingual fractures. These fractures may extend further than the buccal cortex fractures. The reconstruction plate should be of sufficient length to span the length of all of the fractures. Any piece of bone that appears to be devascularized and nonviable should be removed prior to fixation. It is advised that fixation be obtained with at least three or preferably four screws on each side of these high-impact, high-energy fractures. There is often concomitant soft tissue loss over these fractures. Even in the area of soft tissue loss, bone reduction and reestablishment of mandibular contour should be obtained. Obtaining soft tissue closure in such a situation and not reestablishing the mandibular contour will lead to scarring of the soft tissue into the defect and render future mandibular reconstruction extremely difficult. Local, regional, and distant vascularized tissues for coverage of the fractured mandible and plate should be used to ensure healing.

Dentoalveolar Injuries

Injuries to the oral cavity are common in trauma patients. Of these injuries, 80% occur in the area of the four anterior maxillary teeth.[16] Any trauma to the lower face can result in injury to this dentoalveolar complex. Laceration of the lips and intraoral mucosa is often associated with injury to the teeth and their supporting structures. As in other mandibular fractures, signs and symptoms associated with dentoalveolar fractures include intraoral bleeding, tooth malposition, malocclusion, mobility of the affected structures, pain, and change of sensation in the teeth. It is extremely important that the physician always count the patient's teeth after an injury. Missing teeth should be noted and retrieved if at all possible. Damaged teeth may lodge in the surrounding soft tissue, such as lips and tongue, or may be caught in the airway or aspirated into the lungs. If there is any suspicion of aspiration, appropriate airway precautions should be taken along with x-ray films of the chest and neck.

Dentoalveolar fractures involve a fracture of the alveolar bone and the associated teeth. The teeth in turn may or may not have fractures at the crown of the root and may be luxated or avulsed. These injuries are open fractures and should be managed as such. Attention should be paid to tetanus prophylaxis, systemic antibiotics, and reduction and fixation of the fractures.

Tooth Fracture

Tooth fractures can involve the crown or the root or both. Ellis described a classification for tooth fractures.[17] Class I involves a fracture of the surrounding of the tooth enamel. Class I fractures are usually painless. The enamel has no sensory system. This is not an urgent problem. Appropriate referral to a dentist is encouraged. Class II fractures involve the dentin of the tooth that lies below the enamel and contains dentinal tubules. These are extremely sensitive, and the area should be treated with a medicated dental paste such as calcium hydroxide or an acid-etched composite resin to cover the exposed dentin and decrease the pain. A Class III fracture involves the pulp or neurovascular center of the tooth and is extremely painful. Dental consultation should be sought urgently.

Tooth Luxation

Luxation of the tooth is described as malpositioning of a tooth in its alveolar bone socket. This type of injury is indicative of damage to the periodontal ligaments that surround the tooth roots as well as the neurovascular bundle that enters the apex of the tooth root. Treatment involves gentle manipulation of the tooth into position and digital manipulation of the surrounding alveolar bone into position. The prognosis for long-term damage of the tooth is dependent on the amount of displacement from its normal position.[18] Again, dental referral is strongly recommended. Treatment usually involves splinting of the affected tooth to the surrounding teeth with bonded acrylic, a monofilament nylon or wire, or placement of an arch bar segment.

Tooth Avulsion

An avulsion injury is described as subtotal or total separation of the tooth from the alveolar bone. This is a dental emergency. The prognosis for the long-term viability of the tooth in a successful replantation is inversely proportional to the length of time that it is out of its bony socket.[17] The tooth should usually be replanted into its bony socket within 20 minutes to 2 hours. The absolute key to success is the continued nourishment and maintenance of the periodontal ligament surrounding the roots of the tooth. If these periodontal ligament fibers become desiccated, necrotic, or avulsed due to rough handling, the tooth, if replaced in its bony socket, can ankylose to the surrounding bone and ultimately be lost. Therefore, gentle handling of the root of the tooth where the ligaments are attached is of utmost importance. The tooth root should not be scrubbed or brushed. The tooth should be handled by its crown and irrigated with normal saline. If the tooth cannot be immediately reimplanted in its bony socket, then it should be gently cleaned as previously described and placed in the buccal vestibule in the patient's mouth. Then the patient should be transported immediately to a dentist. If this is not possible, then the tooth should be placed in fresh cold milk, sterile saline, or cool tap water depending on the environment surrounding the injury. Milk is considered an ideal storage medium.[18] The periodontal cells have been shown to maintain mitotic activities for up to 6 hours when stored in milk. There are also commercial transport systems available for avulsed teeth. Treatment should be instituted by a dentist and involves replanting the tooth in its socket, splinting the tooth as previously described, placing the patient on a soft diet and antibiotics, and doing a close follow-up. Very often the tooth will require endodontic therapy for ultimate salvage.

Dentoalveolar Fractures

Fractures of the alveolar bone and the associated teeth may or may not be associated with fractures of the crown or roots of the teeth. The teeth may also be luxated or avulsed. A very careful examination will reveal the diagnosis. These types of fractures are to be treated as open fractures. Attention is paid to tetanus prophylaxis, antibiotic coverage, and reduction and fixation of the fractures.

Complications of Mandibular Fractures

Complications of the treatment of mandibular fractures are usually the result of improper surgical technique and operator error. The severity of the injury and poor patient compliance also contribute to development of complications.

Infection at the fracture site can result from a nonvital or damaged or infected tooth in the fracture line, foreign body in the wound, poor oral hygiene, and inadequate reduction and fixation of the fracture. The issues of the tooth in line of fracture have been addressed earlier. Most of the approaches to the fracture sites are now intraoral, thus avoiding an external skin incision. Intraoral contamination may theoretically increase the incidence of infection, though this has not been proven. Poor plate size selection, improper placement of the

plate, or inadequate number of screws, which cannot withstand the forces of mastication, can lead to excessive movement at the fracture site. Plate failure, infection, and nonunion may result. When an infection is diagnosed, the source should be removed, the abscess drained, and an appropriate antibiotic administered. Rigid-plate fixation, an external pin device, or MMF should be used to maintain immobilization while preserving proper occlusion. If bony infection proceeds to sequestrum formation, sequestrectomy and bone graft to bridge the gap may be necessary.

Nonunion results when there is persistent motion at the fracture site, and bone necrosis occurs at the fracture site due to infection. Fibrous tissue fills the gap rather than new bridging bone. Treatment requires curetting of the intervening fibrous tissue and rigid fixation of the fresh bony ends together. If there is a persistent gap after the teeth have been placed in proper occlusion, the gap should be filled with a cancellous bone graft (or a corticocancellous bone graft for large defects).

Malunion occurs when the bone heals under poor anatomic reduction. Even the slightest step off in the tooth-bearing region, or posteriorly in the angle or ramus, can result in malocclusion. Unfortunately, most of the titanium plates that are in use today are not forgiving enough to allow for realignment of teeth by the use of elastics. Therefore, it is important to achieve proper anatomic bony reduction, dental interdigitation, and passive plate adaptation prior to plate fixation. After fixation, the MMF is released; the jaw is manually opened and closed with the condyle seated in the fossa to double-check the occlusion. Any malalignment or open bite must be corrected at this time.

Damage to the tooth roots can occur if screws or pins are placed improperly. Although it is less likely to occur with the inferior border plates, indiscriminate placement of monocortical screws in the tension band plates at the superior border can damage the tooth roots. The inferior alveolar nerve is often contused, stretched, or even severed during injury. However, with proper fracture reduction and alignment of the mandibular canal, nerve regeneration may occur. Hence, further iatrogenic damage to the nerve should be avoided during screw placement. Finally, as an external approach to the mandible is occasionally required, placement of the preauricular incision to expose the condyle, and the submandibular incision for the angle, may risk injury to the temporal branch or the marginal mandibular branch of the seventh nerve. Resolution of traction injury may take 6 months to a year.

CONCLUSION

The treatment of the mandibular fracture has evolved from semirigid- to rigid-plate fixation, permitting immediate jaw opening. Percutaneous screw placement allows performance of most of the reduction and fixation through an intraoral approach, obviating the external incisional scar. There is also increasing awareness of the absolute importance of dental occlusion, bone healing principles, as well as a better understanding of rigid fixation using plates or lag screws. On the horizon appears to be the endoscopic approach to such difficult areas as the TMJ, distraction osteogenesis for bony transport to bridge a gap, and the use of resorbable plates.

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Congenital and Pediatric Facial Plastic Surgery

Section

VI

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Chapter 62

Embryology of the Face, Head, and Neck

George S. Goding and David W. Eisele

Prenatal life has been divided into an embryonic period, consisting of the first 8 weeks of gestation, and a fetal period, which encompasses the ninth gestational week to birth. The embryonic period is particularly important because it is the time during which most organ systems are established[1] and most congenital anomalies appear.[2] By the end of the embryonic period, the major features of the body form are recognizable. The fetal period is characterized by rapid growth and maturation of the tissues and organs.

In the Carnegie system of staging, the embryonic period is divided into 23 stages based on external and internal morphology.[3] This system is thought to provide greater accuracy in the sequencing of developmental events compared with other staging systems that are based on prenatal age or length. The box on p. 788 provides an overview of the 23 stages with reference to development of structures related to facial development. Where possible, developmental events are referenced to the embryonic stage in the first 8 weeks of development and to the gestational age in weeks during the fetal period.

This chapter concentrates on the aspects of normal prenatal development relating to facial plastic surgery. Emphasis is placed on development of external structures of the face, head, and neck. Such topics as the development of the orbital contents, the middle and internal ear, and the central nervous system are either abbreviated or omitted. The reader is referred to general texts on embryology for more detailed discussion of these topics.[1,4]

EARLY DEVELOPMENT

Stages 1 to 5 fall within the first week of development. During these stages, the human organism changes from a single cell to a multicelled, hollow blastocyst embedded in endometrial stroma.[1,5] During the second week (stages 5 and 6), the bilaminar germ disc is formed with ectodermal and endodermal germ layers. The disc has bilateral symmetry, anterior and posterior ends, and dorsal and ventral surfaces.[5] The ectoderm gives rise to the cutaneous and neural systems, and the endoderm develops into the lining epithelium of the digestive and respiratory systems and the secretory cells of the liver and pancreas.

During the third week of development (stages 7 to 9), folding of the embryonic disc occurs in the anteroposterior plane and the lateral plane. Ectodermal cells invaginate between the ectodermal and endodermal layers toward a primitive streak to form the mesodermal layer. The mesoderm becomes mesenchyme from which the cardiovascular system, connective tissues, and locomotor system of bones and muscles develop. Anterior to the primitive streak, the notochord is formed from invaginating cells. Above the notochord, neural folds develop and begin to fuse in stage 10 to form the neural tube that detaches from the surface ectoderm.[1]

Ectodermally derived neural crest cells form an intermediate layer between the neural tube and the surface ectoderm. In the head the neural crest cells infiltrate the developing pharyngeal arch structures and proliferate extensively. The neural crest differentiates into mesenchyme, forming the majority of the facial structures but excluding the retina, lens, epithelial tissues, vascular endothelia, and most skeletal muscle.[6–9]

PHARYNGEAL ARCHES

The formation of the head and neck is intimately associated with the development of the pharyngeal arches. Development of the pharyngeal arches begins during stage 9 (20 days). By stage 13 (28 days), four well-developed pairs of arches are visible. Each arch contains an artery, a nerve, a cartilaginous bar, and a muscle component. Below each arch is an external groove (pharyngeal cleft) and a corresponding outpouching of the primitive pharynx (pharyngeal pouch).

In stage 14 (32 days), the second arch begins to grow rapidly over the third and fourth arches and clefts to form the cervical sinus. The second arch eventually fuses with the ectoderm in an area below the fourth arch. By day 48 (stage 18), the second, third, and fourth arches are obliterated along with the cervical sinus, giving rise to a smooth contour of the neck. Only the dorsal end of the first pharyngeal cleft remains to form the external auditory meatus.[9]

The derivatives of the pharyngeal arches are well described in general embryology texts[1,4] and are listed in Table 62–1.

DEVELOPMENT OF THE FACE

The development of the face can be first recognized in stage 9 with the appearance of stomodeum.[10] The majority of facial structures are near their final position by the end of the embryonic period, but gradual development of the face continues into adulthood.[11] The embryonic face is made up of grooves and bulges created by the uneven distribution of subepidermal mesenchyme. Developmental changes appear

Summary of stages in the embryonic period

Stages 1 to 8
0 to 15 mm; 0 to 18 days. Based on the morphologic appearance of the embryo or its covering.

Stage 9
1.5 to 2.5 mm; 1 to 3 pairs of somites; 20 days. Somites first appear, buccopharyngeal membrane, first pharyngeal pouch, otic disc present.

Stage 10
1.5 to 2.5 mm; 4 to 12 pairs of somites; 20 days. Neural folds begin to fuse, maxillary process, second pharyngeal cleft visible.

Stage 11
2.5 to 4.5 mm; 12 to 20 pairs of somites; 22 days. Rostral neuropore closes, third arch appears, buccopharyngeal membrane ruptures.

Stage 12
3.5 mm; 21 to 29 pairs of somites; 26 days. Caudal neuropore closes and upper limb buds appear. Cervical sinus visible.

Stage 13
4 to 6 mm; 30 or more pairs of somites; 28 days. Four limb buds are developing. 4th and 6th arches develop, nasal placode seen.

Stage 14
5 to 7 mm; 32 days. Optic cup forms.

Stage 15
7 to 9 mm; 33 days. Hard palate appears, olfactory pit is formed.

Stage 16
8 to 11 mm; 37 days. Footplate appears, auricular hillocks appearing, nasolacrimal groove forming.

Stage 17
11 to 14 mm; 41 days. Finger rays appear, inferior turbinate swelling present.

Stage 18
13 to 17 mm; 44 days. Toe rays appear. Choanae identifiable.

Stage 19
16 to 18 mm; 48 days. Changes in remaining stages more subtle.

Stage 20
18 to 22 mm; 51 days. Medial canthus established, merging of auricular hillocks complete.

Stage 21
22 to 24 mm; 52 days. Palatal processes separated by tongue.

Stage 22
23 to 28 mm; 54 days. Few specific changes.

Stage 23
27 to 31 mm; 57 days. The embryo is approximately 30 mm in crown-rump length and approximately 8 postovulatory weeks in age; palatal shelves reorient to horizontal position.

Fetus
Ninth to fortieth week. Bone marrow formation is present in the humerus.

TABLE 62–1 Derivatives of the Pharyngeal Arches

Arch	Cartilage	Muscle	Nerve
1	Maxillary process (premaxilla, maxilla, zygoma), Meckel's cartilage (mandible), incus, malleus	Muscles of mastication, anterior belly of digastric, mylohyoid, tensor tympani, tensor palatini	Mandibular branch of trigeminal nerve
2	Hyoid or Reichert's cartilage (stapes, styloid process, stylohyoid ligament, lesser horn and upper body of hyoid bone)	Stapedius, stylohyoid, posterior belly of digastric, auricular, muscles of facial expression	Facial nerve
3	Greater horn and lower body of hyoid bone	Stylopharyngeus	Glossopharyngeal nerve
4 and 6	Thyroid, cricoid, arytenoid, corniculate, and cuneiform cartilage of larynx	4—cricothyroid, levator palatini constrictors of pharynx 6—Intrinsic laryngeal muscles	4—Superior laryngeal nerve 6—Recurrent laryngeal nerve

to be the result of a disappearance of the grooves, which gradually enlarge with proliferating mesenchyme, rather than migration and fusion of distinct processes.[12,13] Development of the middle third of the face is closely associated with changes in the developing forebrain. The lateral and lower facial regions are formed by the maxillary and mandibular processes of the first pharyngeal arch.[13]

In the stage 11 embryo (Fig. 62–1A), the future region of the face is defined by an invagination of the surface ectoderm called the *stomodeum*. At the depth of the stomodeum is a bilaminar buccopharyngeal membrane consisting of surface ectoderm and endoderm from the anterior portion of the foregut. The buccopharyngeal membrane, which is first seen in stage 9, breaks down during this stage, giving rise to the primitive oral cavity.[10] The stomodeum is bounded by four masses of epithelially covered mesoderm. The cranial portion is the anterior end of the embryo, which contains the developing forebrain. The caudal portion is the mandibular process of the first pharyngeal arch, which meets its counterpart from the opposite side in the midline to separate the stomodeum from the developing heart. The maxillary process of the first pharyngeal arch is present on each lateral border.

In stages 12 and 13 (Fig. 62–1B), the third and fourth pharyngeal arches are well defined.[10,14,15] The forebrain begins to enlarge, and the upper end of the embryo begins to change from a conical shape and broadens to form the frontal prominence. The nasal placode has begun to develop and is seen as an ectodermal thickening on the frontal prominence.

In stages 14 and 15 (Fig. 62–1C), there is a proliferation of the mesoderm surrounding the nasal placodes, which leads to the formation of the lateral nasal fold and later, the medial nasal fold.[16] This process results in a depression of the nasal placodes, which are now referred to as *olfactory pits*. With the formation of the olfactory pits, the frontal prominence can be subdivided into upper and lower parts. The upper part is the primitive forehead, and the lower portion consists of the future external nose and prolabium.[13] While this process is occurring, the hemispheric vesicles expand, resulting in a broadening of the frontal prominence. This growth moves the nasal pits to the anterolateral border of the frontal prominence.

The maxillary prominences have become more distinct at the lateral border of the stomodeum in stage 15.[14] In stage 16 (Fig. 62–1D), the maxillary processes continue to develop medially and contact both the medial and lateral nasal folds. Between the lateral nasal fold and the maxillary prominence is the nasolacrimal groove, which marks the site of the future nasolacrimal duct. The slit-shaped olfactory pits by this time have widened and deepened. The olfactory pits and their associated nasal folds move further toward the midline. The caudal portion of the two medial nasal folds forms the intermaxillary segment. Structures that are thought to arise from the intermaxillary segment include the philtrum of the upper lip and the anterior portion of the maxilla.[17]

Beginning in stage 16, the region of the forehead enlarges because of the extensive growth of the developing brain. In stage 18, the eyes change their position from a lateral to a frontal oblique position. At the same time, the nostrils move medially from a frontolateral position.[14]

In stages 17 and 18 (Fig. 62–1E) the groove between the medial nasal folds begins to fill with mesoderm, and formation of the outer relief of the nose begins. The olfactory pits deepen further and open into the roof of the mouth during stage 18. The furrow between each medial and lateral nasal fold extends into the primitive oral cavity and begins to define the site of the palatal shelves.[14] Mesodermal proliferation begins to fill the grooves between the medial nasal folds and the maxillary processes to form the upper lip by stage 18. In addition, the maxillary processes merge with the lateral nasal folds and the nasolacrimal groove is filled.

The origin of the nasolacrimal duct is controversial. Some believe the nasolacrimal groove is completely eliminated with the nasolacrimal duct arising as a separate process.[11] Others believe the nasolacrimal duct to be a remnant of the nasolacrimal groove.[1]

The external changes that occur in stages 19 to 23 are gradual (Fig. 62–1F, G). Merging of the lateral portion of the maxillary processes with the mandibular processes occurs, thus reducing the opening of the oral cavity. Mesoderm from the second pharyngeal arch infiltrates the facial region and develops into the muscles of facial expression innervated by the facial nerve. Mandibular ossification is present lateral to Meckel's cartilage and extends posteriorly to form the coronoid and condylar processes of the mandible by stage 23.[11,12] At the end of the embryonic period, the temporomandibular joint can be identified.[11] In addition, muscles of mastication develop from the first pharyngeal arch and are innervated by the mandibular branch of the trigeminal nerve.

The nasal pits shift toward the middle of the face. There is no fusion of the median nasal folds; rather, a mesodermal filling between the nostrils occurs, which results in the external nasal prominence.[14] The external nose appears to develop from two distinct but contiguous mesodermal fields. One chondrifies at the end of the embryonic period and forms the cartilaginous skeleton for the nasal cavity. The other chondrifies at 10 weeks gestation to form the future alar cartilages.[18] At stage 22, an epithelial plug is present in the anterior nares, which regresses by week 24 of gestation, allowing patency of the nerves.[14] Near the end of the embryonic period, the epineural ectoderm in the roof of the nasal cavity differentiates into olfactory epithelium.[19]

The lateral wall of the nasal cavity first develops the inferior turbinate (stage 17) and, subsequently, the middle and superior turbinates.[11,16] By 12 to 14 weeks, the nasal region is fairly well developed. The paranasal sinuses develop much later as tiny diverticula from the lateral walls of the nasal cavity. The earliest sinuses to form are the maxillary, followed by the sphenoid. The ethmoid and frontal sinuses develop after birth.

DEVELOPMENT OF THE TONGUE

The floor of the primitive oral cavity in stage 12 to 14 embryos consists of a series of ridges formed by the first four pharyngeal arches (Fig. 62–2A). The first arch gives rise to two lateral lingual swellings and a midline tuberculum impar. The second ridge is the second pharyngeal arch, behind which the hypobranchial eminence forms a second midline structure made up of mesoderm from the second, third, and fourth arches.[1] The third and fourth arch derivatives do not meet in the midline, which is occupied by the epiglottic swelling.[20]

Over the next six embryonic stages, the lateral lingual swellings overgrow the tuberculum impar and form the anterior two thirds of the tongue[1] (Fig. 62–2B), the mucosa of which is innervated by the mandibular branch of the trigeminal nerve. The third pharyngeal arch contribution to the hypobranchial eminence develops into the posterior one third of the tongue, the mucosa of which is innervated by the glossopharyngeal nerve. The muscle of the tongue develops from occipital somites innervated by the hypoglossal nerve.[12]

The foramen cecum lies in the terminal sulcus, separating the anterior two thirds of the tongue from the posterior one third of the tongue. The presence of the foramen cecum marks the origin of the thyroid gland, which appears in stage 13 as an epithelial proliferation between the tuberculum impar and the hypobranchial eminence. The thyroid descends in stage 14 and detaches from the pharyngeal epithelium by stage 15.[10] The thyroglossal duct connects the thyroid to the tongue, becomes solid, and eventually disappears.[1]

From stage 20 to the tenth gestational week, the tongue descends from a position high in the oral cavity (Fig. 62–3A), allowing closure of the palatal shelves (Fig. 62–3B). During this time, the length of the tongue does not increase but its position changes. The musculus genioglossus and m. geniohyoideus are developed by stage 22 and are attached to the mandible, allowing anterior tongue protrusion.[21]

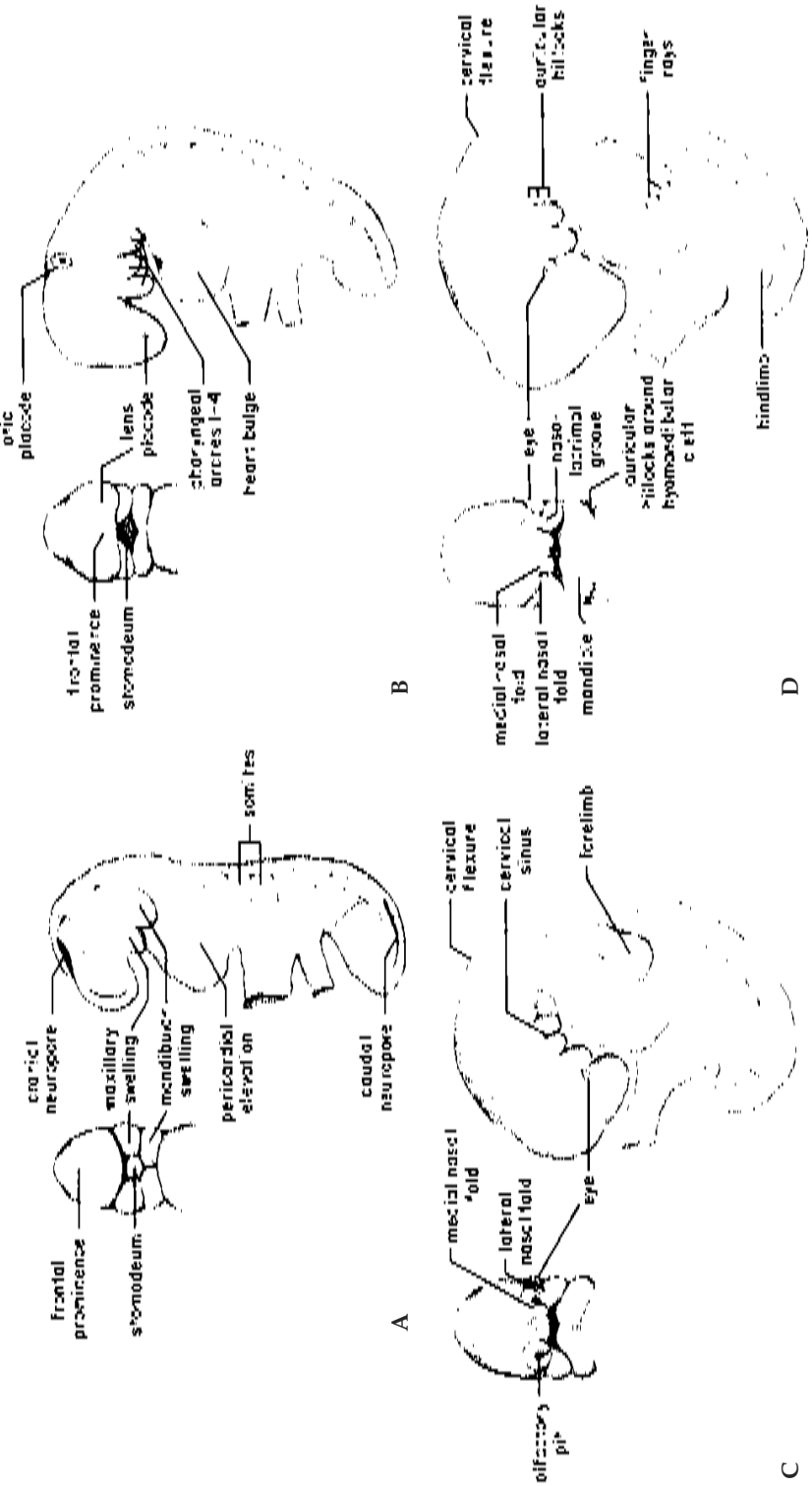

Figure 62–1 Development of the face. **(A)** Stage 11. **(B)** Stage 13. **(C)** Stage 15. **(D)** Stage 16.
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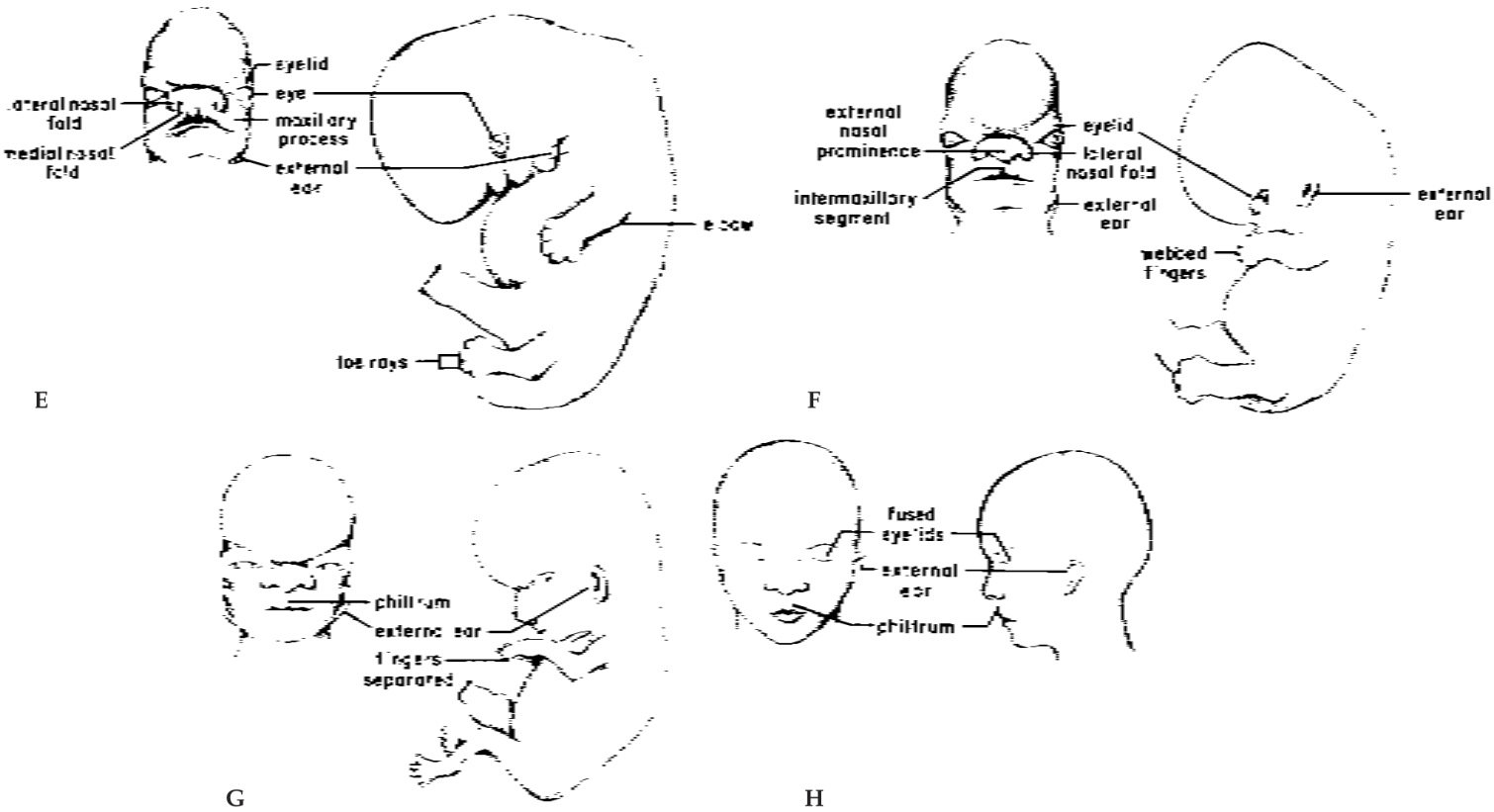

Figure 62–1 *(continued)* **(E)** Stage 18. **(F)** Stage 20. **(G)** Stage 23. **(H)** 19 weeks (Modified from Patten W. The face and jaws and the teeth. In: Patten BM (ed). *Human embryology*. 3rd ed. New York: McGraw-Hill, 1968. Key. The embryonic period. In: Moore KL: *The developing human*. 2nd ed. Philadelphia: WB Saunders, 1977.)

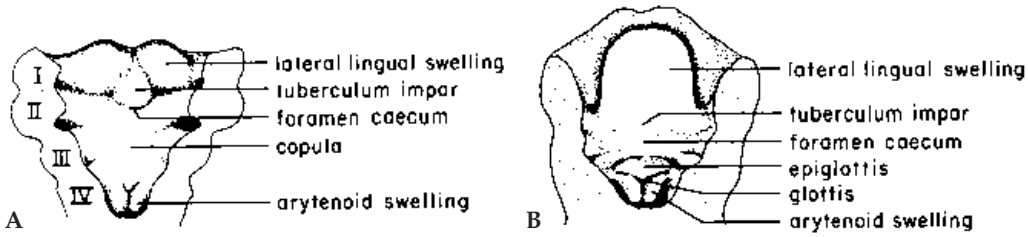

Figure 62–2 Development of the tongue. **(A)** Horizontal section through pharynx at stage 14, showing ridges of pharyngeal arches. **(B)** Horizontal section at stage 20, showing formation of anterior tongue from fusion of lateral lingual swellings. (Modified from Patten BM. *Human embryology*. 3rd ed. New York: McGraw-Hill, 1968.)

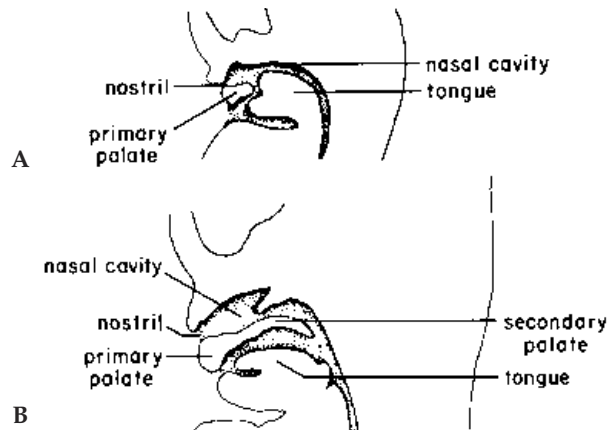

Figure 62–3 Development of the tongue. **(A)** Sagittal section at stage 20. Note position of tongue high in oral cavity. **(B)** Sagittal section at stage 23 showing tongue descent. (From Diewert VM. A morphometric analysis of craniofacial growth and changes in spatial relations during secondary platal development in human embryos and fetuses. *Am J Anat* 1983;167:495. With permission.)

DEVELOPMENT OF THE PALATE

The palate develops over a relatively long period of time, with fusion of the palatal shelves delayed until after the embryonic period. The palate is divided into two components based on its formation. The primary palate is formed at least in part by the caudal portion of the medial nasal folds. The early development of the medial nasal fold has been described previously. The secondary palate develops from processes derived from the maxillary prominence.

In stage 17, the roof of the oral cavity is concave with the opening of Rathke's pouch placed posteriorly. The olfactory pits are prominent and in a frontolateral position. The groove between the medial and lateral nasal folds extends into the oral cavity and borders the middle portion of the roof. Lateral to the groove, swellings are developing that are the first indications of the future secondary palate.[14] There are no openings of the primary choanae at this stage.

As the medial nasal processes start to merge in stage 18, the future primary palate is present as a pair of small swellings, which develop in the anterior roof of the oral cavity (Fig. 62–4A).[14] The primary palate is further defined by the

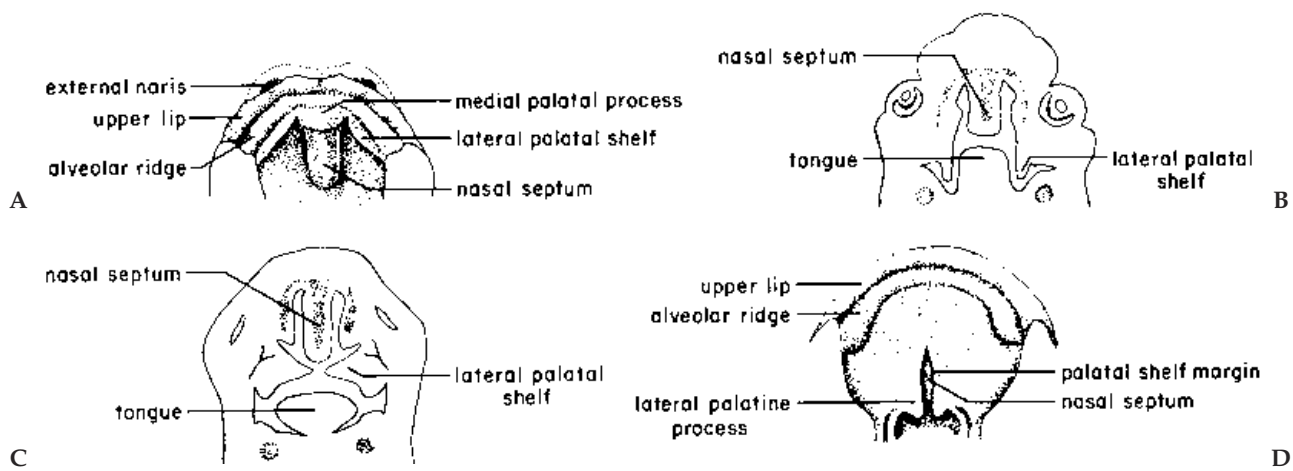

Figure 62–4 Development of the palate. **(A)** Roof of oral cavity at stage 18. **(B)** Coronal section of palate at stage 22. Note separation of palatal shelves by tongue. **(C)** Coronal section of palate at stage 23. Note horizontal change of position of lateral palatine shelves. **(D)** Roof of oral cavity at 9 weeks with fusion of lateral palatal shelves. (From Dirske L. The face and jaws and the teeth. In: Patten BM (ed). *Human embryology*. 3rd ed. New York: McGraw-Hill, 1968. With permission.)

opening of the primitive posterior choanae of the nasal cavity into the roof of the oral cavity.[14,16]

In stages 19 to 22, the lateral palatine shelves of the maxillary processes lengthen bilaterally (Fig. 62–4B). Until stage 22, the shelves project inward and obliquely downward on either side of the developing tongue, which occupies the central portion of the oral cavity.[10,21] During this period, the paired primary palate becomes a single, triangular mass in the anterior roof of the oral cavity and is continuous with the primordium of the nasal septum above.[14]

In stage 23, the palatal shelves swing upward to a more horizontal position (Fig. 62–4C). Debate continues over the mechanism whereby the reorientation of the palatal shelves occurs. Hydration and expansion of mesenchymal mucopolysaccharides within the palatal shelf may produce intrinsic tissue pressure that reorients the palate.[22] A direct role of palatal cell contractility to produce this effect has also been postulated.[23] Others believe that palatal shelf elevation involves a complex interaction between the shelves and the surrounding craniofacial complex.[21,24,25]

The mandibular process and tongue are relatively small in stage 19. In addition, the tongue is positioned high in the oral cavity. The head is rotated downward and forward with the nasomaxillary prominence near the developing heart. By stage 23, the facial profile has been reversed with increased growth of the mandible. With growth of Meckel's cartilage, the tongue is pulled forward and positioned under the primary palate where it no longer interferes with palatal shelf movement (Fig. 62–3). At the same time, extension of the head occurs relative to the body, which further separates the upper facial structures from the mandible-tongue complex.[21,24]

Fusion of the palatal shelves occurs during the fetal period. Growth of the horizontally positioned palatal shelves results in their midline approximation. Palatal fusion occurs in an anteroposterior direction beginning with fusion between the primary and secondary palates (Fig. 62–4D). During this process, the incisive foramena are formed. With continued fusion of the secondary palate, the oral and nasal cavities are separated. By the beginning of the tenth week, hard palate formation is complete.[21] Along the posterior border of the palatine processes, mesenchymal cells form the soft palate, which is closed in the midline by the end of the tenth week.[21]

Formation of the nasal septum during this period has traditionally been described to be a result of downward growth of a free process from the roof of the nasal cavity.[1] In contrast, others have proposed that the nasal septum develops in an anteroposterior direction in concert with palatal shelf fusion.[14]

DEVELOPMENT OF THE EAR

The first indication of the developing ear can be seen in stage 9 with the presence of the otic disc.[26] The disc appears as a thickening of the surface ectoderm forming opposite the rhombencephalic fold. In stage 11, the otic disc has invaginated and is referred to as the *otic pit*. The pit's communication with the external surface narrows and by stage 13 is closed from the surface, forming the otic vesicle.[26] Under the influence of mesodermal and neural induction, the otic vesicle gives rise to the structures of the inner ear.[27]

The middle ear is derived from the first pharyngeal pouch and is endodermal in origin.[28] The distal end of the pouch grows toward the ectodermally derived external auditory meatus to form the tympanic cavity. The proximal end of the pouch forms the eustachian tube. The tympanic cavity expands and envelops the chorda tympani nerve and the middle ear ossicles, tendons, and ligaments, which develop from the first (incus and malleus) and second (stapes) pharyngeal arches.[1,9,28]

Like the middle ear, the external ear develops from the pharyngeal apparatus and begins development near the midline in the future region of the neck.[28] The dorsal parts of the first (mandibular) and the second (hyoid) arch show the beginnings of hillock formation by stage 16. Three hillocks develop from the caudal border of the first arch, and three develop from the cephalic border of the second arch (Fig. 62–5A). The hillocks increase in size secondary to mesenchymal proliferation, and by stage 17 the six hillocks reach their maximum size, move in a dorsolateral direction, and begin to merge (Fig. 62–5B).[9] The first auricular hillock gives rise to the tragus, and the second and third hillocks form the crus helicis. The fourth and fifth hillocks become the crura anthelicis and the helix, and the sixth develops into the antitragus (Fig. 62–5C).[9,26]

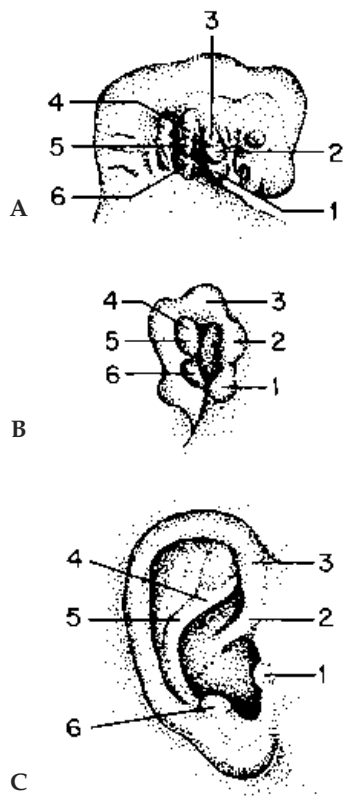

Figure 62–5 Development of the auricle, lateral views. **(A)** 11-mm embryo; 1 to 3 = first (mandibular) hillocks, 4 to 6 = second (hyoid) hillocks. **(B)** 15-mm embryo; hillock fusion begins. **(C)** Adult auricle. (1 = tragus; 2, 3 = crus helicis; 4, 5 = anthelicis, 6 = antigragus). (Modified from Anson BJ and McVay CB. *Surgical anatomy*. 5th ed. Philadelphia: WB Saunders, 1971.)

After obliteration of the cervical sinus by the second pharyngeal arch, only the first pharyngeal cleft (hyomandibular groove) remains. While the auricular hillocks are forming, the dorsal portion of the first pharyngeal cleft begins to widen (stage 17), and the ectodermal cells at its base begin to proliferate to form the meatal plug. The meatal plug extends medially and begins to approach the expanding tympanic cavity by the tenth week.[9] The central cells in the plug begin to dissolve in the eighteenth week to form a cavity that forms the external auditory meatus.[29]

A rudimentary pinna can be identified by stage 20 with differentiation of the fused auricular hillocks.[9] The auricle consists of a core of mesoderm covered by an epithelium of ectodermal origin. The mesodermal portion of the auricle develops from the bars of the first and second arches, which may begin to chondrify as early as stage 18.[26] At this point, the contributions of the first arch and the second arch to the auricle are roughly equal. With subsequent fetal development, however, the relative contribution of the second arch increases.[9]

The external ear is anatomically complete by the twentieth week of development. Mandibular growth during the late embryonic period and continued growth of the face during the fetal period allow the auricles to migrate to their final position.[28] The shape of the auricle is largely due to the plical folding of the cartilaginous plate, which is continuous with the cartilage of the external auditory canal. The pattern of plical folding of the auricular cartilage appears to be determined by the insertions of the intrinsic and extrinsic auricular muscles.[30]

DEVELOPMENT OF THE EYE

The first indication of the developing eye occurs in stage 10 with the appearance of the optic sulcus at the level of the diencephalic portion of the brain.[26] In stage 11 the optic vesicles have formed as lateral evaginations. By stage 12, the optic vesicles have grown laterally to lie close to the surface ectoderm but remain attached to the brain by an optic stalk. The overlying surface epithelium thickens in response to the nearby optic vesicle to form the lens disc in stage 13. In stages 14 and 15 the optic vesicle flattens distally and invaginates to form the optic cup.[15] The invagination extends along the optic stalk to form a groove that will later encompass the hyaloid artery and vein (Fig. 62–6A). Thus, the optic cup has two layers: a thin outer layer, which develops into the pigment layer of the retina, and a thick inner layer, which develops into the neural portion of the retina. Meanwhile, the lens disc invaginates and then separates from the surface epithelium to form the lens vesicle, which is situated in the opening of the optic cup (Fig. 62–6B).[28] The anterior one third of the optic cup near the lens vesicle develops into the iris and ciliary body, whereas the posterior two thirds of the optic cup develop into the pars optica retina containing rods, cones, bipolar cells, and ganglion cells.[1] The hyaloid vessels, which initially extend all the way to the lens, degenerate distally to become the central retinal artery and vein.[28] The choroid, sclera, and extraocular muscles develop from mesenchyme that envelops the optic cup.

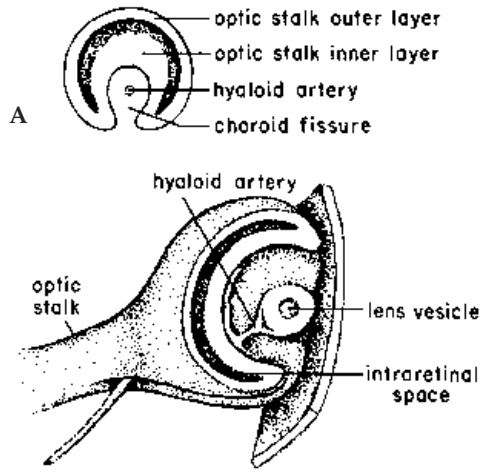

Figure 62–6 Development of the eye. **(A)** Developing eye with optic cup, formed lens vesicle, and hyaloid artery. **(B)** Optic stalk transverse section with optic fissure. (From Reid G. The special sense organs. In: Moore KL: *The developing human*. 2nd ed. Philadelphia: WB Saunders, 1977. With permission.)

FORMATION OF THE CORNEA AND EYELIDS

After the lens detaches from the surface ectoderm in stage 15, the defect is restored by epithelium destined to participate in the formation of the eyelids, conjunctiva, and cornea. The presence of the eye does not appear to be necessary for formation of the lids.[31] In stage 16, the first indications of the eyelids are the formation of small depressions above and below the eye.[15] These grooves become more distinct in stage 17. The inferior groove is continuous with the nasolacrimal groove, which is forming between the maxillary process and the lateral nasal process.[15] During stages 17 to 19, mesodermal proliferation from the frontonasal process forms the upper lid and proliferation of mesodermal cells from the maxillary process forms the lower lid (Fig. 62–1E).[32] The mesoderm is contained by an epithelial layer with the outer epithelial layer and the inner epithelial layer destined to become eyelid skin and conjunctiva, respectively. By stage 19, the eyelid folds have developed into eyelids, and at the lateral canthus, the upper and lower lids meet. The medial canthus is established by stage 20 (Fig. 62–1F). During stages 21 to 23, the eyelids are rapidly encroaching over the globe, but fusion of the eyelids does not occur until approximately 1 week after the end of the embryonic period.[26]

During the last week of the embryonic period and the first 2 weeks of the fetal period, the developing eye is shifted medially from its original lateral position to the greatest extent.[28] This change in position appears to be closely related to the enormous development of the cerebral hemispheres and a general broadening of the head.[14]

Before fusion of the eyelids, the future lacrimal gland appears as a grouping of buds at the upper outer portion of the conjunctival ectoderm. At the same time, lacrimal ducts are forming medially in both upper and lower lids. The lacrimal sac is soon formed at the junction of the two lacrimal ducts.[28]

By the ninth week, fusion of the eyelids is complete. With fusion of the eyelids, the conjunctival sac is completely separated from the amniotic sac.[33] At this time, lacrimal gland secretion begins to fill the closed conjunctival sac. Soon after eyelid fusion, cilia hair bulbs are formed from epithelial ingrowths from the lid margins. During the tenth week of gestation, the first signs of the orbicularis oculi appear beneath the skin and the developing tarsus is indicated by an increased density of the connective tissue deep to the muscle.[33] The levator palpebrae superioris, rectus superior bulbi, and obliquus superior bulbi develop from the same mesodermal complex. The levator palpebrae superioris merges with the upper border of the tarsal plate at approximately 11 to 12 weeks and with the skin anteriorly at 13 to 14 weeks.[32]

During the sixteenth to twentieth week, the glands of the lid margin develop. By the end of that period, the glands are producing lipid, and keratin is forming in the duct walls.[34] Separation of the eyelids begins at approximately 20 weeks gestation and takes 3 weeks to complete. Lid separation begins anteriorly and is completed with separation of the conjunctival ectoderm.

Both keratinization of the lid margin and lipid secretion, leading to breakdown of epithelial bridges, have been proposed as initiating mechanisms behind lid separation.[33] Epithelial growth factor may also play a role.[32] Eyelid separation may prevent keratinization of the epithelium of the conjunctiva and cornea, which is necessary for clarity of the cornea and a healthy mucous membrane.[33]

By the time lid separation is complete, all of the major elements of the developing eye and lid are present. Further development of the muscular, glandular, and connective tissue elements occurs during the remainder of the fetal period. The eyelashes appear to shed twice during fetal life, once at the beginning of the second month and again at the end of the seventh month.[33]

ACKNOWLEDGMENT

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Chapter 63

Craniomaxillofacial Deformities

Craig A. Vander Kolk, Benjamin S. Carson, Sr., and Michael Guarnieri

Craniomaxillofacial deformities present a wide range of abnormalities from congenital conditions to trauma and tumors. This chapter concentrates on congenital craniofacial deformities that present as a continuum from nonsynostotic deformations (posterior plagiocephaly), to single-suture synostosis, to multiple-suture craniosynostosis (craniofacial dysostosis) (Table 63–1). Treatment of these extends from conservative to multiple complex reconstructions over many years (Fig. 63–1).

In the first edition of this text, we described a trend toward a team management approach to the pediatric patient.[1] The cranium, cranial base, and facial region must be evaluated prior to surgery and as structures grow. Brain development, vision, sinuses, and airways must be considered. The craniomaxillofacial team also must evaluate midfacial growth in childhood and adolescence, as well as occlusion and mastication in the primary mixed and permanent dentition phase. A typical evaluation includes pediatric neurology, radiology, neurosurgery, anesthesiology, ophthalmology, and orthodontics. The growing demand for outcome-based studies and evidence-based medicine also has accelerated the team management approach.

Since publication of the first edition, the use of resorbable plates and screws has significantly changed surgical options. Gene mutations underlying several syndromes affecting craniofacial bone structure have been identified. Computer programs have been designed to analyze the cranial vault and to predict growth patterns of abnormal sutures.

Craniomaxillofacial surgery in pediatric patients continues to focus on syndromic and nonsyndromic craniosynostosis, craniofacial tumors, trauma, and aesthetics.[2,3] The present chapter focuses on indications, methods, and outcomes for craniosynostosis surgery. Trauma, anesthesiology, aesthetics, and embryology are discussed in separate chapters.

TABLE 63–1 Craniomaxillofacial Deformities

Positional	Single suture	Craniofacial dystosis–multiple suture
Positional	Uni- and bicoronal Metopic Sagittal Lambdoidal	Apert's syndrome Cruzon's syndrome

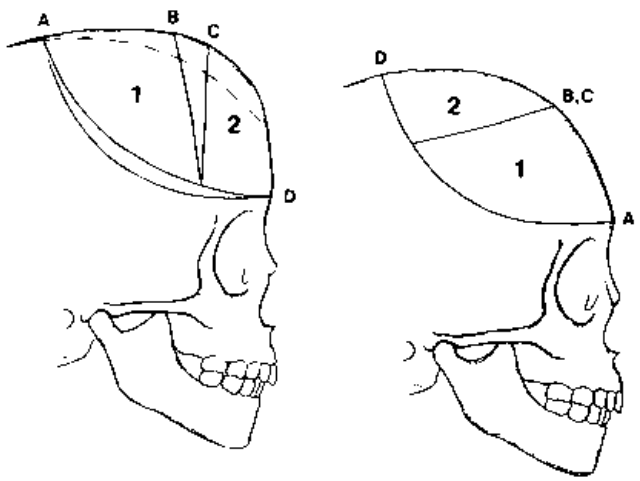

Figure 63–1 Artistic demonstration of how bone pieces can be interchanged to dramatically alter cranial configuration. In this case, a towered forehead is given a more natural slope by interchanging pieces 1 and 2.

BIODEGRADABLE PLATES AND SCREWS

Newly available resorbable polymers continue to extend innovative approaches to craniomaxillofacial surgery first introduced by metallic biomaterials. Metal implants improve aesthetic outcomes, speed rehabilitation, and facilitate substantially more complicated surgical reconstructions. Yet some devices require removal. Reoperations can be difficult and lead to postoperative problems.[4] Biodegradable devices promise a significant technical advance because of the potential for their use beyond bone fixation to assist bone regeneration as well as to secure bone grafts in cranial defects.[5–7]

An ideal material would provide strength, promote normal bone regrowth, and biodegrade without mischief. Absorbable biomaterials, such as polymers of lactic acid and glycolic acid, have been studied for strength and clearance.[8–10] A mixed lactic acid–glycolic acid polymer (LactoSorb, Walter Lorenz Surgical, Jacksonville, FL) was approved for human use by the U.S. Food and Drug Administration in 1996. Other constructs subsequently won approval.[9] The latter have not been reviewed substantially because of their relatively recent availability.

Numerous short-term (0.5 to 3 years) studies suggest that polymers can be used safely in a variety of procedures, although it is obvious that long term (more than 10 to 25 years) follow-up studies are needed before any polymer and its fabrication (e.g., plate, screw) can be used with maximum confidence.

Short-term outcome reviews of patients treated with lactic acid–glycolic acid polymers to stabilize segments in bifrontal craniotomies with cranial vault or orbital reconstruction show good results.[11–13] Absorbable plates were used to design an alternative to the reverse pi procedure to correct deformities seen in patients with posterior sagittal craniosynostosis.[6] A 1-year follow-up study of resorbable plates and screws in Le Fort I osteotomies found no significant complications. In one case, an L plate was palpable in the paranasal region and resolved after 6 months.[10] In a series of 22 craniofacial cases involving elective reconstruction and trauma, 2 patients had palpable plates at the 4-month follow-up period and 1 had difficult wound healing.[14] Palpable plates were seen in the early postoperative period of 9 of 35 patients (26%) in another series.[15]

Several disadvantages have been noted. Biodegradable screws are not self-tapping like metal screws and require this additional step for placement of screws. In addition, the placement of the screws and plate is more technique-sensitive than metallic screws.[12] These issues will likely be resolved as more experience develops with biodegradable devices. Perhaps the major disadvantage is the absence of long-term outcome studies.

CRANIOSYNOSTOSIS

Craniosynostosis or premature fusion of the coronal, sagittal, metopic, or lambdoidal sutures may be primary or secondary to known teratogens, metabolic disorders, hematologic disorders, or malformations such as microcephaly.[16–18] Craniosynostosis also can be found when patients are overshunted and sutures subsequently override and fuse.[19,20]

The condition may be "isolated," involving a single suture, or "complex," involving multiple sutures. The manifestations have been classified as nonsyndromic and syndromic; the latter have been linked to several chromosomes.[17,21] Defects in fibroblast growth factor receptor (*FGFR*) genes have been identified by several groups.[22–24] Apert's, Pfeiffer, Jackson-Weiss, and Crouzon's syndromes associate with mutations in *FGFR* genes.[25] However, pathophysiology may be heterogeneous because clinical features do not always associate in craniosynostosis with specific mutations.[26]

It has been postulated that a cranial base malformation was the primary anomaly. More recent studies lend support to Virchow's theory that the proximal cause is the premature closure of the cranial sutures, although the underlying dura may also play a role, as in Moss's theory.[27,28] Recently developed computer-assisted morphologic analyses undoubtedly will play a major role in our understanding of normal and abnormal growth.[29,30] In addition, computer modeling of the surgical procedure offers the additional promise of reduced operating time and blood loss.[31]

The incidence is difficult to measure because the conditions are not often lethal and are not always recognized in newborns or recorded in adults.[16] Reports have estimated 0.2 to 0.5 per 1000 births.[16,32] A population-based study in western Australia during the period 1980–1994 found a prevalence of 5 per 10,000 births.[33] Such studies note that rates appear to be increasing, and suggest that the increase is due to enhanced awareness of the condition and improved diagnostic imaging technology. Isolated lambdoidal craniosystenosis accounted for approximately 1% of cases in two large series[34,35] and zero cases in a series of 204 patients.[36]

INDICATIONS FOR TREATMENT

Until we have clinical guidelines based on well-defined input and output variables, indications for procedures must be considered by the craniomaxillofacial team for each case based on clinical signs, syndromic and genetic information, radiographic indicators, and whether the child is stable or developing symptoms. Major issues to be considered are (1) frontal-orbital retrusion, usually manifest secondary to coronal or metopic synostosis affecting the frontal-orbital region; (2) posterior constraint occurring with growth anomalies in the parietal, lambdoidal, and squamosal sutures; (3) diffuse calvarial anomalies seen in sagittal or multiple suture synostosis; and (4) midfacial anomalies. In addition, the evaluation frequently exposes Chiari malformations, hydrocephalus, hypertelorism, cleft palate, extraocular muscle movement, and ocular anomalies. Shunts further complicate reconstruction and increase opportunities for infection. Care must be taken to maintain the highest pressures possible to prevent large areas of dead space.

Pediatricians often request neurosurgical and plastic surgical consultation for infants with abnormal head circumference in relation to standard growth curves, abnormal head shape, and other evidence of syndromic anomalies. Infants also are referred for posterior and several other cranial deformities that were initially considered positional molding. These positional anomalies frequently are noted at birth; the parents report a progressive worsening of the deformity and routinely express a concern about potential developmental abnormalities.[37] The anomalies demonstrate a parallelogram shape to the skull and no premature suture fusion. Absent complications, one may take a conservative approach and use positional treatment or helmet therapy. Newborns with mild localized bone deformities may develop normally despite their cosmetic appearance. However, craniosynostosis by definition results in progressive deformities due to limitations of the growth of the skull perpendicular to the involved suture.[38–40]

Anomalies in skull morphology usually precede complications such as visual impairment and increased intracranial pressure (ICP).[38,39] Multiple suture synostosis and syndromic synostoses frequently are associated with increased ICP and hydrocephalus.[41,42] On the other hand, hydrocephalus rarely is found in single-suture, mild, nonsyndromic craniosynostosis. The latter is thought by some to be an aesthetic problem with occasional consequences on brain function and development. Mild asymmetries per se appear to be of little threat to normal intelligence. Despite clinical impressions associating appearance with adolescent and adult behavioral problems, studies have suggested that abnormal skull shapes do not directly affect intelligence test scores. In infants with nonsyndromic, single-suture craniosynostosis, mental development, measured by intelligence tests, appears to be normal in the absence of

Figure 63–2 Cranial vault expansion in a 5-year-old who was discovered late to have mental retardation and severe scaphocephaly resulting from an untreated sagittal craniosynostosis. His mental status improved markedly after the cranial expansion. This photograph was taken prior to placement of bone paste and struts in the defect area.

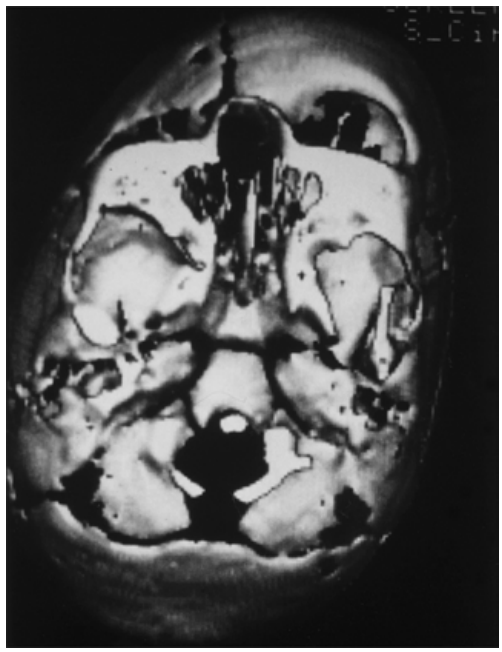

Figure 63–3 Worm's-eye view of a patient with unilateral coronal craniosynostosis demonstrating the marked anterior cranial asymmetry and the effect on the cranial skull base.

increased ICP and other pathologies.[43] In this regard, it is of interest to note the anthropologic studies of the many civilizations that practiced cranial deformation for cosmetic and political gains.[44,45] Such practices imply that an abnormal skull shape does not interfere with normal intelligence, although one cannot conclude that the physiologic results of endogenous and exogenous deformations are the same. Studies of cerebral glucose metabolism showed an increased metabolic rate in the posterior occipital region following reconstructive surgery in children with single-suture craniosynostosis.[46] Future developmental studies will be needed to correlate the functional consequences of the metabolic changes.

Infants undergo three-dimensional computer tomography (CT) to evaluate the skull, cranial base, and brain. The initial evaluation of the CT scan reveals the amount and location of cranial deformity and the compensatory changes that have occurred.[47,48] The film frequently demonstrates an open anterior fontanelle and sutures. Fernbach and Feinstein have reported that a deformed petrous bone may be a plain film diagnostic indicator of premature lambdoid synostosis.[49] Infants with severe deformities may show diminished posterior subarachnoid fluid similar to the changes seen with increased ICP but on a more localized basis. This finding may correlate with an irregular, patchy diminished thickness of the occipital bone (Figs. 63–2 and 63–3). The patchiness is greatest in bilateral cases and appears to be similar to the copper-beaten or thumb printing appearance seen on plain radiographs. These findings support the theory of Kaiser that bilateral deformities have increased ICP that requires surgical intervention,[50] although copper beating of itself may not be a good marker for raised ICP because it occurs late and is an inconsistent finding.[51]

AGE

Indications for specific procedures depend on age and functional problems. Throughout, aesthetic considerations need to be considered (Fig. 63–4). Much of the debate about the timing of surgery has to be reevaluated because of the availability of biodegradable plates and screws. Because outcome data only recently became available, it is difficult to describe

Figure 63–4 Worm's-eye view of a patient with unilateral coronal craniosynostosis demonstrating anterior cranial asymmetry.

specific age limitations for surgery. Much of the discussion must be considered as broad generalities.

Part of the question about the timing for frontal-orbital advancement at 3 to 6 months as opposed to 6 to 12 months is due to the bone and soft tissue responses. Rigid fixation is helpful in obtaining a stable advanced construct. We prefer a timing of 3 to 6 months, with the latter 6 months perhaps being the ideal time to obtain the best possible stability in advancement. Because abnormality at a single suture strongly influences the development of other areas in the craniofacial complex, there is a clinical impression that surgical correction during the neonatal period yields superior results.[35,52–55] Early surgery also is recommended in complex syndromic cases.[56]

Midfacial treatment typically is considered at age 4 years and older, depending on the deformation. Early correction is indicated for patients with tracheotomy. The final parts of the treatment protocol would include subsequent reconstruction of the minor anomalies during the school age years if the cranium is involved. Le Fort I osteotomy for occlusal abnormalities, if they persist, can be considered in the teenage years. Most of the lower orbital problems occur early on because the majority of orbital growth occurs during the first 5 to 8 years. Occasionally, early correction can be considered for occlusal and aesthetic considerations. Frequently, subsequent growth anomalies can continue and require secondary revision at a later date, with definitive treatment at age 16 to 18 years.

TECHNIQUES

Unicoronal, metopic, bicoronal synostosis is treated with variations of a bilateral orbital advancement and frontal-temporal reconstruction. Surgical advances have addressed the question of technique through a union of multidisciplinary pediatric neurologic and plastic surgical teams to achieve optimal craniorbital recontouring and cosmetic results.[54,57,58]

Orbital advancement is usually bilateral, with attendant forehead and temporal remodeling for relatively symmetrical and bilateral craniofacial dysostosis (Figs. 63–5 and 63–6). The floating forehead concept has not become a universal technique. Surgeons have gone to overcorrection and fixation to hold the reconstruction in place. Rigid fixation with titanium plates and screws has been replaced with biodegradable materials to provide three-dimensional constructs. No longer do temporal tenons need to be incorporated into the osteotomy segment, allowing segments to be individually osteotomized, subsequently contoured, and held in place (Figs. 63–7 and 63–8).

Our preferred technique involves a combined neurosurgical and plastic surgery approach. The craniofacial procedure begins with a zig-zag bicoronal incision followed by a subperiosteal dissection down to the brow region. A frontal craniotomy is performed followed by a lateral temporal and anterior parietal. The craniotomy is performed to allow advancement of these areas and more extensive remodeling of the forehead, temporal, and anterior parietal regions. The anterior cranial base is exposed. Most of the time, exposure can be assisted with lowering CO_2. However, occasionally this requires the use of mannitol. Spinal drainage is no longer utilized because pharmacologic manipulation usually provides adequate exposure.

Subperiosteal dissection is further extended by the plastic surgery service down over the supraorbital ridge and brow, down to the nasofrontal region, and along the lateral orbital rim to the zygomatic arch. The temporalis muscle is included with the subperiosteal dissection, limiting the need to reposition this at the completion of the procedure. Because of the advancement of the orbital segments in the temporal region, the muscle routinely redrapes into the appropriate position and has less potential for atrophy with separate dissection. The osteotomy can extend into the temporal region because rigid fixation, originally with titanium plates, can bridge a defect in this region and provide stable fixation, which is augmented with bone grafting at the completion of the advancement.

The orbital osteotomy is carried out by first cutting the anterior cranial base. This is accomplished by protecting the orbital contents because the subperiosteal dissection extended around the periorbita. One centimeter behind the orbital rim, the osteotomy is performed with a Lindeman

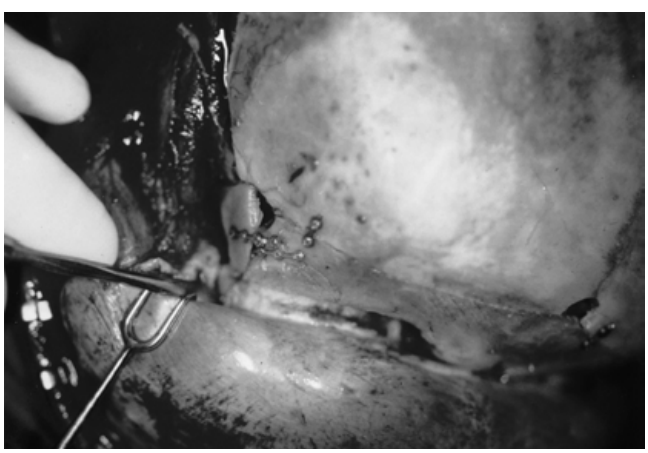

Figure 63–5 Demonstration of use of small cranial pieces to obliterate cranial defects during the reconstruction process with the use of microplates and screws. This can be accomplished with absorbable plates and screws as well as with titanium products.

Figure 63–6 Bird's-eye view of a patient who had unilateral coronal craniosynostosis that has been surgically repaired. One can still notice some residual midface asymmetry, but the cranial deformity is corrected.

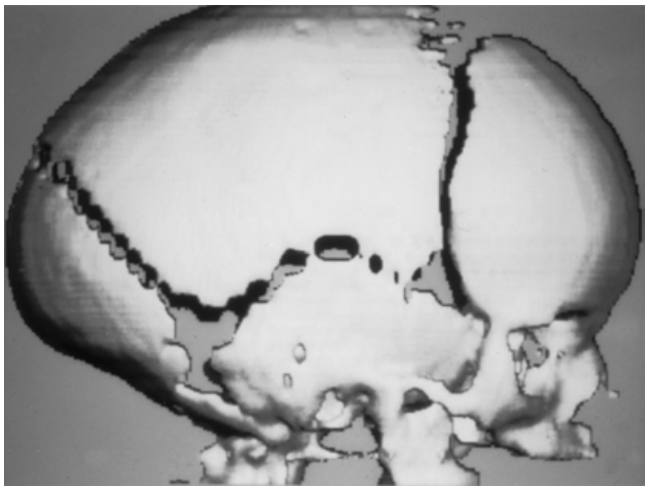

Figure 63–7 Sagittal three-dimensional CT reconstruction of a patient with sagittal craniosynostosis demonstrating the typical dolacocephalic configuration.

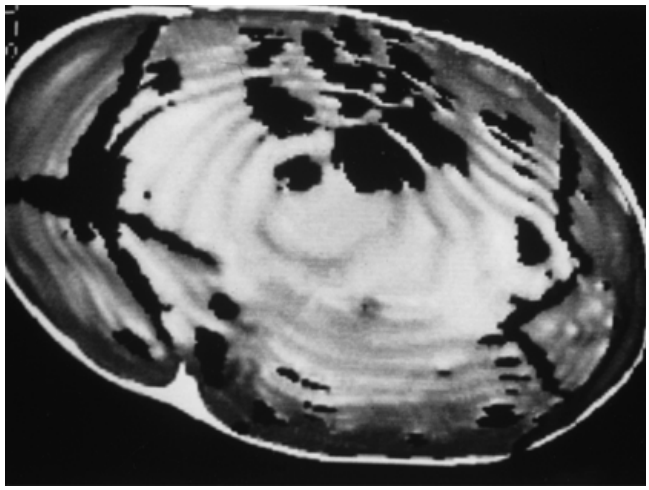

Figure 63–8 Three-dimensional CT reconstruction of the calverial portion of the skull in a patient with sagittal craniosynostosis.

burr. This side-cutting burr allows easy osteotomy of the anterior cranial base under direct vision. This is extended medially and laterally. Next, the osteotomy along the nasofrontal region is accomplished as low as possible without extending into the nose. Usually this is at the nasofrontal suture. This can be accomplished with a Lindeman burr or an oscillating saw. The lateral osteotomy begins as a Z osteotomy, allowing the maximum advancement and recruitment of bone. The Z allows the osteotomy to be performed low in the lateral orbital rim and permits stable fixation below the osteotomized segment. The connection between this Z osteotomy on the lateral orbital rim into the temporal area is accomplished with either the Lindeman burr or reciprocating saw at approximately 7 to 10 mm, depending on the age of the patient. The segment is then fractured and brought out of the field. The brain and periorbita are checked for irregularities or cerebrospinal fluid (CSF) leakage. The orbital segment is then contoured. In the single-suture patient, this usually requires minimal contouring except perhaps for some bending and rounding. In severe cases of asymmetry or other abnormalities, biodegradable plates can be placed on the surface to get an improved three-dimensional shape.

The osteotomized segment is then advanced to a normal position. Often this requires 20 mm of advancement. Originally fixation was established with metal microplates and screws. Again, these have been replaced by biodegradables. Occasionally, to get a large advancement, metallic microplates and screws are used first to stabilize the advanced segment; then biodegradable plates are placed around the construct to stabilize it, and the microtitanium plates and screws are removed. Because systems such as the Synthes absorbable system allow contouring of the segments in situ, the plates can be placed on the segment on the near operating table and then brought up to the field where it can be contoured and held in place.

Because the procedure is performed on young patients, a portion of the temporal parietal bone can be used as a bone graft behind the advanced orbital segment and connected to the absorbable plate in the temporal advancement area. Following this, the frontal bone is contoured and attached to the orbital segment with wires or absorbable plates. The temporal bones are then brought to the forehead and orbital segments. If extensive advancement has been performed, this is further fixed to the native temporal bone to provide good stable fixation when the forces for closure may be excessive (Fig. 63–9).

Closure proceeds in a routine fashion after it has been established that there is no bleeding or CSF leakage. Standard postoperative care includes monitoring of the patient in the intermediate care unit, and discharge usually is accomplished after 3 to 4 days. Erythropoietin injections reduce the need for transfusion. This is further supplemented by the use of the cell saver during the procedure. Frequently, not enough blood is lost to require this unless there is extensive bleeding from the sagittal sinus. Throughout the procedure, the patient is monitored for an embolism, with a central venous catheter in place for treatment.

Posterior reconstructions follow a similar pattern to that of the anterior cranial expansions. Occasionally, it is advantageous to use an occipital bar, similar to the orbital bar, for advancement. Asymmetries are corrected by rotation of the segments. Rigid absorbable fixation is particularly helpful in this region because usually extensive recontouring is necessary; stable fixation so that the patient can lie on his or her back is appropriate. The general goal of the procedure is to advance the posterior segment as much as possible along, with some expansion in width to decrease the towering. Occasionally the vertex cranial portions must be lowered to allow for posterior expansion. This can be accomplished by twisting wires down to the native bone and allowing the reconstructed segments to gradually decrease in volume.

OUTCOME

The major challenges to outcome studies have been the absence of accurate methods to document the presenting deformity and to evaluate postoperative results. Guidelines for the evaluation of the results are few.[18,59] Some studies have been difficult to evaluate for several reasons, including uncertainties about the

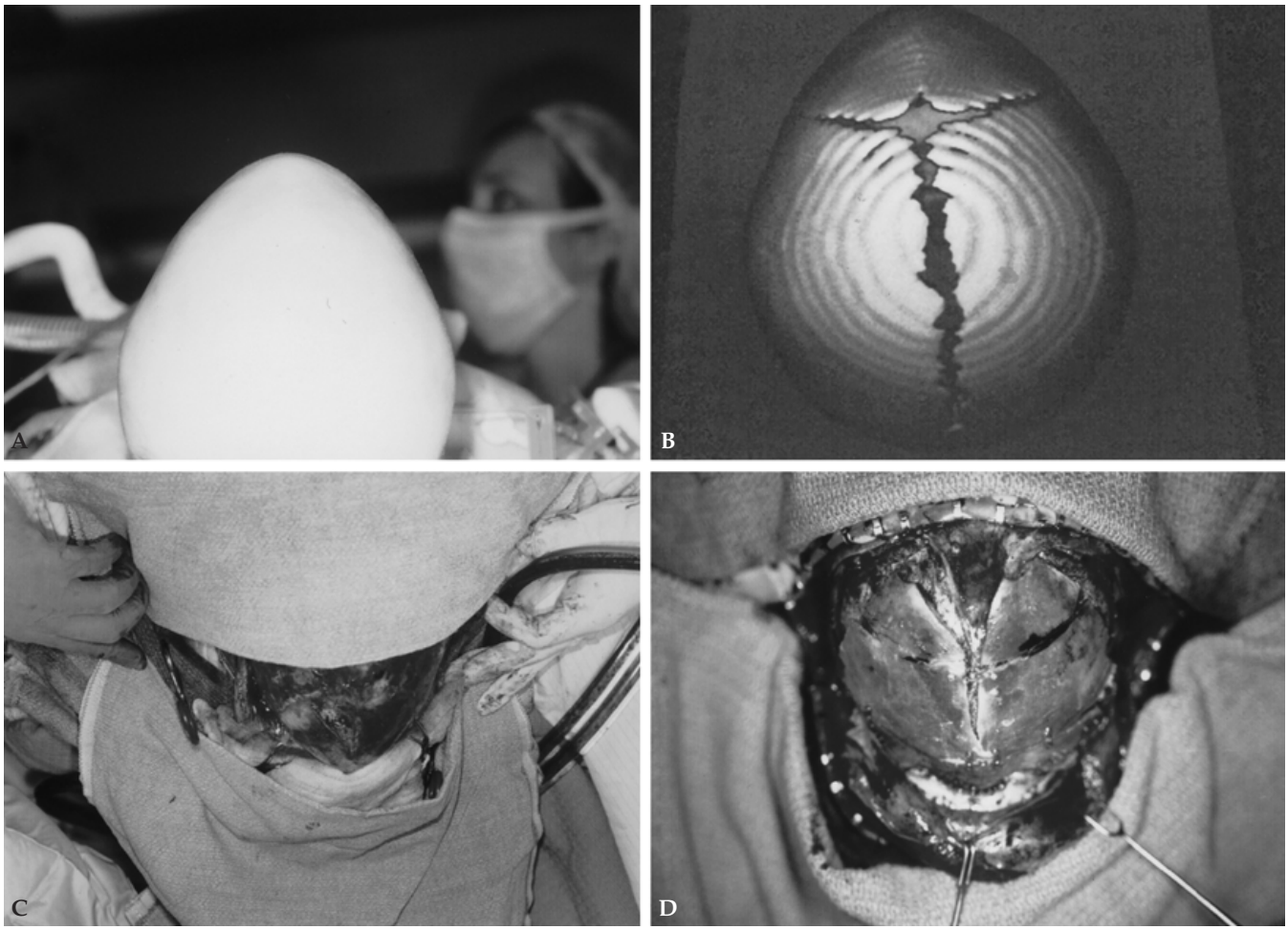

Figure 63–9 **(A)** Preoperative photograph of the patient with metopic craniosynostosis. **(B)** 3-D CT reconstruction of a patient with metopic craniosynostosis. **(C)** Intraoperative photograph of exposed, fused metopic suture. **(D)** Intraoperative photograph after correction of fused metopic craniosynostosis.

initial diagnosis. For example, earlier reports attempted to confirm craniosynostosis by histologic studies. Yet histologic samples can be misleading because craniosynostosis usually begins at a single point before spreading along the suture.[60,61] Fortunately, more recent radiographic diagnosis appears to be remarkably accurate.[49] Suture abnormalities do not appear to exist as a continuum with normal development, and reports of uncertainties in the diagnosis may be attributed to inexperienced readers and ambiguous imaging rather than genuine similarities between abnormal and normal states.[62]

Despite these uncertainties and the relatively recent emergence of tools to document results, a body of literature highlights areas of concern. Clearly, mortality rates with experienced craniomaxillofacial teams are low. Morbidity increases with the presence of complex syndromes and tumors of the orbit and cranium. Morbidity includes loss of vision, infection, hydrocephalus, and CSF leakage. Hindbrain herniation has been reported in one series.[63] An analysis of surgical outcomes revealed that complications may increase significantly with duration of surgery.[64]

Approximately 1% of patients with single-suture synostosis eventually develop multiple sutures.[65] Increased intracranial pressure may persist after reconstruction, despite a lack of clinical signs or symptoms of intracranial hypertension and normal imaging studies.[66] A review of 1297 cases with a 5-year follow-up showed abnormal CSF hydrodynamics in 8% of patients—less than half of whom had been shunted. Abnormalities included progressive hydrocephalus with ventricular dilation, nonprogressive ventriculomegaly, and dilation of the subarachnoid spaces. Hydrocephalus was found in 12% of complex syndromic patients and 0.3% of isolated suture patients.[67] Surgery itself may have to be repeated; approximately 6% of patients develop increased intracranial pressure after initial suture release and decompression.[61,68] Reoperation rates for syndromic and nonsyndromic patients were approximately 27% and 6%, respectively, in a series of 167 consecutive children with a mean length of follow-up of 2.8 years. Interestingly, age at initial surgery, length of operation, and estimated blood loss were not predictive of a higher reoperation rate.[69]

CONCLUSION

Several management systems have been proposed, but it is important to recognize that such systems cannot be viewed as absolute. For example, the decision not to operate can change

rapidly with new information. A number of systems have focused on radiographic descriptors of the skull. However, we believe that it is more important to focus on the brain, and indications of its normal development, than the bone that surrounds it. Finally, severe cosmetic factors are in their own right a valid indication for surgery, especially as the intraoperative risks decrease with improved techniques and the increasing availability of biodegradable surgical tools.

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Chapter 64

Congenital Malformation of the Auricle

Robert O. Ruder

Microtia is a malformation of the auricle, ranging from a small external ear with minimal structural abnormality, to an ear with major external, middle, and inner ear structural aberrations. Management of these patients may be one of the most satisfying or frustrating experiences encountered by otolaryngologists. Most facial plastic surgeons have little exposure and experience with severe traumatically and congenitally deformed auricular anomalies. There are numerous descriptions of varied malformations and the techniques to correct them. I initially experienced considerable confusion and frustration with such terms as "prominent," "cupped," "hooded," "lidded," "cryptotic," and "peanut ears." It is best to separate ear anomalies as either dysmorphic or dysplastic. Reconstruction requires a thorough understanding of the normal anatomy and supporting element of the pinna. Each anatomical subunit must be evaluated to distinguish dysmorphic developmental anomalies from arrested dysplastic anomalies.

EMBRYOLOGIC CONSIDERATIONS

The anlage of the external ear is first seen by the fourth week of gestation. It develops from the first and second branchial arches and the fundus lying between. Six separate accumulations of mesoderm and epiderm, called hillocks, rotate and fuse to form the auricle. In the second month of development, the forming ear migrates from beneath the mandible to its proper position on the mastoid. By week 20 it has attained an almost normal adult shape. However, it may still not have reached the mastoid area.

Congenital auricular malformations are often one aspect of a multifaceted problem. Genetic factors and even subtle environmental events can severely influence this rapid sequence of movement and configuration, causing catastrophic anomalies. Even after the ear has attained its adult shape, abnormal intrauterine forces (fibroids, malpositioning) and fetal masses (Turner's syndrome, cystic hygroma) may affect growth, causing lop, cupped, or prominent ear deformities. However, even with microtia deformity, in only a minority of cases has a genetic or environmental cause been found.[1] In these specific patients, severe ear deformities may be part of a sequence of multiple congenital anomalies. The microtia deformity is an essential component of thalidomide and isotretinoin (Accutane) embryopathies. It can also be a part of the fetal alcohol syndrome and maternal diabetes embryopathy. It has been reported in a number of genetic disorders, such as Treacher Collins, Goldenhar's, and Nager's syndromes.[2] Almost fifty percent of our patients with microtia have anomalies of concomitantly developing organ systems. Malformations of the urinary tract, heart, ribs, and cervical spine (hemivertebrae) must be evaluated. Other derivatives of the first and second branchial arch and groove structures may also be present. Canal atresia, facial microsomia, facial nerve paresis, and preauricular appendages are often seen. An experienced and well-coordinated team from the fields of pediatrics, otolaryngology, plastic surgery, genetics, dentistry, audiology, speech, orthodontics, nursing, psychiatry, and social work is essential to adequately handle this multifactorial problem. Because of these close associations of ear anomalies with a variety of specific pattern of defects (syndromes), careful evaluation of all patients for associated anomalies is mandatory. This is usually most effective if accomplished by an experienced dysmorphologist or clinical geneticist.

At birth the normal auricle is almost 60% of its adult size. It is rounder rather than having the oval shape of a mature ear. It is also slightly low set, not yet lying between the eyebrow and the nostril. The cartilage is soft and pliable because of the circulating maternal estrogens.

PHILOSOPHY OF RECONSTRUCTION

Although shape and contour are important, proper position is perhaps the most essential factor to consider. Farkas has assessed ear morphology and has given us detailed uniform standard measurements for planning reconstruction.[3] The ear is not vertical but inclined and almost parallel to the dorsum of the nose. It should not lie on the cheek but rather be the distance of the vertical height of a normal ear (6 cm) from the lateral orbital rim (on the mastoid). A well-constructed pinna will bring adverse attention to itself if placed too far forward, too low, or too inferiorly.

The auricle is a multicontoured *flaplike* structure that is slightly oval and protrudes mildly from the skull. It is three-dimensional, composed of three separate layers. The *scapha* is the main structural support. When weak, the ear falls over on itself and looses its vertical height (Fig. 64–1). The *helix* is the most lateral layer and outlines and defines the silhouette. The most internal layer is the *concha*. It appears as an entrance to the cavelike canal opening.

Auricular deformities have been categorized and graded in a variety of ways. Several confusing classifications of ear

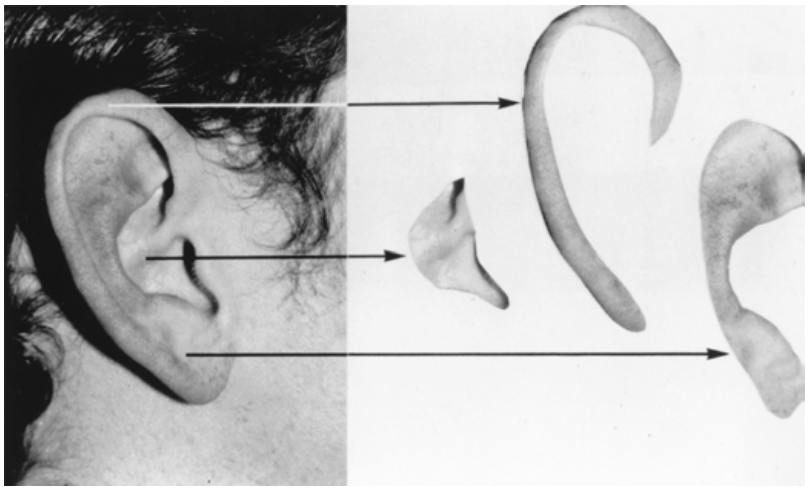

Figure 64–1 The auricle is composed of three layers. The internal layer is the concha, which acts as an entrance to the canal. The scapha is the middle layer and the main structural support of the ear. The helix delineates the outer margin.

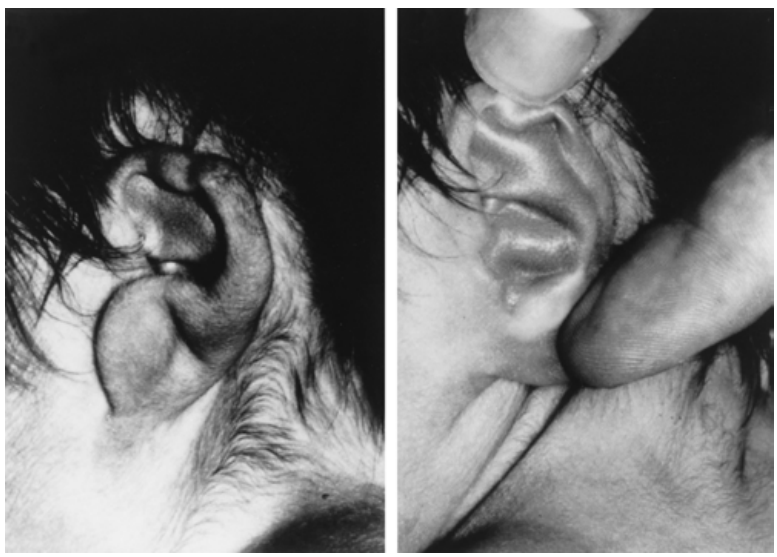

Figure 64–2 Dysmorphic ear anomalies result from abnormal intrauterine positioning causing pressure on the developing auricle. Dysmorphic ears have all their "anatomic subunits" present but are misshapen. Using one's fingers as a measuring tool, deformities can easily be identified.

anomalies exist. The terms "protruded," "cupped," "lop," "hooded," "lidded," cryptotia," "macrotia," and "microtia" are often misused. It is perhaps better to consider *dysmorphic* and *dysplastic* deformities when evaluating these patients. I find it best to use my fingers and eyes as measuring tools.[4] Even the most severe-appearing deformities can be easily analyzed by "unfolding" the ear against the mastoid.

Grade I deformities have all anatomical subunits present but misshapen (Fig. 64–2). The most common deformities of these *dysmorphic* auricles are unfurling of the anthelical fold and an excessively deepened and overangulated concha. Congenital weakness of the auricular musculature, abnormal intrauterine positioning, or compressing masses can cause these dysmorphic anomalies. *Grade II* deformities are *dysplastic* because they lack anatomical subunits (Fig. 64–3). These ears are also often unfurled and protruding. The scapha is usually deficient, allowing the superior aspects to fall over on itself causing lidding, absence of the fossa triangularis, flattening of the helical arch, and foreshortening of the vertical height. Reconstruction requires chondrocutaneous grafts to strengthen the framework.

Grade III deformities represent the most severe dysplastic anomalies (microtia). These ears have almost no normal remnants other than a malpositioned fibroadipose lobule. They lack an adequate skin envelope, have deficient cartilage, and are abnormally positioned in relation to the opposite ear (Fig. 64–4).

GRADE I: DYSMORPHIC AURICLES

If all anatomical elements are present at birth, the seemingly severe deformity can often be corrected at birth without surgery. Circulating maternal estrogens make the neonatal ear cartilage extremely pliable for several days after birth. This short-term plasticity allows us to correct these anomalies by nonsurgical methods. Using one's fingers as measuring "tools," the ears appear to have all of their anatomical components present. These ears should be sculptured and molded immediately after birth. The deformed ear is pressed backward against the mastoid. Moist cotton is placed in each convolution to sculpture each

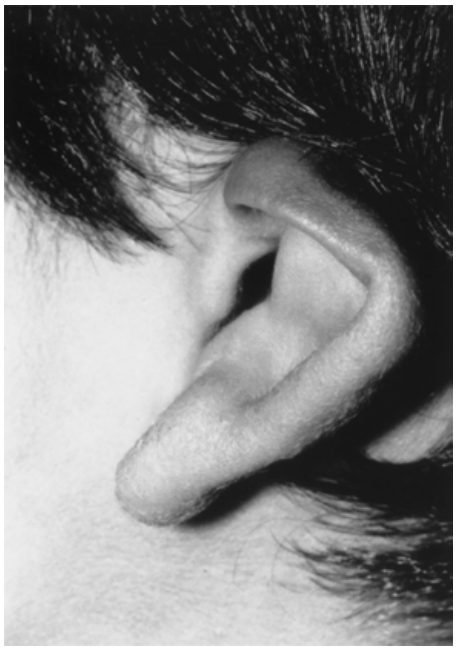

Figure 64–3 Class II deformities are "constricted" and small. These ears lack anatomic subunits. The constricted ear often seems to fold over on itself. Often the scapha and fossa triangularis is deficient or absent.

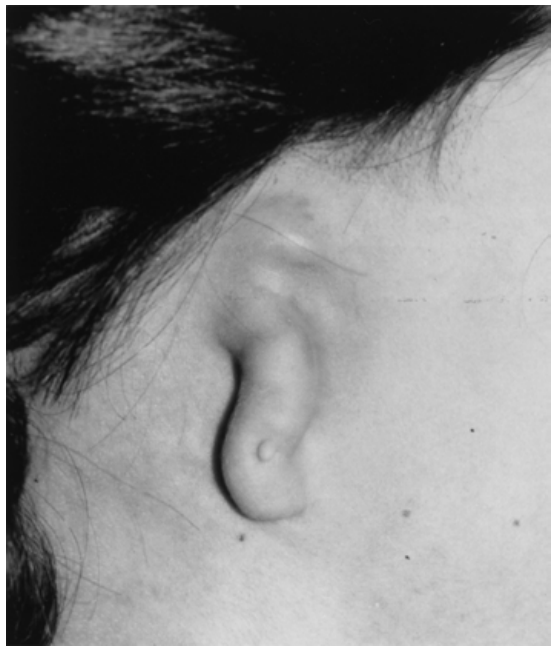

Figure 64–4 Class III microtia deformities have an inferior fibroadipose lobule and a nubbin of cartilage in the superior remnant.

abnormal auricular fold. Benzoin and tape are applied to secure the ear molding. The tape and cotton are changed weekly for a month. If molding is started within the first few postpartum days, 2 to 3 weeks of sculpturing is usually adequate (Fig. 64–5).

The protruding or prominent ear presents a special problem (Fig. 64–6). Although many minor anomalies improve spontaneously in the first year, excessive ear protrusion can be an acquired deformity that may be more accentuated at 1 year than at birth. Two different mechanisms may explain the

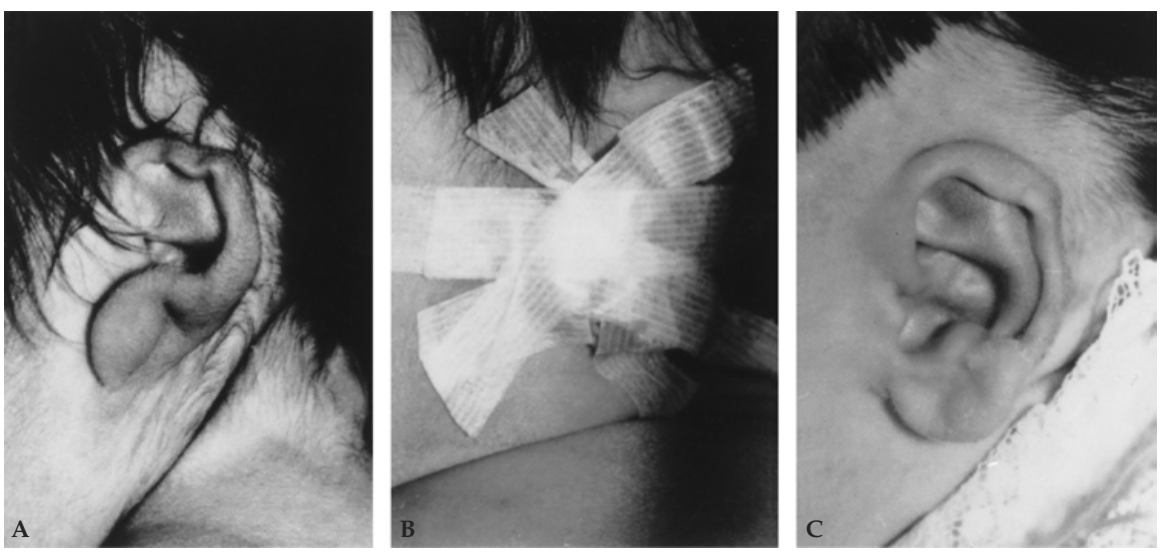

Figure 64–5 Molding of the ear is accomplished with moistened cotton placed in the deformed areas for 2 weeks. **(B)** Tape secures the cotton in place. Patient before **(A)** and after **(C)** nonsurgical molding of the auricle.

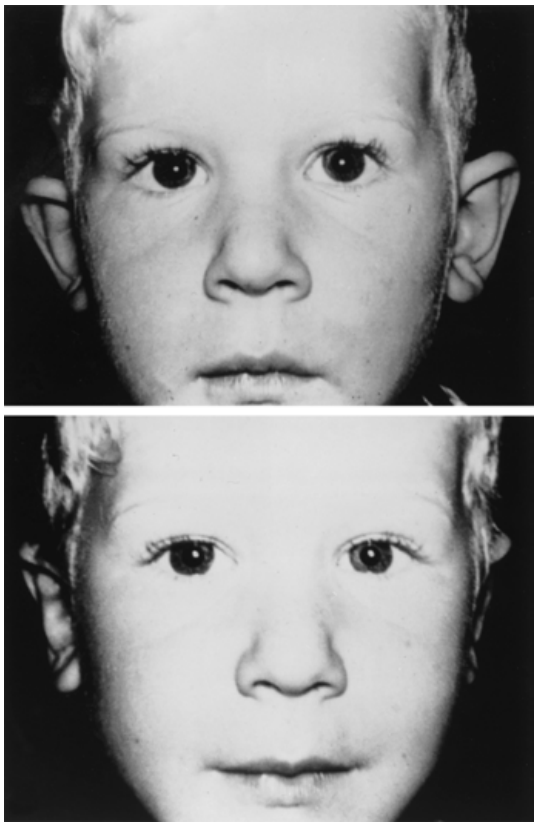

Figure 64–6 The protruding ear may worsen in the first year because of extrinsic factors. Often reconstruction requires "open" surgical otoplasty at age 5 years. This prodruding ear has been improved with Mustarde's suture molding and excision of the excessively angulated conchal segment.

excessive unfurling of the anthelical fold and the increased angulation of the concha in these prominent ears: (1) weakness of the intrinsic auricular muscles and (2) forward displacement of one ear when the infant lays with his head turned to one side for excessive periods (e.g., plagiocephalytorticollis formation sequence).[5] Whenever the rim of the helix protrudes more than 2 cm from the mastoid, one should consider placing a tubular elastic head band over the pinna when the infant is lying supine. Such "head banding" must be continued throughout the entire first year. If ear molding is begun immediately after birth, such prolonged head banding may not be necessary.

Older children with protruding ears require "open" surgical otoplasty at age 5 or 6 years. If protrusion is caused by anthelical fold anomalies, suture setback techniques with weakening of the excessive "spring" are reliable. Excessive angulation of the concha must also be corrected with excision of the offending conchal cartilage. We have not been satisfied with conchal setback procedures to lessen conchal angulation problems. Without excision of deeply angulated conchal cartilage, isolated suture and setback techniques can adversely narrow the external canal and cause an abnormal-appearing, exaggerated anthelical fold.

GRADE II: CONSTRICTED (DYSPLASTIC) AURICLES

These grade II malformations result from dysplastic or aplastic development of the auricular hillocks of the first two branchial arches. One or more anatomical subunits fail to develop. In addition to excessive angulation of the concha and unfurling of the anthelix, we often find these auricles lack development of the three-layered framework. The scapha, which is the main supporting buttress, is weak. This deficiency allows the superior aspect of the ear to fold over on itself, causing lidding and flattening of the superior half of the pinna. The crus of the helix is too low, and there is inadequate cartilage and lack of a skin envelope (Table 64–1). Composite chondrocutaneuos grafts from the opposite normal ear have excellent support, as well as ideal texture and color match. The crus helix is disarticulated and reattached superiorly to gain vertical height. The composite free graft is placed in the defect. Six weeks later the pinna is elevated from the skull with skin grafts (Fig. 64–7).

GRADE III: CLASSICAL MICROTIA

The microtic auricle is usually peanut-shaped, with a superior element of cartilage and an inferior fibroadipose nubbin of lobular tissue. Hearing must be evaluated at birth with brain stem audiometry. Other organ systems may need evaluation with renal ultrasonography, cervical spine radiography (hemivertebrae), and electrocardiography (dysrhythmia).

The congenitally deformed ear may lie anywhere along the pathway of its migration from beneath the mandible to the mastoid (Fig. 64–8). We have been using two different methods of reconstruction over the past 8 years.[6] Patients with unilateral microtia should have auriculoplasty completed before the atretic canal is approached. Rib cartilage has been a reliable donor tissue for reconstruction of a framework. By age 6 years the normal ear has attained 80% of its adult size, and the chest wall is usually adequately contoured and large enough for donor grafts to be harvested without leaving a cosmetic deformity. Also by age 6, these children often

TABLE 64–1 Common Problems Seen with Increasing Severity of Auricular Deformities

Unfurling of anthelical fold
Increased angulation of vertical portion of concha
Protrusion of ear
Flattening of helical fold
Low-lying crus helicis
Absent fossa triangularis
Inadequate support of scapha causing "lidding" of helical rim
Inadequate cartilage framework
Lack of adequate skin envelope

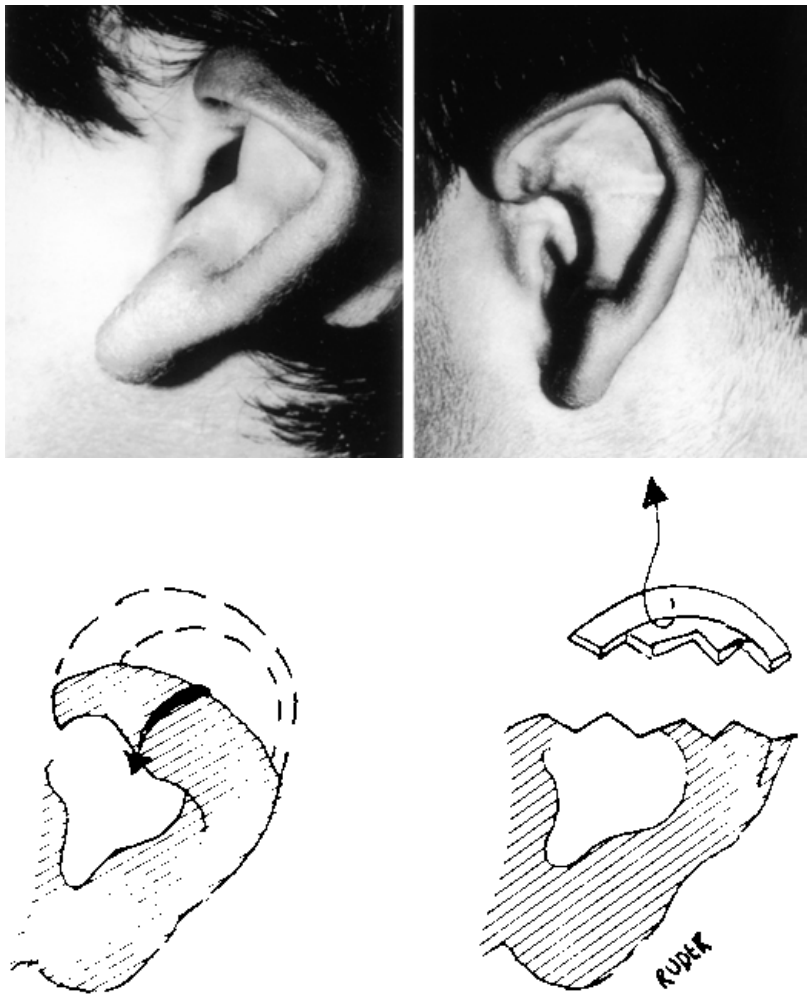

Figure 64–7 The constricted ear has deficient support from the scapha and appears to be lidded and fallen over on itself. Many anatomic subunits are missing. When elevated, deficient units are easily recognized. This constricted ear has been repaired with grafts taken from the opposite auricle.

Figure 64–8 The developing auricle has failed to migrate to the mastoid. It lies on the mandible. The reconstructed ear should be properly positioned. It should lie $5\frac{1}{2}$ cm (vertical height) from the canthus. It should not lie vertically but be angulated and parallel to the nasal dorsum.

become objects of curiosity to their playmates. They can suffer from the emotional impact of undue attention and jokes by their peers, which may cause intense shame and anguish. Bilateral microtia is an even more compounded problem. Hearing loss must be evaluated and improved with bone amplification aides as early as possible.

Several different implant materials have been used. In 1920, Gilles described his methods with autogenous cartilage.[7] Cronin (1978) and later Ohmori (1984) used silicone frameworks because of the ease of sculpturing these preformed grafts and the reduced morbidity of harvesting rib cartilage.[8,9] The rejection and extrusion rate with the Silastic implants was more than 30% even when Dacron mesh was added. In 1980, Tanzer popularized autogenous rib cartilage for a three-layered framework.[10] Brent (1978) used costal cartilage for an "open framework."[11] He soon found that this template was too unstable to maintain its contour permanently. He now also uses a three-tiered framework, as we have been using since 1986. Gorney uses conchal cartilage from the opposite ear.[12] This technique is extremely demanding and requires experience and skill that others have not been able to duplicate. Reinish has been using Medpor covered with a temporoparietal fascial flap and skin grafts with minimal problems since 1991.[13] This flexible allograft gives a more natural, durable, softer, and more pliable reconstructed auricle. However, long-term results have not been adequately evaluated. Eavey has described his preliminary research with developing autogenous cartilage growth in vitro.[14]

Preoperative Events

The initial consultation must be comforting, educational, and reassuring to both parents and child. A thorough evaluation of the genetic history and events of pregnancy is essential. Other family members with deafness, ear tags, ear or facial anomalies, and still births should be identified. Too often we find parents feeling guilty because their genetic composition or ototoxic medication intake during pregnancy may have caused their child's problem. Other facial, cervical, or renal anomalies may suggest syndromic problems that are present in almost 30% of these children.

The ideal reconstructive candidate should have adequate nonscarred mastoid skin to cover the implant. Prior trauma or surgery (atresia repair or elevation of the lobule) will compromise skin elasticity that is necessary to accommodate the three-dimensional graft. If the atresia and auriculoplasty teams are not well coordinated, the reconstructed auricle and the canal may be on different levels.

At birth, the ear is well formed but low set. It reaches its adult configuration by the end of the fourth intrauterine month. The neonates's auricle is 66% of adult size, by age 8 years, it is almost 90%. The reconstructed auricle continues to enlarge as does the normal side. Brent's studies suggested that 49% of reconstructed ears grew at an even pace with the opposite, normal ear. Forty-one percent grew several millimeters larger, and almost 10% lagged by several millimeters.[15]

Placement of the newly reconstructed ear may be difficult in patients with severe hemifacial microsomia, and adjustments must be made. Differences in height of each side of the face and in the anterior posterior dimensions of the affected side may require a "compromise" in positioning of the reconstructed pinna. If both auriculoplasty and craniofacial reconstruction are necessary, it is best to first begin the external ear reconstruction to avoid scars and vascular compromise. A low-lying hairline is often problematical. The ear may have to be made smaller, and the opposite normal auricle can also be reduced in size.

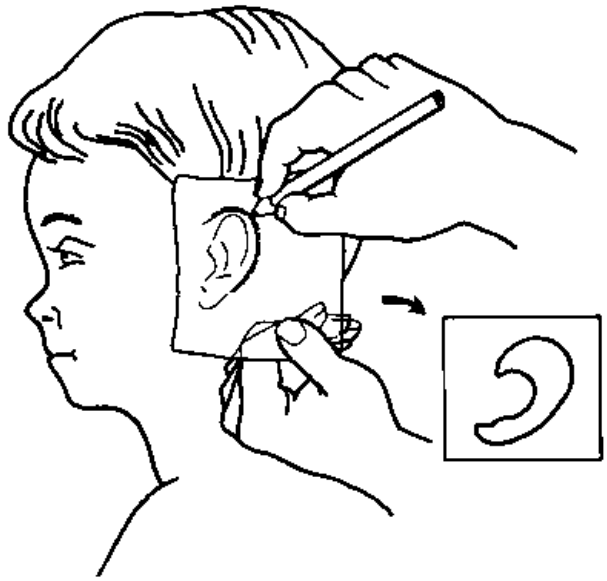

Figure 64–9 A template of x-ray film from the normal pinna, drawn slightly smaller to allow for skin thickness, is made for size and configuration of the microtic ear.

Two templates are made from x-ray film. Using the lateral canthus, lip commissure, and ala from the normal side as landmarks will ensure proper placement of the cartilage framework (Fig. 64–9). If a severe chest deformity exists (pectus carinatum or excavatum), a thoracic surgeon should also be involved when rib grafts are harvested to correct this concomitant problem. A second template is designed from the normal pinna to establish symmetry in size and configuration.

OPERATIVE TECHNIQUE

Costal cartilage is taken from the opposite side of the chest because its curvature will be a better conformation for the sculptured auricle. An incision is made 2 cm above and parallel to the inferior border of the rib cage. The rectus muscle and fascial sheath are divided and dissected until the underlying ribs are seen. The preoperatively constructed x-ray template is used to delineate the adequate amount of donor graft needed. It is imperative both to preserve the nourishing perichondrium and to avoid perforations of the closely adherent parietal pleura. Small tears, however, are frequently made. They are safely closed, without chest tubes, with purse-string sutures after all air is aspirated by the surgeon while the lung is hyperinflated by the anesthesiologist. The synchondrotic region of ribs 7 and 8 are usually ample for the framework. Eight to ten centimeters of the "floating" ninth rib is separately dissected for the helical rim. The chest wall

must be meticulously repaired in three layers to prevent postoperative hernia formation. After the wound is closed, a chest radiograph is ordered to evaluate for a pneumothorax.

Carving the Framework

The cartilage grafts are taken to a separate sculpturing table while the assistant repairs the chest wound. A three-tiered auricle is sculptured to represent the three levels of the concha, scapha, and helical rim (Fig. 64–10). Perichondrium must be preserved to nourish the graft and prevent absorption and infection. The framework is made 2 to 3 mm smaller than the template of the normal ear to allow for the thickness of the skin pocket. A common error is to make the ear too wide rather than too long. The ninth rib has an ideal shape and curvature for a helix. The ninth rib is sculptured only on its convex side to preserve perichondrium and to allow the graft to "bend." This helix extends 2 mm beyond the base anteriorly to represent a crus helicis. Inferiorly, it should reach the level of the antitragus to resemble a cauda helix. 4-0 stainless steel sutures are used to secure the helical rim onto the framework. A fossa triangularis and scapha are excavated with carving tools. This three-layered monoblock framework has been more reliable than other "expansile" frameworks that flatten and eventually lose their contour.

Placement of the Graft and Creation of the Lobule

The second x-ray template is tattooed onto the microtic side with methylene blue to ensure proper location and position. An adequate, pliable, and unscarred skin is crucial to achieve definition. The inferior fibroadipose nubbin is rotated posteriorly and inferiorly to lie below the implanted cartilage framework. A thin subdermal skin pocket is created, and vestigial microtic cartilage is removed. An "island" of undissected skin in the proposed conchal area should not be undermined or elevated to ensure adequate vascularity to the peripheral margins of the elevated skin pocket (Fig. 64–11). To better evaluate vascularity and skin tension, no vasoconstricting agents are used. Excessive skin tension will prevent the elevated skin envelope from lying within the newly sculptured contours and losing definition. Even moderate tension can cause skin necrosis and graft exposure. If skin blanching is present after the cartilage framework is inserted, the pocket must be enlarged.

The framework is rotated into proper position along the previously tattooed marks. The inferior fibroadipose nubbin is rotated posteriorly and inferiorly below the inserted cartilage to form a lobule. Two 10-Fr drains are inserted and attached to continuous wall suction at 80 mm Hg for 3 days. These drains coapt the skin to the graft, avoiding bolsters and mattress sutures that further compromise vascularity. Petroleum jelly gauze is placed over the graft, and antibiotics are continued for a week until the sutures and dressing are removed.

Creation of a Tragus and Conchal Excavation

There is relative asymmetry in protrusion of the two ears. After 3 months, a tragus can be constructed with a composite chondrocutaneous graft from the normal side. Cartilage and skin are harvested from the vertical portions of the cavum concha. A 2-cm-diameter full-thickness postauricular skin graft is also taken and thinned. Closure of the donor defects reduces relative protrusion by bringing the normal ear closer to the mastoid.

A "J"-shaped incision is made at the proposed tragus on the microtic side. The soft tissue is removed to deepen the conchal bowl. These three tissues (anterior skin, composite

Figure 64–10 A three-layered auricular framework is sculptured, creating a concha, scapha, and helix.

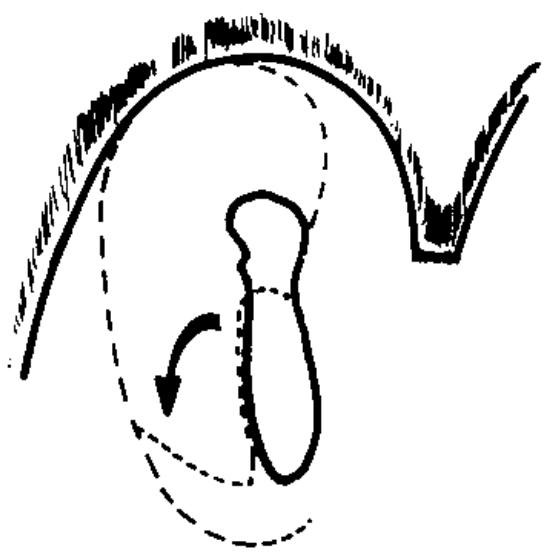

Figure 64–11 The inferior fibroadipose lobular remnant is rotated posteriorly and inferiorly to create a lobule. An "island" of undissected tissue is left to enhance vascularity. Drains are placed and attached to wall suction to help coapt the skin against the cartilage framework.

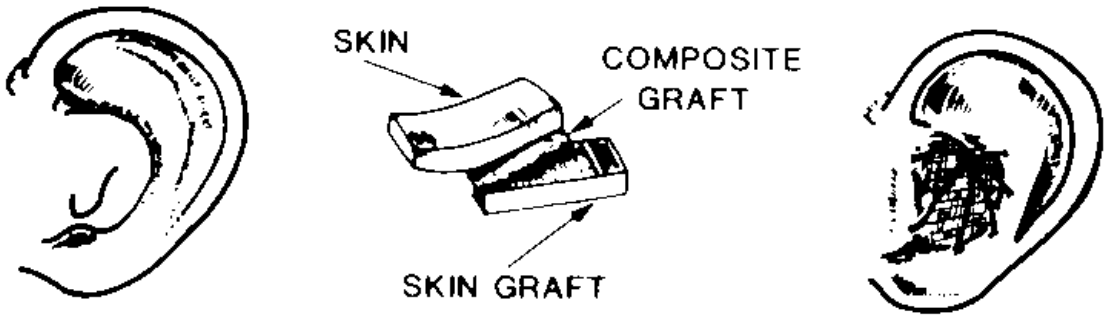

Figure 64–12 A J-shaped incision is made at the proposed site of the tragus. The chondrocutaneous graft is sutured to the facial skin anteriorly and the free skin graft posteriorly. They are folded in an accordion-like fashion to create a tragus.

chondrocutaneous graft, and the full-thickness postauricular skin graft) are sutured together in an accordian-like fashion with the supporting composite graft on the undersurface of the skin flap (Fig. 64–12). This technique forms a naturally appearing meatus with no shrinkage as seen with other procedures using unsupported soft-tissue advancement flaps. The introitus of the canal and conchal bowl are packed with bismuth tribromophenate (Xeroform) for a week to prevent blunting.

Elevation of the Auricle

The reconstructed auricle may still lack adequate projection from the skull. Many patients need further elevation of the auricle and creation of a postauricular sulcus for the securing of glasses or hearing aides. An incision is made 5 mm lateral and parallel to the helix. The scalp is dissected posteriorly in a subgaleal plane almost 5 cm. The auricular cartilage framework is undermined to the level of the concha, with care taken not to expose the cartilage. The scalp flap is advanced beneath the elevated framework and sutured with 3-0 Vicryl with moderate tension (Fig. 64–13). The denuded posterior aspect of the ear is covered with a full-thickness skin graft from the ipsilateral groin. Gauze bolsters are sutured into the sulcus for a week (Fig. 64–14).

THE OLDER PATIENT AND TRAUMATIC AVULSIONS

Prior facial surgery often causes additional reconstructive problems. Nonpliable scarred skin will not allow adequate definition of the new auricle. In patients older than 30 years, the rib grafts can be prematurely ossified, preventing sculpturing of the framework. We have approached these problems with vascularized temporoparietal fascial flaps (TPFF), skin grafts, and biosynthetic implants. Medpor (Fig. 64–15) premolded implants have been reliable over a 5-year evaluation when covered by vascularized fascia and skin grafting. Although not ideal, we have experienced only one complete rejection in 15 cases. The TPFF is an abundant, accessible, thin, well-vascularized, and hairless tissue used to cover either autogenous cartilage or Medpor. TPFF is continuous with the superficial musculoaponeurotic fascia superiorly and inserts on the zygomatic arch inferiorly. It should not be confused with the deeper, less vascularized temporalis fascia, which inserts deep to the zygomatic arch onto the mandibular condyle. Dissection of this delicate flap is just beneath hair follicles and above the axial arrangement of vessels within the flap. This tedious dissection must be made without vasoconstrictors to allow for circulation at the distal margins. The vascularity of this flap can easily be damaged if

Figure 64–13 The tragus has been formed, but the neoauricle is still adherent to the skull. Additional protrusion is obtained through a scalp advancement flap. A full-thickness skin graft is placed over the elevated posterior surface.

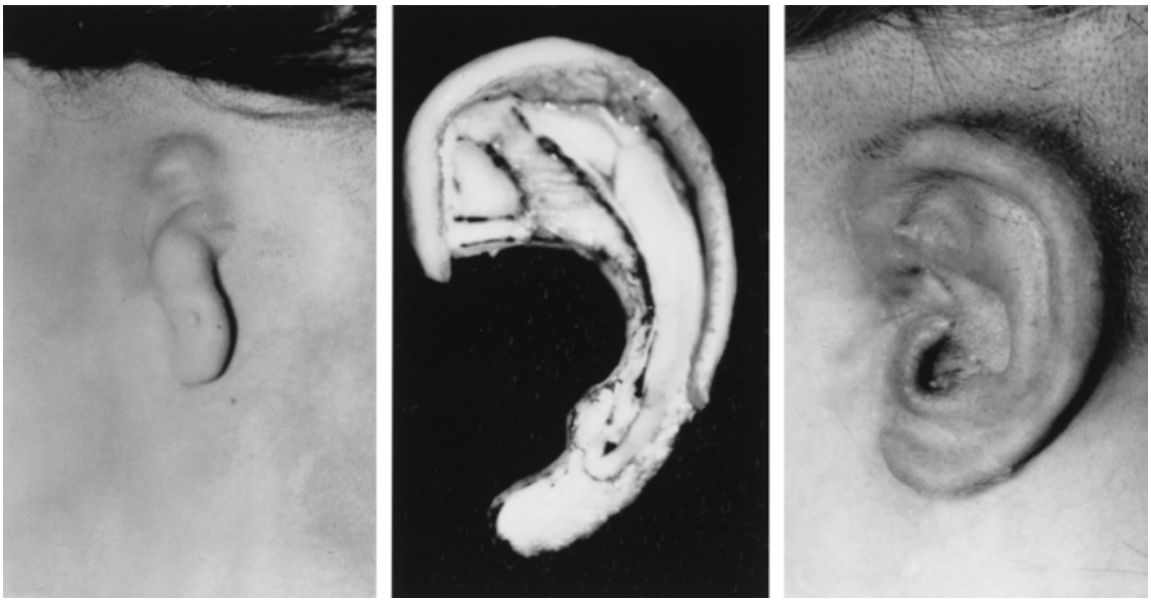

Figure 64–14 The microtic ear has been reconstructed with a sculptured rib graft.

Figure 64–15 Premolded Medpor implants are used in older patients when the rib grafts are often ossified.

the superficial temporal and the auricular arteries are not identified with a Doppler and preserved. Too superficial dissection will damage the hair follicles and cause alopecia. These arteries extend 12 cm above the ear until they become superficial and fuse with the parietal scalp subdermal plexus where the TPFF becomes continuous with the galea. Twelve centimeters is the superior boundary of vascularity and is therefore the superior limit of dissection. The anterior border is limited by the temporal branch of the facial nerve as it crosses the zygomatic arch. Posteriorly the dissection must not extend beyond the posterior branches of the temporal artery and vein.

An incision is made around the posterior edge of the proposed placement of the framework. The skin is elevated anteriorly and the parietal scalp is incised to permit dissection of the underlying TPFF. Full-thickness skin grafts are taken from the opposite postauricular area and the subumbilical abdomen. The elevated TPFF is rotated inferiorly to cover the framework. The fibroadipose lobular nubbin is rotated inferiorly and skin grafts are sutured over the fascia (Fig. 64–16). The skin grafts from the abdomen are sutured to the donor site of the opposite postauricular area and to the posterior area of the elevated framework. Two suction drains are inserted under this elevated framework and are attached to wall suction for 3 days. Four months later, a tragus is formed with a composite graft from the opposite auricle, as has been previously described. No long-term follow-up of the two-staged technique is yet available.

SUMMARY

Auricular reconstruction requires a thorough analysis of the missing elements and the techniques available to correct them.[16] Other congenital maldevelopments must also be identified and addressed as early as possible. Temporal bone scans will often alter the entire reconstruction process. The otologist and the plastic teams must be involved in decision making to avoid unnecessary incisions and scarring from other craniofacial and atresia repairs. Considerable investigation is evolving to grow the ideal implant of durable autologous cartilage.

Figure 64–16 The Medpor framework is placed on the mastoid and covered by a temporoparietal flap and full-thickness skin grafts from the opposite postauricular area.

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Chapter 65

Diagnosis and Treatment of Cleft Lip and Palate Deformities

Jonathan M. Sykes

Cleft lip and palate deformities are the most common congenital malformations of the head and neck. Patients with these deformities experience problems with chewing, swallowing, and speech, in addition to obvious alterations in appearance and facial growth.

The evaluation and treatment of patients with cleft lip, palate, and nasal deformities is a challenging task. Complete care of the cleft patient necessitates a multidisciplinary team approach. Successful treatment requires a dedicated effort, including ongoing evaluation and management of dental, psychosocial, speech, otologic, and aesthetic needs of the cleft patient.

This chapter will detail the unique embryology and anatomy of both the unilateral and bilateral cleft malformation. A classification of cleft deformities is outlined. A treatment philosophy including the timing and technique of various cleft repairs is described.

EMBRYOLOGY OF THE LIP AND PALATE

Normal development of the lip and palate occurs during the embryonic period (the first 12 weeks of intrauterine life). The midportion of the face develops anterior to the forebrain by the differentiation of the broad midline frontonasal prominence. The *primary palate* forms at approximately 4 to 6 weeks and forms the initial separation between the oral and nasal cavities. The primary palate, or median palatine process, is formed by the fusion of the paired median nasal prominences (MNPs). Fusion of the paired MNPs gives rise to the central upper lip, the central maxillary alveolar arch and associated lateral and central incisors, and the hard palate anterior to the incisive foramen (Fig. 65–1).[1,2] Development of the primary palate is distinct embryologically from normal formation of the secondary palate (posterior to the incisive foramen).

The paired median nasal processes coalesce during the sixth week and eventually form the premaxilla, philtrum of the upper lip, columella, and nasal tip. The lateral elements of the upper lip (from the philtral column laterally) are derived from the paired maxillary processes. The cheek, maxilla, zygoma, and secondary palate (see below) are also formed from the maxillary processes. The upper lip is therefore formed from both the median nasal and maxillary processes.[3]

The *secondary palate* begins developing at approximately eight weeks of gestation, after development of the primary palate is completed (Fig. 65–2). Formation of the secondary palate occurs by inferior and medial growth and migration of the palatal shelves (the medial projections of the maxillary processes). As the palatal shelves displace inferiorly (similar to a drawbridge), the developing nasal cavities expand laterally and inferiorly.

The paired palatal shelves are initially separated by the developing tongue. Growth of the mandible with associated anterior movement of the tongue allows the palatal shelves to migrate inferiorly and assume a more horizontal orientation. If fetal development and migration of the mandible do not proceed normally, the paired palatal shelves cannot migrate inferiorly and medially. Lack of contact of these shelves creates palatal clefting. This malformation can result in the *Pierre Robin* sequence (micrognathia, relative macroglossia, and U-shaped cleft palate) (Fig. 65–3A, B).[4]

The normal sequence of normal palatal formation begins when the palatal shelves and nasal septum contact each other and proceeds in an anterior-to-posterior direction. Palatal closure first occurs at the incisive foramen at approximately 8 weeks of gestation and is usually completed through the uvula by 12 weeks. The degree of clefting of the secondary palate is related to many factors, including when in the fetal development the fusion process is interrupted. Therefore, the palatal abnormality can be only a bifid uvula, a submucous soft-palate cleft, or a complete cleft of the secondary palate.[5]

CLASSIFICATION OF CLEFTS

The embryologic development of the lip and palate serves as a natural mechanism to classify congenital clefts. The primary palate and lip develops between weeks 4 and 8. Interruption of this development can cause clefts of the lip and alveolus (primary palate). Cleft lips may be unilateral or bilateral, complete or incomplete. Clefts of the lip may be isolated, may be associated with clefts of the alveolus and palate, or may be associated with other malformations (syndromic clefts). Human cleft lip, with or without associated cleft palate, is caused by failure of the median MNP to make contact with the lateral nasal process (LNP) and the maxillary process (MXP) during embryogenesis. Interruption of this embryologic process often creates maldevelopment of some or all of the upper lip, central maxillary arch, and the anterior portion of the palate. A minor malformation of normal lip development may cause dehiscence of the orbicularis oris muscles with no overt clefting of the epidermis of the upper lip.

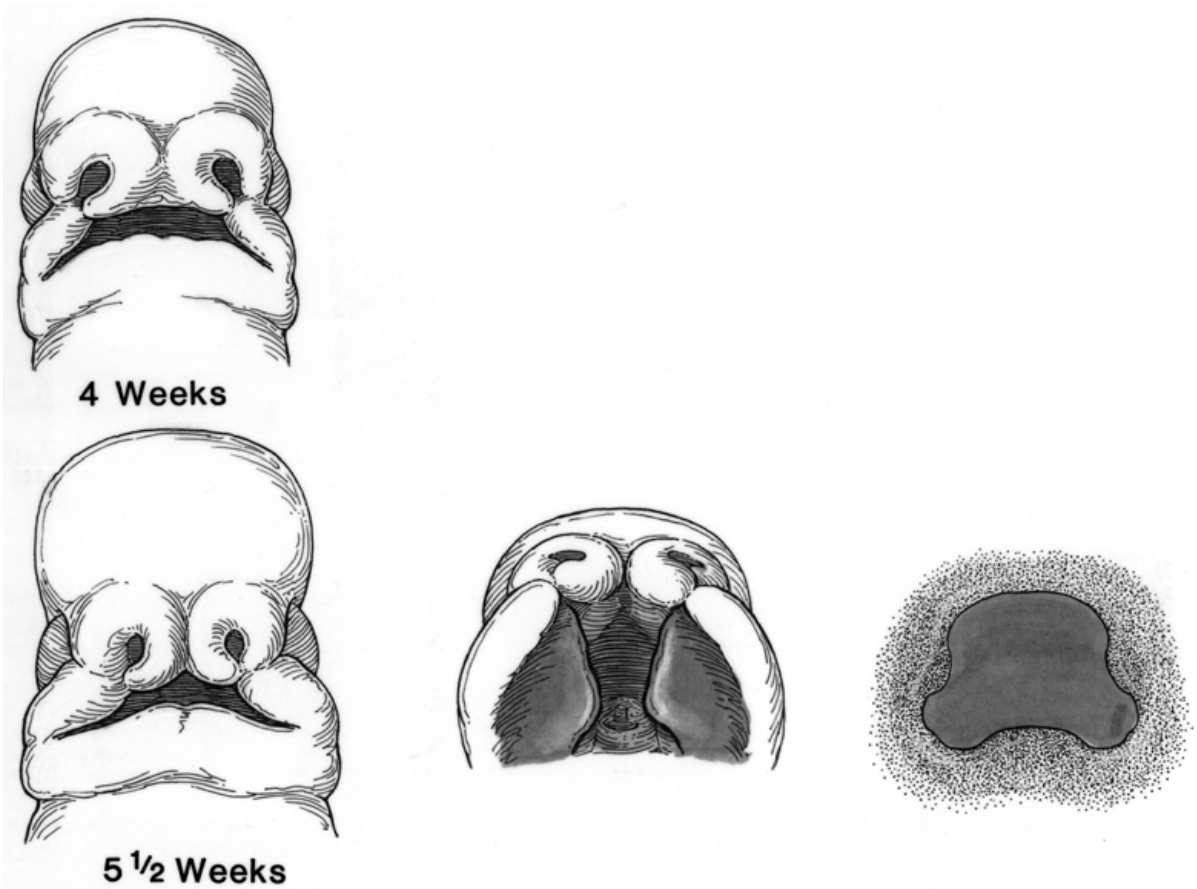


Figure 65–1 Schematic diagram of the development of the lip and palate at 4 and $5\frac{1}{2}$ weeks of gestational age. The primary palate is forming at approximately 4 to 6 weeks by fusion of the paired median nasal prominences.

This condition is known as a *microform* cleft of the upper lip (Fig. 65–4). A more significant interruption of the upper lip development is known as an *incomplete cleft lip* (Fig. 65–5). An incomplete unilateral cleft lip involves a through-and-through defect of skin, muscle, and mucosa of the lower aspect of the lip but does not extend superiorly though the entire lip height. A *complete unilateral cleft lip* occurs when the defect involves all tissue layers of the lip and extends through the entire height of the lip and floor of the nose (Fig. 65–6). A cleft of the alveolus is almost always associated with complete clefting of the upper lip.

The degree of clefting of the upper lip depends on the timing and degree of interruption of normal lip development. If disruption of both sides of lip development occurs, a bilateral cleft lip results. In the *incomplete bilateral cleft lip*, there is usually some skeletal continuity and little or no protrusion of the premaxilla (Fig. 65–7). In *complete bilateral cleft lips*, the central premaxilla is totally detached from each maxilla (Fig. 65–8A, B).

Either the unilateral or bilateral cleft lip deformity may be isolated or associated with clefts of the alveolus or palate. Because a greater interruption of lip development is required to create a bilateral cleft lip, this deformity is more likely to be associated with clefting of the secondary palate than is the unilateral cleft lip deformity.

The primary palate is formed simultaneously with the upper lip and central maxillary alveolar ridge. The secondary palate is composed of the horizontal plate of the maxilla and palatine bone. It fuses in an anterior-to-posterior direction between embryologic weeks 8 and 12. Interruption of the normal fusion of the secondary palate causes various degrees of clefting.

Clefts of the secondary palate can be variable in expression, depending on the timing and degree of interruption of palatal development. A *bifid uvula* is the smallest expression of clefting of the soft palate. This common deformity occurs when there is a lack of normal fusion of the uvula. A *submucous cleft of the soft palate* occurs when there is dehiscence of the muscles of the soft palate. In this condition, the palatal mucosa is intact but incomplete development of the underlying palatal musculature is present and often requires speech therapy and/or surgical repair. Full-thickness clefting of the soft palate (incomplete secondary palate clefts) may also occur (Fig. 65–9). Finally, *complete clefting* of the

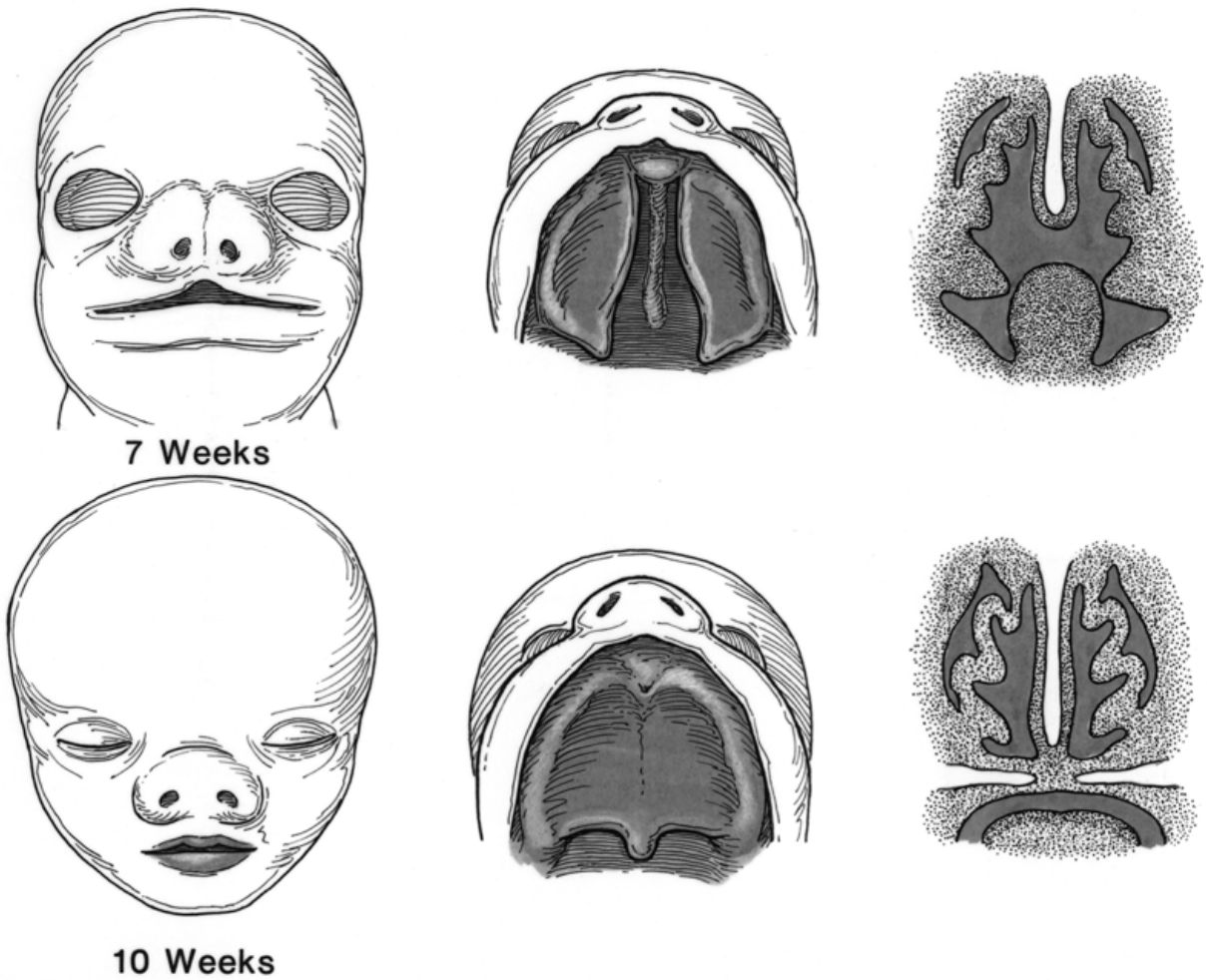


Figure 65–2 Schematic diagram of the embryo at age 7 and 10 weeks during which time the secondary palate forms in an anterior to posterior fusion process beginning anteriorly at the incisor foramen.

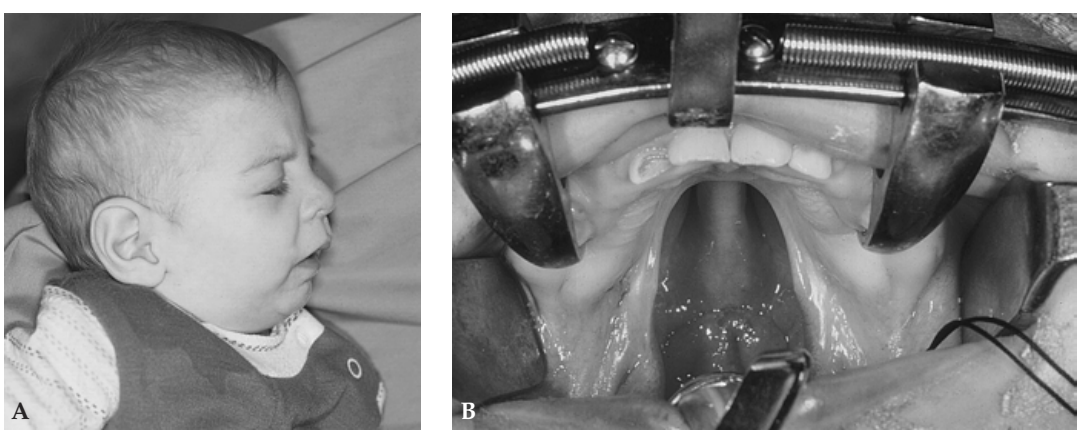


Figure 65–3 Child with Pierre Robin sequence including micrognathia, relative macroglossia, and u-shaped cleft palate.

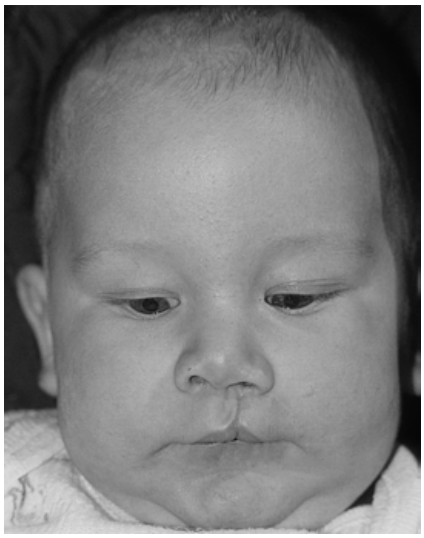


Figure 65–4 A 6-month-old child with a left microform cleft of the upper lip.

Figure 65–5 A 3-month-old child with an incomplete left cleft lip.

Figure 65–6 A 2-month-old child with a complete cleft of the right lip and palate.

Figure 65–7 Basal view of a child with an incomplete bilateral cleft lip and palate.

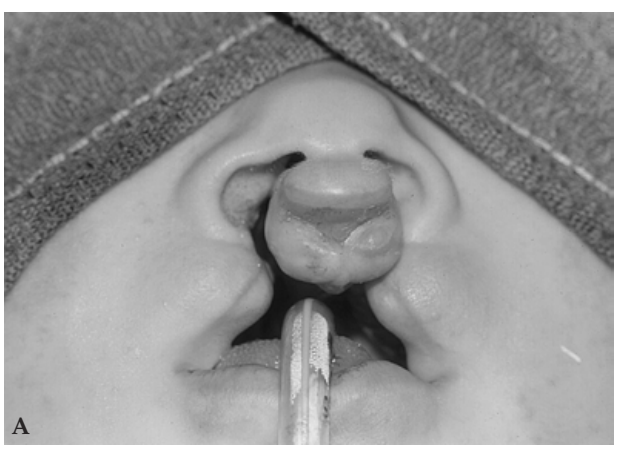


Figure 65–8 A 3-month-old child with a symmetrical complete bilateral cleft of the lip and palate. Note the anterior protrusion of the premaxilla and prolabium associated with very poor projection of the nasal tip.

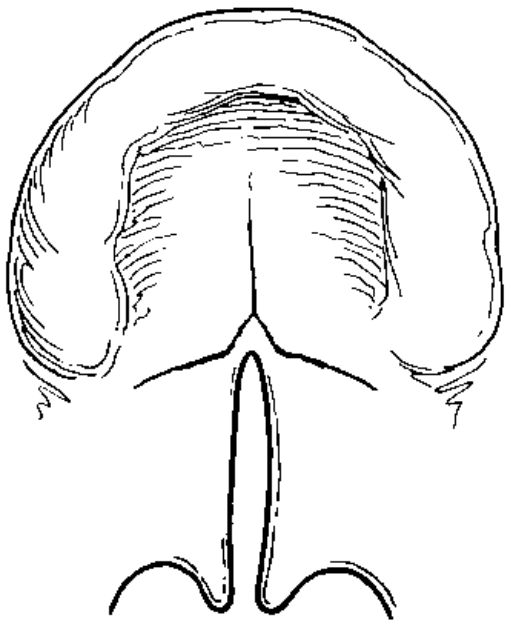


Figure 65–9 Schematic diagram of a cleft of the soft palate.

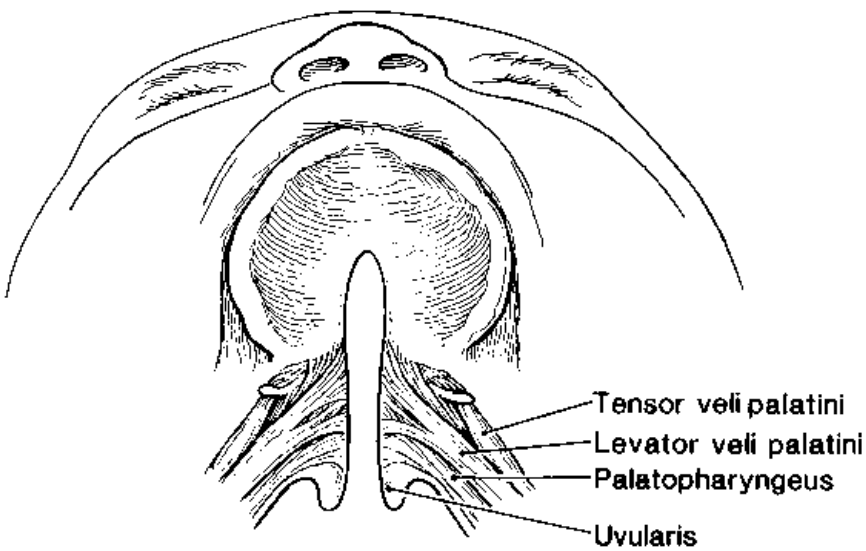


Figure 65–10 Schematic diagram of a complete cleft of the secondary palate beginning at the incisor foramen.

secondary palate may result from total interruption of the normal formation of the palate posterior to the incisive foramen (Fig. 65–10).[6]

Clefts of the secondary palate may be associated with complete cleft lips and are termed *complete clefts of the lip and palate*. Complete cleft lip and palate may be unilateral or bilateral. The complete unilateral cleft lip and palate usually involves attachment of the vomer to the maxillary palatal shelf of the noncleft side (Fig. 65–11). Complete bilateral clefts of the lip and palate usually have the central vomer and premaxilla detached from the two lateral palatal shelves (Fig. 65–12). In all cases, clefting of the lip and palate is variable in expression and typically follows known embryologic patterns.

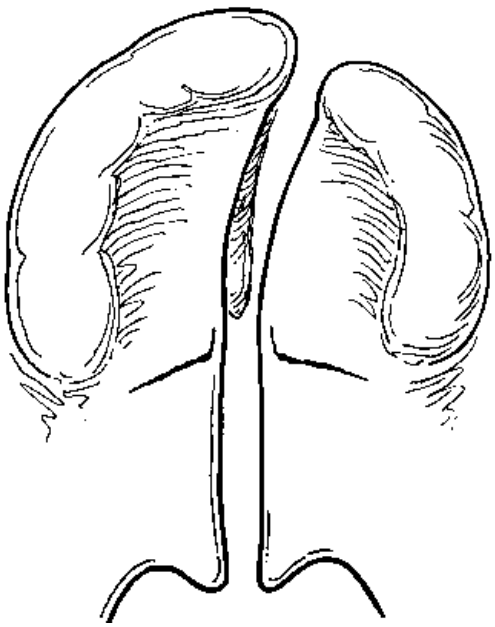


Figure 65–11 Schematic diagram of a complete unilateral cleft of the hard and soft palate.

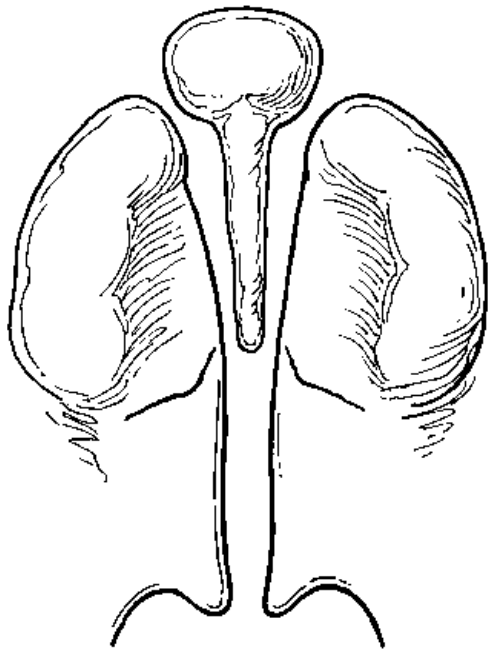


Figure 65–12 Schematic diagram of a complete bilateral cleft palate.

TIMING AND PHILOSOPHY OF CLEFT REPAIR

The decision to repair a cleft lip or palate deformity is based on a variety of factors. These include consideration of speech development, facial growth, psychological impact, and safety to undergo anesthesia. The timing of repair of cleft deformities is outlined in Table 65–1.[7] In all patients with cleft palate, tympanostomy tube placement is performed at age 3–6 months to aerate the middle ear, decrease conductive hearing loss, and minimize the likelihood of chronic ear disease. In patients with cleft lip and palate, cleft lip repair and tympanostomy tube placement are performed at approximately 3 months of age. Cleft palate repair is performed prior to the initial development of speech to minimize the possibility of velopharyngeal dysfunction (VPD). Long-acting tympanostomy tubes are placed at the time of palatoplasty.

After cleft palate repair, patients are monitored carefully for speech development, beginning at age 2 years. If VPD is identified, a VPD work-up, including nasopharyngoscopy and videofluoroscopy, is performed. If the degree of VPD is significant, surgical treatment is performed between 4 and 6 years of age.

Other surgical treatments for cleft deformities include alveolar bone grafting at 9 to 11 years of age, nasal reconstruction at 12 to 18 years of age, and orthognathic surgery after growth of the facial skeleton is complete. The need for these interventions is related to the initial deformity as well as the growth and development of the patient.

TABLE 65–1 Timing of Cleft Repairs

Procedure	Age
Cleft lip repair	3 mo
Tip rhinoplasty	
Tympanostomy tubes	
Palatoplasty	9–18 mo
T-tube placement	
Speech evaluation	3–4 yr
Velopharyngeal insufficiency workup and surgery (if necessary)	4–6 yr
Alveolar bone grafting	9–11 yr
Nasal reconstruction	12–18 yr
Orthognathic surgery (if necessary)	At completion of mandibular growth (>16 yr)

CLEFT LIP

Anatomy

The upper lip can be separated into red (mucous membrane) and white (cutaneous) components (Fig. 65–13). The mucocutaneous junction is an important aesthetic border separating the convex red lip from the relatively concave white lip. A round roll of epithelium is present just superior to the vermilion–cutaneous junction of the upper lip. This tissue is referred to as the *white skin roll*.[8] It spans the entire upper lip and reflects ambient light. Precise reconstruction of the mucocutaneous junction and white roll of the upper lip is essential in reestablishing normal and natural upper lip aesthetics.

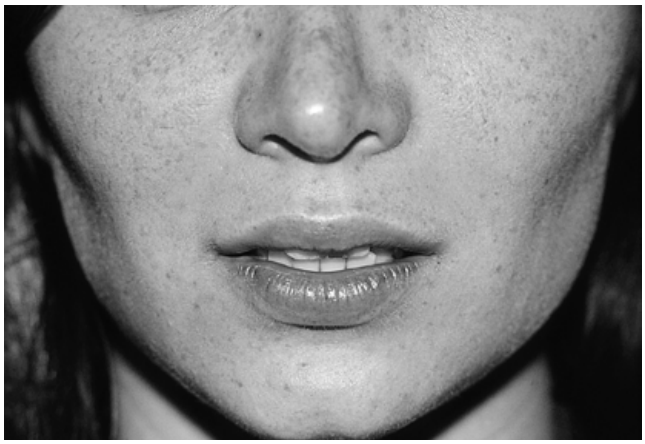


Figure 65–13 Frontal photograph of the perioral complex including the mucous membrane and cutaneous components of the upper and lower lip. Note the distinct white skin roll that reflects light just above the vermilion cutaneous junction.

The muscles of the upper and lower lips play an important role in the appearance and function of the lips. Careful attention must therefore be paid to recreating muscle continuity in repair of any traumatic or congenital deformity. The principal muscle of the lips is the orbicularis oris (Fig. 65–14). This muscle acts as a sphincter with the fibers encircling the oral orifice within the substance of the lips.[9] The superficial layer of this muscle arises from the deep surface of the skin and passes obliquely to insert into the mucous membrane lining the inner surface of the lips. The fibers of the deep layer arise from the maxilla above and the mandible below.[10] The nerve supply to these muscles is the buccal and marginal mandibular branches of the facial nerve.

The Unilateral Cleft Lip Deformity

The unilateral cleft lip deformity may involve any combination of skin, muscle, mucosa, and underlying skeletal mucosa. Subcutaneous (microform) cleft lip involves partial or total clefting of the upper lip musculature. Partial (incomplete) cleft lip involves skin, muscle, and mucosa but may spare the underlying skeletal structures. Complete unilateral lip deformities involve all tissue layers.

The orbicularis oris muscles associated with the unilateral cleft lip deformity are hypoplastic and incompletely developed when compared with their noncleft counterparts. In addition, the upper lip muscles are prevented from attaching to their normal insertions and find unnatural substitute insertions (Fig. 65–15). Although it is obvious that no muscle crosses the cleft "gap" in complete clefts, the skin bridge in incomplete clefts has also been found to contain no functional musculature. Muscle dissections by Fara et al on stillborn babies with incomplete clefts confirmed that the muscles in unilateral cleft lips are more hypoplastic on the medial side than on the lateral side of the cleft.[11] Additionally, these dissections revealed that the upper lip muscles in incomplete clefts did not cross the cleft gap unless the skin bridge was at least one third the height of the lip. Even if the orbicularis oris muscle is present in the skin bridge of an incomplete cleft, the orientation of the musculature is abnormal.

The major vascular supply to the lips and nose arises from the facial artery, which is a branch of the external carotid artery. The facial artery gives rise to the superior and inferior labial arteries at each oral commissure. The paired superior labial arteries anastomose in the midline of the upper lip, and the two inferior labial arteries behave similarly in the lower lip. In the unilateral cleft lip, the aberrant vascular supply parallels the findings of the unilateral cleft lip musculature (Fig. 65–16). As with the musculature, the blood supply on the lateral aspect of the cleft is better developed than the vasculature on the medial side. The superior labial artery courses along the margin of the cleft, anastomosing with either the angular artery or the lateral nasal artery at the base of the nose. In incomplete clefts, a thin, terminal branch of the superior labial artery crosses the skin bridge.

Unilateral Cleft Lip Repair

Many techniques have been described over the years for repair of the unilateral cleft lip. Early descriptions of cleft lip repair utilized variations of straight-line closures. The main disadvantage of straight-line closure is the tendency for vertical scar

Figure 65–14 Illustration of the orbicularis oris muscles as they relate to the other facial musculature.

Figure 65–15 Diagram of the orbicularis oris muscles associated with a unilateral cleft lip deformity. Note the unnatural substitute insertions of the muscle along the cleft margin.

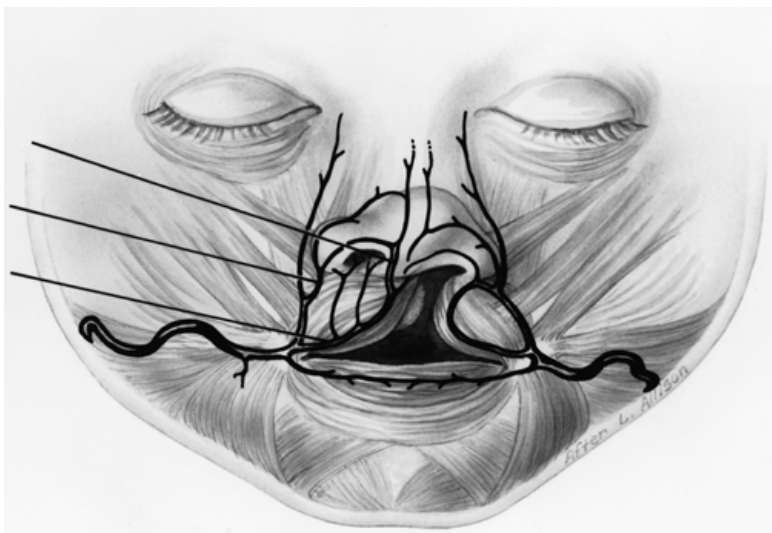


Figure 65–16 Diagram of the aberrant vascular supply of the unilateral cleft lip.

contracture across the mucocutaneous junction of the lip, resulting in notching of the lip. Wide complete unilateral cleft lips are also difficult to repair by the straight-line method.

In the mid-twentieth century, various geometric closures were proposed for repairing the unilateral cleft lip. Geometrical techniques, such as modified Z-plasties, quadrangular flaps, and triangular flaps,[12–14] were designed to decrease the amount of lip shortening that occurred with cleft lip repair and to improve orbicularis oris muscle realignment and function. LeMesurier[15] described the quadrangular flap and Tennison[12] described the triangular flap technique as a reliable, consistent method for decreasing vertical lip contraction in unilateral cleft lip repair.

The primary advantage of geometrical lip repair techniques is that they provide a reproducible method to repair the lip. Exact measurements can be made with calipers to ensure reliable tension-free closure of the lip. The basic disadvantage of the geometrical designs is that the incisions always violate the curved philtral column on the noncleft side, creating a scar that crosses boundaries of known anatomical subunits. In addition, geometrical repairs require exacting presurgical measurement and lack flexibility in surgical application.

In 1957, Millard incorporated aspects of multiple previously described repairs and developed the rotation–advancement flap technique for repair of the unilateral cleft lip.[16] This method maximized flexibility for the surgeon while facilitating elimination of a minimal amount of normal lip tissue. This method is the most common one used today for unilateral cleft lip repair. The advantages and disadvantages of the Millard rotation–advancement flap technique are shown in Table 65–2.[17]

Operative Technique: Rotation–Advancement Repair

The important reference points of the rotation–advancement flap technique are summarized in Table 65–3 and Fig. 65–17A, B.[17] Some of these points are anatomical points (e.g., 1, 2, 4, 5, 6, 10), whereas other points are "measured" (e.g., 3, 5, 8, 9). Several measurements are used to maximize flap design and lip aesthetics. These measurements are outlined in Table 65–4. The main objective of these measurements is to ensure that the length of the rotation flap (3 to 5 + x) equals the length of the advancement flap (8 to 9) (Fig. 65–18).

TABLE 65–2 Millard Rotation–Advancement Repair

Advantages	Disadvantages
Flexible	Requires experienced surgeon
Minimal tissue discarded	Possible excessive tension
Good nasal access	Extensive undermining required
Camouflaged suture line	Vertical scar contracture
	Tendency to small nostril

TABLE 65–3 Millard Rotation–Advancement Technique: Reference Points

1. Center (low point) of Cupid's bow—noncleft side (NCS)
2. Peak of Cupid's bow—lateral NCS
3. Peak of Cupid's bow—medial NCS
4. Alar base—NCS
5. Columellar base—NCS

X. Back-cut point—NCS

6. Commissure—NCS
7. Commissure—cleft side (CS)
8. Peak of Cupid's bow—CS
9. Medial tip of advancement flap—CS
10. Midpoint of alar base—CS
11. Lateral alar base—CS

TABLE 65–4 Measurements for Flap Design

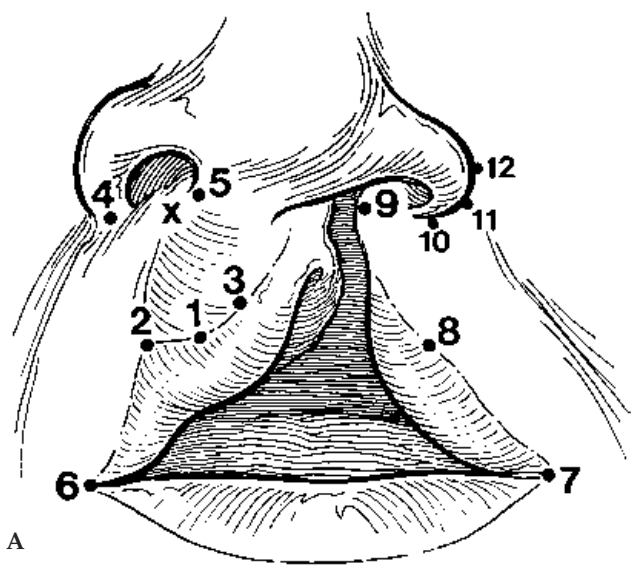
1 to 2 = 1 to 3 = 2–4 mm
2 to 6 = 8 to 7 = 20 mm
2 to 4 = 8 to 10 = 9–11 mm
3 to 5 + X = 8 to 9

TABLE 65–5 Flaps Labels and Designations

A: Rotation flap
B: Advancement flap
c: Columellar base soft tissue, NCS
D: Alar rim—CS
M: Medial mucosal flap
l: Lateral mucosal flap

The reference points and premarked incisions create major flaps A (rotation) and B (advancement), and minor flaps C (skin), M (medial mucosal), and L (lateral mucosal) (Table 65–5). After incising and dissecting these lip flaps, meticulous dissection and reapproximation of the orbicularis oris muscle is performed. This closure maximizes lip function while minimizing tension across the lip wound.

The Millard rotation–advancement lip repair also allows active closure of the nasal floor and nasal tip rhinoplasty (Fig. 65–19A, B). These procedures create improved symmetry of the nasal tip and alar base. Complete access to the nasal tip can be obtained through the standard perialar and cleft margin incisions, without additional nasal incisions.



A

B

Figure 65–17 **(A)** The marked and measured points of the Millard Rotation Advancement unilateral cleft lip repair. **(B)** A 5-year-old patient with unrepaired left cleft lip showing the marked points for the rotation advancement lip repair.

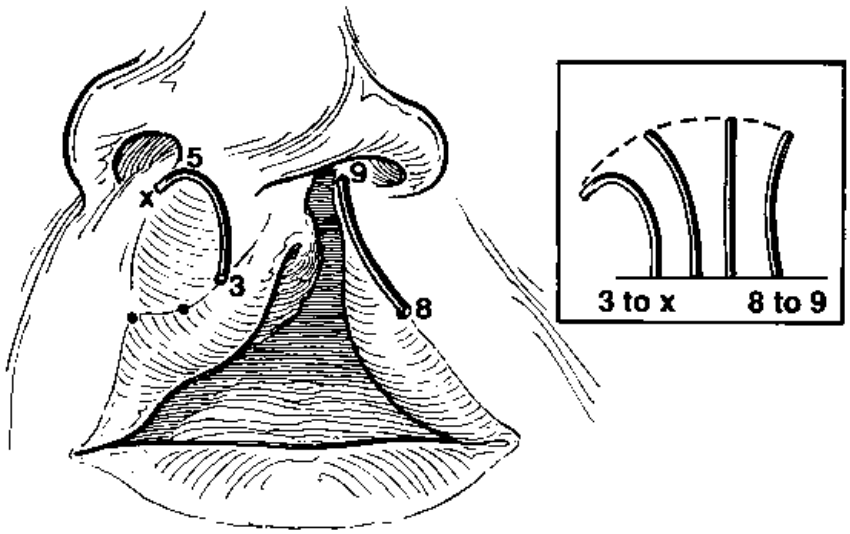


Figure 65–18 Schematic diagram of the rotation advancement incisions. Note that the length of the rotation flap incision (3 to 5 + *x*) should equal the length of the advancement incision (8 to 9).

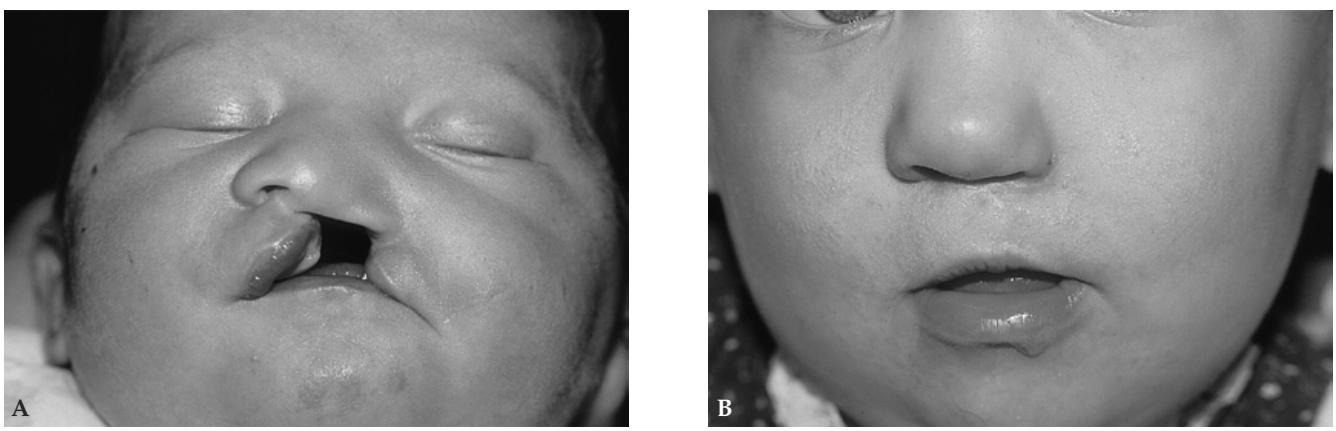


Figure 65–19 **(A)** A 10-day-old patient with complete left cleft lip and palate. **(B)** An 8-month-old patient after Millard unilateral cleft lip repair at 3 months of age.

The Bilateral Cleft Lip Deformity

The shape and configuration of the two lateral segments of the bilateral cleft lip are similar to the lateral segment of the unilateral deformity. However, the central or medial element of the bilateral deformity is markedly different from that of the unilateral lip deformity.

In complete bilateral cleft lips, the premaxilla is totally detached from each maxilla. The central premaxilla and the attached prolabium (central segment of the bilateral cleft lip) may find its own position, unrelated to the position of the maxilla on either side. In the incomplete bilateral cleft lip, there is usually some skeletal continuity and very little protrusion of the premaxilla/prolabium. The premaxilla in complete bilateral cleft lip usually protrudes more than in the incomplete deformity; therefore, the columella of the nose is usually shorter in the complete bilateral deformity.

The arterial network and musculature of the lateral elements of the complete bilateral cleft lip parallels that of the lateral segment in the unilateral anomaly. The abnormal insertion of the cleft lip musculature follows the margin of the cleft (Fig. 65–20).[18,19] In complete bilateral clefts, the central prolabium contains no muscle. In incomplete bilateral cleft lip, some orbicularis oris muscle fibers cross the cleft from the lateral to the medial segment. The amount of muscle crossing the skin bridge is variable and related to the size of the skin bridge.[11]

The arterial supply in bilateral cleft lips is characterized by an aberrant course of the superior labial artery (Fig. 65–21). This artery runs superiorly along the edge of the cleft and anastomoses with the angular and lateral nasal arteries. This abnormal course is similar to that in the lateral segment of the unilateral deformity. The prolabial segment in the bilateral complete deformity receives its blood supply from the septum, columella, and premaxilla.

Surgical Repair of the Bilateral Cleft Lip

The timing and technique for repair of the bilateral cleft lip are related to the extent of the deformity and the philosophy of the operating surgeon. The repair can be performed after

Figure 65–20 Schematic diagram showing the abnormal insertion of the bilateral cleft lip musculature.

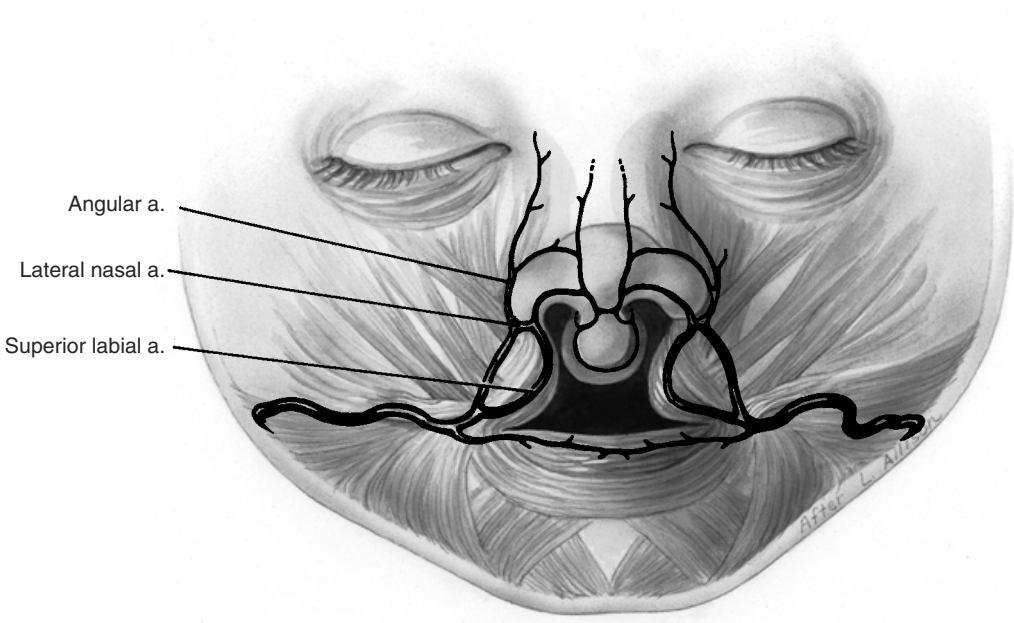


Figure 65–21 Schematic diagram showing the aberrant arterial supply in the bilateral cleft lip deformity.

presurgical orthopedics or lip adhesion, both designed to narrow the cleft gap and to better align the cleft segments. Definitive lip repair can be performed in a single stage or carried out in two separate surgical procedures.

In patients with a wide complete bilateral cleft lip, alveolus, and secondary palate, a one-stage bilateral lip adhesion may be indicated.[20] This procedure converts a complete cleft lip deformity to an incomplete deformity. The lip adhesion procedure also exerts an orthopedic force on the prolabium and premaxilla, inhibiting its forward growth. This orthopedic force retropositions the central premaxilla into an improved position in relation to the lateral lip segments.

The decision to perform a single-stage versus a two-stage lip repair is often related to the comfort and experience of the surgeon. The two-stage technique has the advantage of allowing better vascularity to the central prolabial segment and the capability to apply the techniques of the Millard rotation–advancement technique to each side of the bilateral repair. However, the two-stage repair tends to create asymmetry of the lip and does not allow muscle to be advanced across the central prolabial segment. The single-stage bilateral cleft lip repair, as described by Millard in 1977, is designed to produce an intact lip with scars mimicking the philtral columns.[21] The single-stage repair maximizes symmetry of the lip and is

designed to reorient the orbicularis oris muscle from each lateral lip segment across the central prolabial segment. Intact lip musculature improves lip aesthetics and decreases tension across the two vertical lip incisions.[22]

Palatoplasty

The goals of palatoplasty are normal speech development and prevention of nasal regurgitation through the oronasal fistula. To minimize the chance of postoperative VPD, recreation of the velopharyngeal muscular sling should be performed. Successful repair of palatal clefts requires (1) adequate flap mobilization to minimize wound tension, (2) atraumatic technique to minimize injury to flap vessels, (3) two-layer closure of the oral and nasal mucosa to minimize postoperative fistula formation, and (4) recreation of the soft palate muscular sling to maximize velopharyngeal function and speech (Table 65–6).

To maximize blood supply to the periphery of the palatal flaps, an atraumatic "no touch" technique should be used when elevating and advancing the palatal mucosal flaps. Monopolar cautery is avoided. The palatal flaps are not grasped with the tissue forceps. Although different palatal clefts require different flap design, the general surgical techniques are maintained irrespective of the type of palatal repair performed.

TABLE 65–6 Principles of Palatoplasty

Minimization of wound tension
Atraumatic technique
Two-layer closure of oral and nasal layers
Recreation of soft-palate muscular sling

von Langenbeck's Palatoplasty

In the early nineteenth century, elevation of bipedicled mucoperiosteal flaps to close clefts of the hard palate was independently reported by Dieffenbach,[23] Warren,[24,25] and von Langenbeck.[26] This method involves incisions along the cleft margin (medial) and adjacent to the alveolar ridge (lateral) (Fig. 65–22A, B). Undermining the bipedicled flaps in a subperiosteal plane allows flap release and advancement. The bipedicled flaps can be approximated in a "drawbridge" fashion to achieve closure of the hard-palate cleft.

The bipedicle flap palatoplasty (often called the von Langenbeck repair) employs several important principles of palatoplasty. The most important idea is the use of two-layered closure (oral and nasal layers). A two-layered closure decreases the incidence of postsurgical fistula when compared to the fistula rate of closure of only the oral layer. In a two-layered closure, if there is slight wound breakdown of either the oral or the nasal layer, a fistula usually does not result as the other intact layer often prevents fistula formation. The other important principle in the bipedicle flap technique is adequate flap mobilization to minimize tension across the wound.

Although the von Langenbeck palatoplasty technique works well in many palatal clefts, it has a major disadvantage in not allowing visualization of the vascular pedicle of the palatal flaps. The greater palatine vascular pedicle is located approximately 1 cm medial to the upper second molar tooth. Identification of this pedical allows greater flap mobilization and can decrease wound tension in wide palatal clefts. For this reason, most surgeons connect the medial and lateral cleft incisions, thereby converting the bipedicled flaps to posteriorly based unipedicled flaps. These three-flap (incomplete clefts) and two-flap (complete clefts) repairs allow increased visualization of the vascular pedicle, increased flap mobilization, and decreased wound tension.

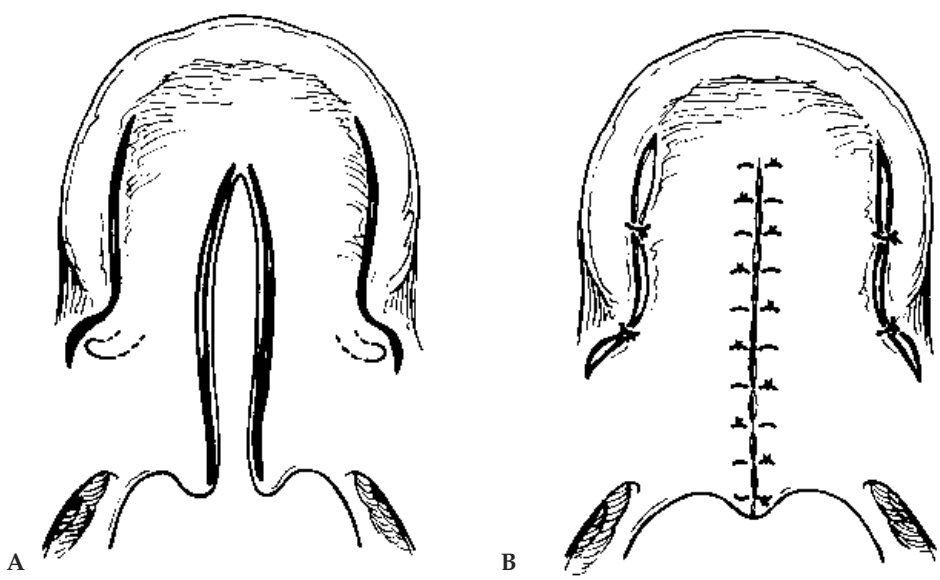


Figure 65–22 **(A)** Schematic diagram showing the incisions of the bipedicle von Langenbeck cleft lip repair. **(B)** Schematic diagram showing closure after the von Langenbeck palatoplasty procedure.

Three-Flap Palatoplasty

The three-flap palatoplasty is used to repair clefts of the secondary palate (the entire soft palate and the hard palate posterior to the incisive foramen).[27,28] The medial cleft incisions are the same as those used in the bipedicle flap technique (Fig. 65–23A). The lateral incisions are made adjacent to the tooth crowns and carried around the maxillary tuberosity. The medial cleft margin and lateral incisions are joined anteriorly by oblique incisions that connect at the level of the canine teeth laterally. These anterior oblique incisions convert the flaps to posteriorly based unipedicled flaps.

Both lateral and palatal flaps are elevated in a submucoperiosteal plane and contain the greater palatine vessels. The nasal mucosa is also elevated, and complete closure of the nasal layer is accomplished prior to oral mucosal closure. After mobilization of the posteriorly based mucoperiosteal flaps, dissection and release of the malaligned soft palatal musculature from the posterior edge of the hard palate is performed. This allows repositioning of the velopharyngeal muscular sling from an oblique to a more physiologic transverse orientation.[29]

Repair of the palate is performed in layers, beginning with reapproximation of the nasal layer. The muscular layer of the soft palate is then closed. Closure of the soft palatal musculature is the strength of the repair and decreases tension on the midline incision. The oral layer is then closed with alternating simple and vertical mattress sutures (Fig. 65–23B). At least one "tacking" suture is used to coapt the oral and nasal layers and to prevent dead-space and hematoma formation.

Two-Flap Palatoplasty

The two-flap technique is used to repair complete palatal clefts (of the entire primary and secondary palate). Modifications of the two-flap technique may be used for both unilateral and bilateral palatal clefts. In the complete unilateral cleft palate, the medial cleft margin incisions are carried anteriorly almost to the alveolar cleft (Fig. 65–24A). These medial incisions are joined to the two curved lateral incisions, creating two posteriorly based palatal flaps.

Subperiosteal flap elevation with an atraumatic technique is performed to expose and isolate the neurovascular pedicles (Fig. 65–24B). Dissection posterior to the pedicle aids in further mobilization of the palatal flaps. The edges of the palatal flaps can be medialized with forceps to determine if adequate flap mobilization has occurred. This "pinch" technique ensures a tension-free closure.

After flap elevation, the palate is again repaired in layers, beginning with the nasal layer (Fig. 65–24C). The soft-palate musculature is again closed with interrupted sutures, decreasing the tension across the palatal wound. Closure of the oral palatal mucosa followed by a coapting suture is then performed (Fig. 65–24D). In complete clefts, the entire cleft with exception of the anterior alveolar cleft is thus accomplished.

Furlow's Palatoplasty

The double-reversing Z-plasty, or Furlow's palatoplasty, was first described by Leonard Furlow in 1978.[30,31] This technique is usually used to repair a submucous cleft or a cleft of the soft palate only. The technique involves the creation *and closure* of opposing Z-plasties of the oral and nasal mucosa. The repair is designed to lengthen the palate and recreate the muscular sling of the soft palate.

The central limbs of the double-reversing Z-plasty technique are made at the margin of the soft-palate cleft (Fig. 65–25A). If this technique is performed on a submucous cleft of the soft palate, a full-thickness incision is made through the palate in the midline to create a soft palate cleft.

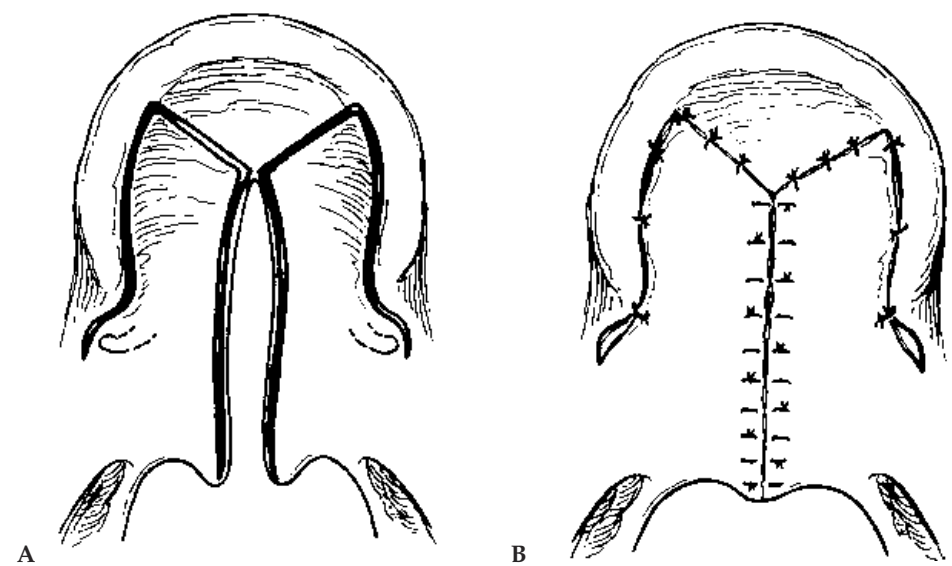


Figure 65–23 **(A)** Schematic diagram of the incisions for the three-flap palatoplasty. **(B)** Schematic diagram after closure of the nasal and oral layer of the three-flap palatoplasty for repair of the complete secondary cleft palate deformity.

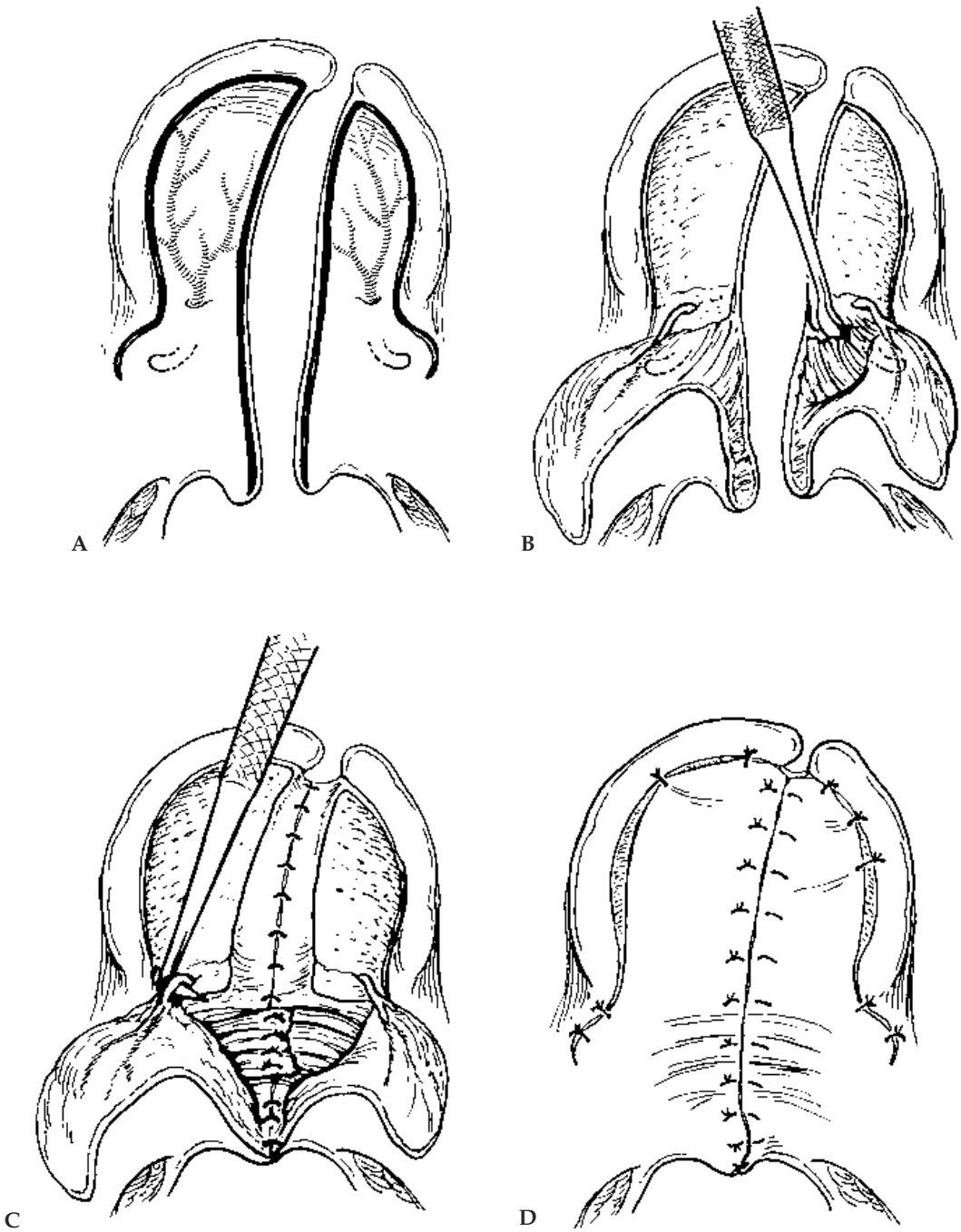


Figure 65–24 **(A)** Schematic diagram of the incisions for a two-flap palatoplasty for repair of the complete unilateral cleft palate deformity. **(B)** Elevation of the flaps in a subperiosteal plane dissecting out the greater palatine arteries bilaterally. **(C)** Dissection posterior to the greater palatine artery in the space of Ernst. Note that the nasal mucosa and soft-palate musculature have been closed and the oral flaps await closure. **(D)** Repair of the oral musculature in a complete unilateral cleft lip deformity.

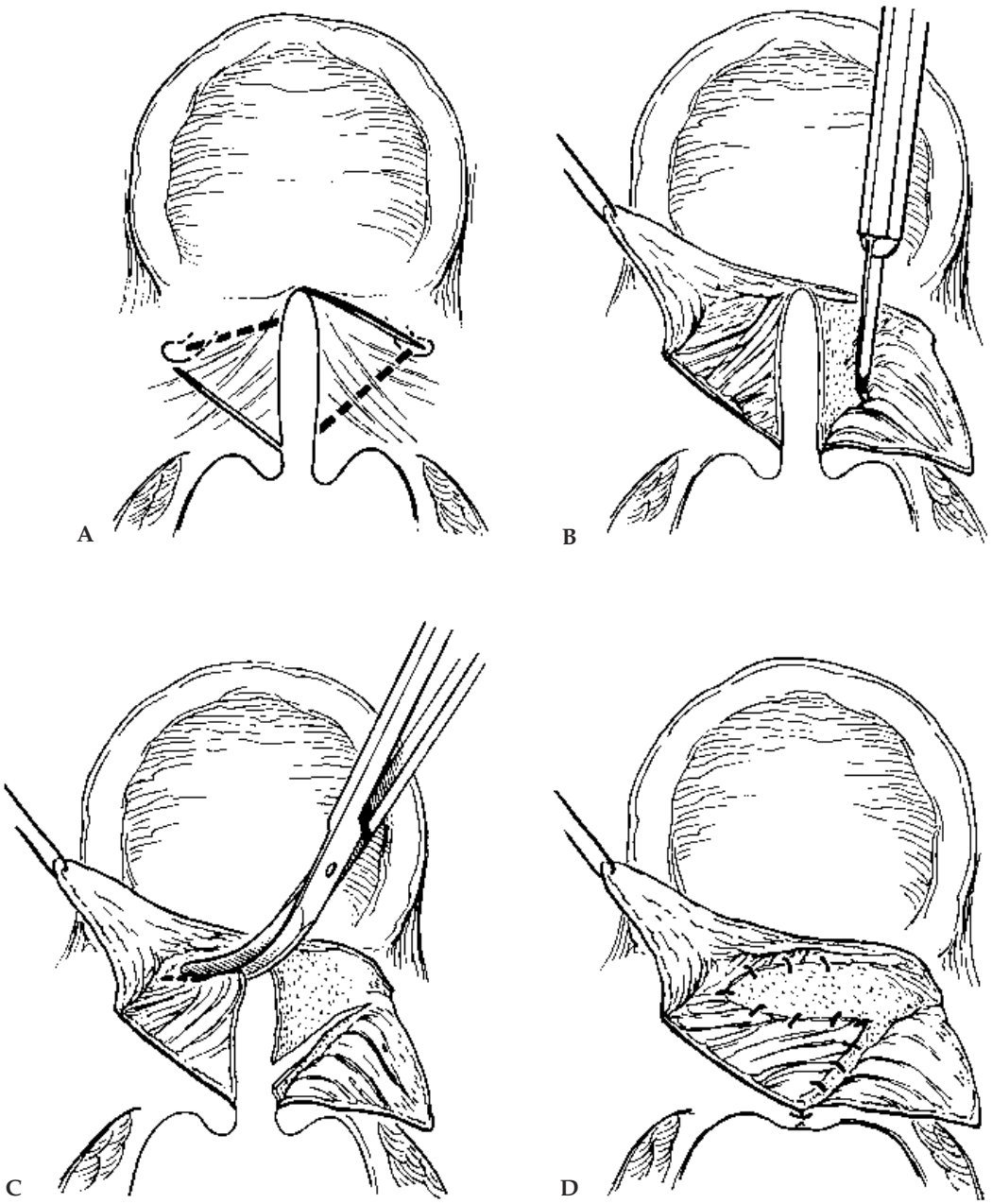


Figure 65–25 **(A)** Schematic diagrams of the double-reversing Z-plasty (Furlow's palatoplasty). Note that the dotted lines indicate the nasal incisions and the straight lines indicate the oral incisions. **(B)** Elevation of the oral flaps bilaterally. Note that the patient's left flap is elevated below the musculature, so that the oral flap contains both oral mucosa and palatal musculature. The right flap contains only oral mucosa. **(C)** Incision of the flaps with curved scissors on the nasal side. **(D)** Closure of the nasal mucosal and palatal musculature.

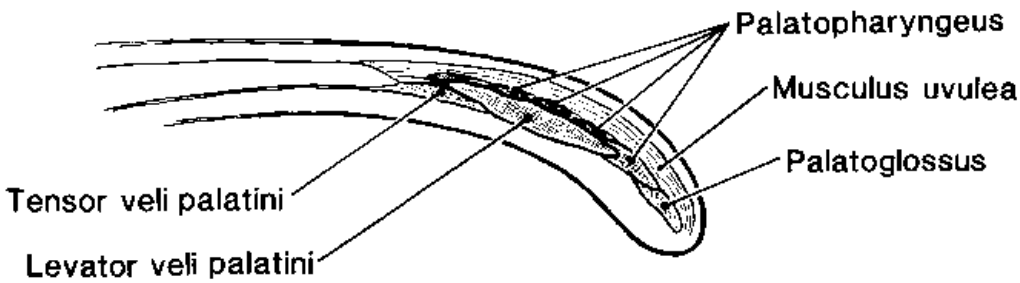


Figure 65–26 Sagittal view of the soft palate showing that the palatal musculature is closer to the nasal mucosa than it is to the oral mucosa.

On one side, an incision is made extending from the cleft margin obliquely toward the hamulus laterally. Dissection is carried on this side deep to the soft palatal musculature. This posteriorly based oral mucosal flap contains both oral mucosa and soft-palate musculature (Fig. 65–25B). On the opposite side, an incision is made in the oral mucosa from the uvula to the ipsilateral hamulus. This triangular oral mucosal flap does not contain soft palatal musculature.

On the nasal side, mirror-image incisions (to the oral mucosal incisions) are then made to create two triangular-shaped nasal flaps (Fig. 65–25C, D). The anatomy of the soft-palate musculature is important in dissection, elevation, and transposition of the oral and nasal flaps. In that the levator veli palatini muscles are located immediately adjacent to the nasal (not the oral) mucosa, elevation of these muscles from the nasal mucosa is often difficult (Fig. 65–26). It is important that the muscular sling of the soft palate be reoriented to a horizontal direction during closure of the Z-plasty flaps. For this reason, the soft-palate musculature must be based posteriorly within the flaps. Right-handed surgeons can more easily perform the difficult dissection of the soft-palate musculature from the nasal mucosa on the patient's left or contralateral side; left-handed surgeons should design the incisions in the mirror image.

After dissection of both oral and nasal flaps, transposition of all four flaps is accomplished. The nasal flaps are first transposed and reapproximated. The soft-palate muscular sling is then reoriented and closed with 4-0 braided absorbable suture. The oral flaps are then reapproximated (Fig. 65–27). Postoperative fistula is usually prevented in that the oral and nasal suture lines do not overlie one another. This technique both lengthens the palate and recreates the velopharyngeal muscular sling.

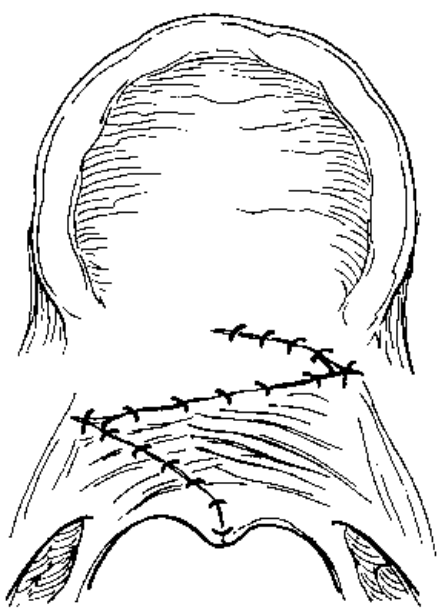


Figure 65–27 Double-reversing Z-plasty palatoplasty after closure of the oral mucosa.

Preferred Techniques of Palatoplasty

A summary of preferred surgical techniques for repair of cleft palate is listed in Table 65–7. They include two-flap palatoplasty for complete unilateral and bilateral clefts, three-flap palatoplasty for incomplete clefts, and double-reversing Z-plasty (Furlow's technique) for submucous clefts and cleft of the soft palate only.

TABLE 65–7 Preferred Palatoplasty Techniques

Cleft type	Technique
Complete unilateral	Two-flap
Complete bilateral	Two-flap (with vomerian flaps)
Complete secondary palate	Three-flap
Soft palate	Double-reversing Z-plasty
Submucous	Double-reversing Z-plasty

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Chapter 66

Cleft Lip Rhinoplasty

John R. Coleman, Jr. and Jonathan M. Sykes

Reconstruction of the cleft lip nasal deformity remains an ongoing challenge for the facial plastic surgeon. The deformity is a complex, three-dimensional alteration in nasal anatomy with defects in all tissue layers: skin, cartilage, vestibular lining, and bone. The extent of the deformity varies with the degree of lip abnormality; it may be unilateral or bilateral and subtle or complete.[1] The sheer number of publications and techniques reported in the twentieth century speaks to the difficulty of this reconstructive dilemma.[2]

The goal of this chapter is to provide the reader with an understanding of the pathophysiology of the cleft lip nasal deformity, to discuss the timing of the various repairs needed, and to highlight a selection of techniques currently used to repair the deformity.

PATHOPHYSIOLOGY OF THE CLEFT LIP NASAL DEFORMITY

Theory

The exact cause of the cleft lip nasal deformity remains unknown. The two most common theories relate to intrinsic deficiencies and external pressures. Likely, the true answer is a combination of the two.

Veau proposed that the cleft lip nasal deformity is the result of agenesis of tissue within the lip and maxilla due to mesenchymal deficiency.[3] This leads to hypoplasia of the maxilla and lack of bone at the piriform margin and alar base and causes posterolateral displacement of the piriform margin and alar base. The abnormal position of the alar base is central to the overall formation of the defect. Other authors have contended that decreased growth or hypoplasia of the lower lateral cartilage contributes to the deformity.[4,5] These findings have been challenged by Park et al who made direct measurements of the completely dissected lower lateral cartilages at the time of rhinoplasty in 35 patients (ages 6 to 40).[6] They found no difference between the cleft lower lateral cartilage and the noncleft cartilage when comparing thickness at the intercrural, middle, and distal portion of the cartilage, width at the widest point, and overall length from the intercrural point to the distal end.

Extrinsic force theory holds that abnormal insertion of ligaments and muscles leads to tensions on the cartilage and soft tissue. Latham has postulated that the septopremaxillary ligament plays a critical role in causing the unilateral cleft lip nasal defect.[7,8] This ligament binds the anterior septum to the premaxilla. Because the premaxilla is dissociated from the lateral maxilla by the cleft condition, these two growth centers are abnormally affected. The septopremaxillary ligament on the noncleft side provides unopposed tension on the caudal septum and columella, causing deviation from the cleft. Furthermore, the disassociation of the growth centers leaves the lateral maxilla more posterior, thus creasing added tension on the lower lateral cartilage. Additional extrinsic force is applied by the discontinuity and abnormal insertion of the orbicularis oris muscle.[9,10] On the noncleft side in the unilateral cleft deformity, the muscle inserts into the columella, providing further distraction of the columella and anterior septum away from the cleft; on the cleft side, the orbicularis oris inserts into the alar base, causing additional lateral pull on the alar base. Three-dimensional computerized tomography (CT) scans of twelve 3-month-old children with unilateral cleft lip confirmed four consistent and statistically significant findings related to the asymmetry of the nasal base. All of the findings can be explained by the extrinsic force theory as detailed previously: the columella is deviated to the noncleft side, the cleft alar base is more posterior than the noncleft, the noncleft alar base is further from the midline than the cleft, and the cleft piriform margin is more posterior than the noncleft. Finally, Fisher and Mann were able to recreate the cleft lip nasal deformity in three-dimensions with *origami* paper models.[11] Their models highlight the role that external tension places on the lower lateral cartilage and alar rim due to changes in the position of the piriform margin/alar base and columella in the development of the deformity.

These same theories can be applied to the bilateral cleft nasal deformity. Intrinsic deficiency theory allows for the absence of lip and maxilla to cause posterolateral displacement of the alar base with resultant widening of the nose but with little impact on columellar symmetry. On the other hand, extrinsic force theory shows that insertion of the septopremaxillary ligament is symmetrical, thereby causing no alteration in the anterior septum/columella unit. Insertion of the orbicularis oris musculature into the alar base bilaterally contributes to the widening of the nose and flattening of the lower lateral cartilages.

Characteristics of the Cleft Nasal Deformity

Although the pathophysiologic process that causes the cleft lip nasal deformity is not completely understood, the characteristics of the deformity have been well elucidated. The deformity begins with the deficiency of tissue in the nasal base related to the maxillary hypoplasia and continues with findings related to the external pressures applied after surgical repair and during development. The following discussion will examine unilateral and bilateral defects and will subdivide the nose into thirds to illustrate both the deformity and its repair.

Unilateral: Lower One Third

The lower one third (Table 66–1) is the central portion of the cleft lip nasal deformity. Alterations from the noncleft nose are observed in the tip, the septum, and the external nasal valve. The nasal tip refers to the subunit composed by the alar bases, the columella, and the lower lateral cartilages. The position of both the columella and the alar base places distortional pressure on the lower lateral cartilage and influences the overall development of the deformity (Fig. 66–1).

TABLE 66–1 Characteristics of the Unilateral Cleft Lip Nose

Lower one third
Nasal Tip
Deflects toward the noncleft side.
Columella deviates to the noncleft side.
Lateral steel of the lower lateral cartilage on the cleft side produces a long lateral crus and a short medial crus. This also causes blunting of the dome with a more obtuse angle.
Cleft side alar base is positioned posteriorly, laterally, and inferiorly.
Nasal floor and sill are often absent on the cleft side.
Cleft nostril is horizontally oriented and widened.
Septum
Caudal septum deflects toward the noncleft side.
Cartilaginous and bony septum deviates toward the cleft side.
External nasal value
Compromised by introversion of the lower lateral cartilage and webbing of the nasal vestibule.
Middle one third
Upper lateral cartilages
Weakened support leads to bowing or collapse with deep inspiration on the cleft side.
Abnormal relationship between the cleft upper and lower lateral cartilage.
Internal nasal valve
Frequently compromised by weakened support of the upper lateral cartilage and the deviation of the septum.
Upper one third
Wide basal dorsum.
Skeletal base
Bony deficiency on the cleft side.

The columellar complex, which is created by the medial crura and feet of the lower lateral cartilage, the caudal septum, and soft tissue, is typically deviated toward the noncleft side (Fig. 66–2). Although the total length of the lower lateral cartilage is the same on the cleft and noncleft sides, the medial crus on the cleft side is foreshortened, giving additional length to the lateral crus and creating a more obtuse angle to the dome. Furthermore, the additional length leads to flattening of the dome and widening of the cleft nostril and nasal floor. The alar base is positioned posteriorly, inferiorly, and laterally in relation to the noncleft side. This changes the three-dimensional configuration of the entire tip.

The nasal septum is deflected caudally into the noncleft nasal airway due to the unopposed pull of the orbicularis oris muscle and the septopremaxillary ligament (Fig. 66–3). Further posteriorly, the lack of these attachments to the middle and posterior cartilaginous septum leads to bowing of the septum into the cleft side airway.[3] Moreover, Crockett and Bumsted found in a study of 140 cleft septums that the bony septum was deviated into the cleft airway in 80% of cases.[12] Therefore, in the unilateral cleft condition the nasal airway is compromised on both the cleft and noncleft sides.

The external nasal valve is created by the relationship of the columella, lower lateral cartilage, nasal ala, and nasal sill. In the unilateral cleft deformity the external nasal value is compromised by two related factors: introversion of the nasal ala and webbing of the nasal vestibule. Introversion of the cleft nasal ala is the result of posterior inferior rotation of the lower lateral cartilage due to the distortional pressures on the cartilage from the position of the columella and alar base.[13] The introversion leads to hooding and thickening of the ala; it also contributes, along with surgical scarring, to webbing of the nasal vestibule. An oblique fold is formed by posterolateral displacement of the piriform margin and introversion of the lower lateral cartilage. This bulk influences airflow and alters the relationship of the upper and lower lateral cartilages.

Unilateral: Middle One Third

The middle one third of the nasal deformity can be characterized by interrelated changes to the upper lateral cartilages and to the internal nasal valve. On the cleft side, there is limited attachment of the upper and lower cartilage and a side-to-side relationship rather than the more typical overlap seen on the noncleft side.[12] Both of these factors lead to decreased support of the upper lateral cartilage and collapse of the upper lateral cartilage with deep inspiration. The internal nasal valve is formed by the relationship of the upper lateral cartilage, the nasal septum, and the inferior turbinate. In the cleft lip nasal deformity, the septum is bowed into the cleft side at the internal nasal value, and the upper lateral cartilage support is weak, causing the cartilage to bow or collapse with respiration. Therefore, the internal nasal valve can significantly limit the nasal airway on the cleft side.

Unilateral: Upper One Third

Although there is no classic deformity to this portion of the nose in the cleft lip nasal deformity, the osseous pyramid is typically reduced in width at the time of definitive rhinoplasty to enhance the overall appearance of the nose.

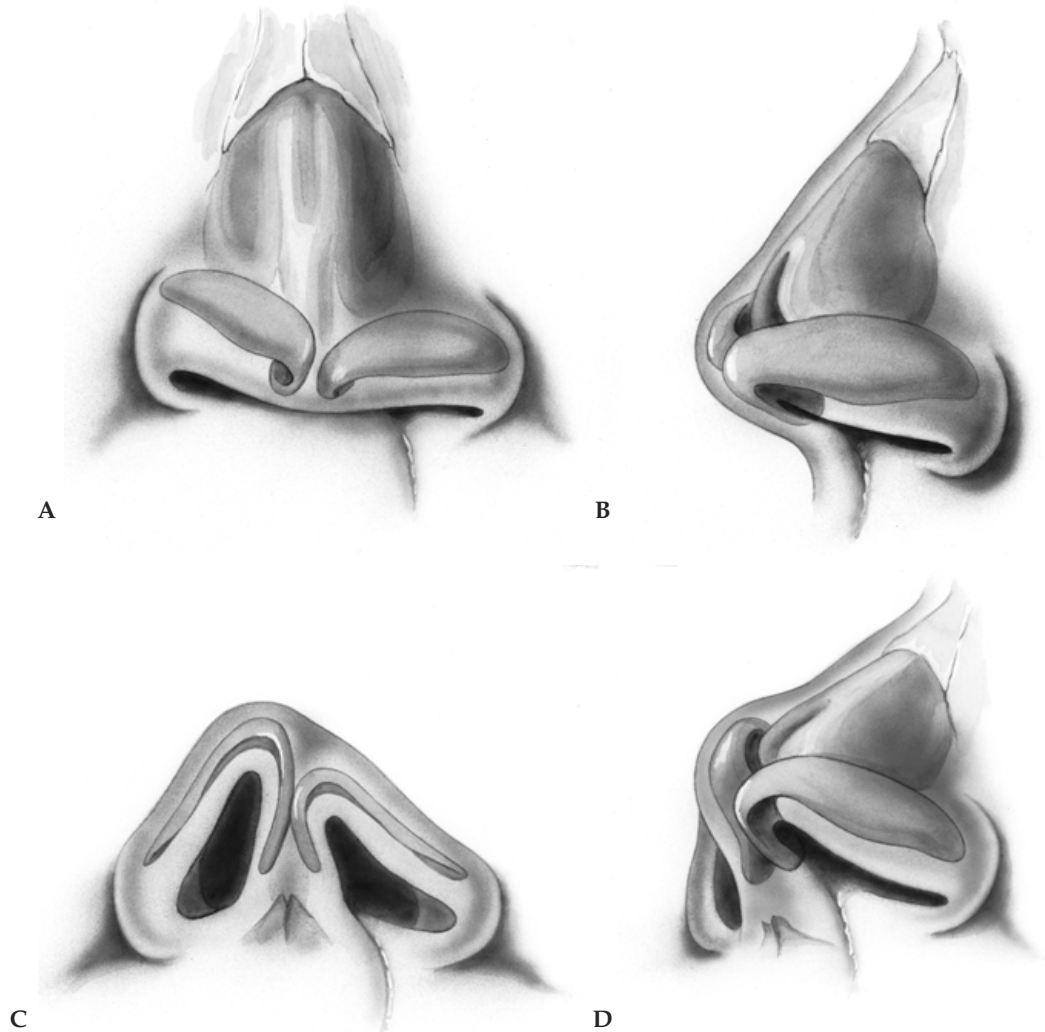

Figure 66–1 Multiple views (anteroposterior, lateral, basal, and oblique) of the secondary unilateral cleft lip nasal deformity. Note the characteristic inferior, posterior, and lateral displacement of the alar base. (From Sykes JM, Senders CW, Wang TD, Cook TA. Use of the open approach for repair of secondary cleft lip nasal deformity. *Fac Plast Surg North Am* 1993;1:111–126. With permission.)

Figure 66–2 Basal view of the primary unilateral cleft lip deformity demonstrating deviation of the columella toward the noncleft side, widening of the nasal floor, displacement of the alar base, and flattening of the lower lateral cartilage.

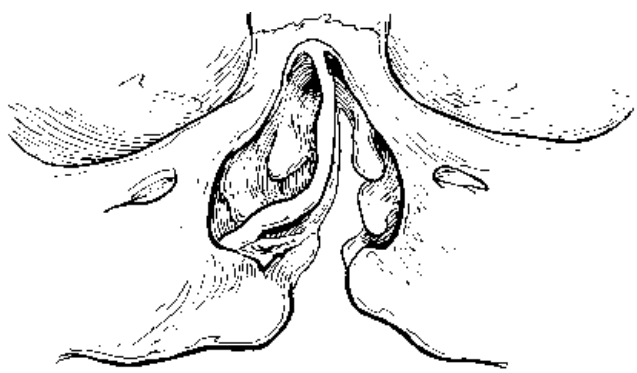

Figure 66–3 Coronal section through the caudal septum showing deviation of the caudal septum to the noncleft side and more posterior bowing of the septum into the cleft side nasal airway. (From Jablon JH, Sykes JM. Nasal airway problems in the cleft lip population. *Fac Plast Surg Clin North Am* 1999; 7:391–403. With permission.)

TABLE 66–2 Characteristics of the Bilateral Cleft Nasal Deformity

Lower one third
Nasal tip
Deviates toward less involved side if discrepancy exists.
Columella is short and deviates toward less involved side if discrepancy exists.
Lateral steel of lower lateral cartilage on the cleft side produces a long lateral crus and a short medial crus. This also causes blunting of the dome with a more obtuse angle.
Medial crura are splayed, producing a poorly defined, bifid tip.
Alar bases are displaced posteriorly, laterally, and inferiorly.
Nostrils are wide and horizontally oriented.
Septum
Deviated to less involved side if a discrepancy exists.
External nasal valve
Compromised by introversion of the lower lateral cartilage and webbing of the nasal vestibule.
Middle one third
Upper lateral cartilages
Weakened support leads to bowing or collapse with deep inspiration.
Abnormal relationship with the lower lateral cartilage.
Internal nasal valve
Compromised by weakened support of the upper lateral cartilage.
Upper one third
Wide nasal dorsum.
Skeletal base
Bony deficiency on both sides.

Bilateral: Lower One Third

Similar to the unilateral deformity, the primary characteristics of the bilateral deformity (Table 66–2) revolve around the lower one third of the nose (Fig. 66–4). The nasal tip is typically in the midline in the bilateral complete deformity. If one side of the lip is more involved than the other, the short columella is typically deviated toward the less involved side, pulling the tip in that direction (Fig. 66–5). The lower lateral cartilages demonstrate short medial crura and long lateral crura. The domes of the lower lateral crura are splayed, contributing to a poorly defined, frequently bifid tip (Fig. 66–6). The angle at the dome is obtuse. The alar bases are posterior, lateral, and inferior, giving rise to flaring of the base and widening of the nostril. The tension on the lower lateral cartilage leads to introversion and webbing of the vestibular floor. The septum is in the midline in the complete bilateral deformity and deviated caudally toward the less involved side if an asymmetry exists.

Bilateral: Middle One Third

The middle one third is analogous to the unilateral deformity, with poor support to the upper lateral cartilage leading to bowing and possible collapse of the upper lateral cartilage with deep inspiration. However, because the septum is typically in the midline, the compromise of the internal nasal valve is often not as significant.

Bilateral: Upper One Third

The upper one third is typically not involved in the bilateral nasal deformity.

TIMING OF THE REPAIR IN CLEFT LIP NASAL DEFORMITY (TABLE 66–3)

In Utero

The potential advantages of in utero repair of the cleft lip nasal deformity are analogous to those described for lip and palate repair and include scarless healing, use of postrepair fetal growth to create symmetrical results, elimination of social stigmata, and reduction in the number of surgeries required to obtain the desired results.[14–18] To date, experimentation has been limited to animal models, and recently, an article focused on the alteration of nasal anatomy with in utero surgery.[19] The authors placed a hypertonic sponge in the nostril of a fetal lamb, allowing it to function as a tissue expander. They measured increases in septal length, nostril area, and intranasal volume with no evidence of histologic scarring at varying time intervals. They believe that they can not only induce scarless in utero change but actually control that change. Their long-term proposal is to use specifically designed tissue expanders to impact the characteristic anatomic abnormalities found in the cleft nasal deformity. As techniques improve with in utero surgery, repositioning of the alar base followed by controlled nasal expansion may become the principal treatment of this deformity.

Primary

With in utero repair still on the distant horizon, we must continue to rely on techniques that have surfaced in this century. One of the most important movements was the acceptance and use of primary rhinoplasty. Experimental work by Sarnat, Bernstein, and others had demonstrated growth retardation of the nose and midface following aggressive resection of the nasal septum and mucoperichondrium.[20,21] The concern was that alterations of nasal growth centers with cleft rhinoplasty would cause growth retardation of the nose and midface. McComb and Coghlan demonstrated in an 18-year longitudinal study that nasal and midface growth was not significantly different in children who underwent primary cleft rhinoplasty versus age-matched normal and age-matched cleft controls who did not have primary rhinoplasty.[22] Moreover, the symmetry obtained with primary rhinoplasty was maintained into adult life.

Primary rhinoplasty is defined as alteration in the nose at the time of lip repair. As lip repair is often staged, with the first operation dedicated to lip adhesion followed by the complete repair at least 3 months later, so nasal reconstruction can also be staged. The purpose of the surgery is to close the anterior nasal floor; to relocate the posteriorly, inferiorly, and laterally displaced alar base; and to bring early symmetry to the nasal base and tip. The advantage with a staged repair relates to smaller movements with each procedure and added opportunities to achieve a symmetrical result.[23]

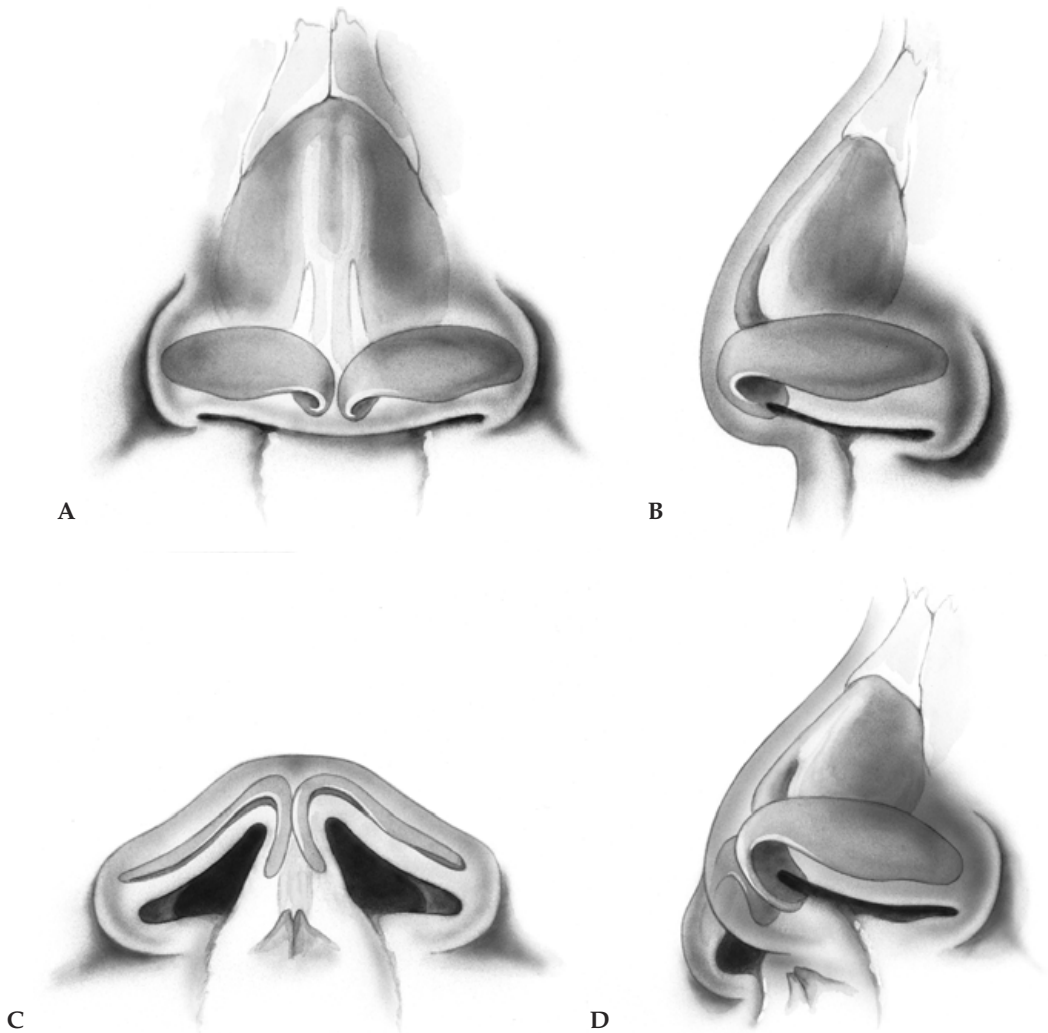

Figure 66–4 Multiple views (anteroposterior, lateral, basal, and oblique) of the secondary bilateral cleft lip nasal deformity. Note the short columella and relatively symmetrical base. (From Sykes JM, Senders CW, Wang TD, Cook TA. Use of the open approach for repair of secondary cleft lip nasal deformity. *Fac Plast Surg North Am* 1993;1:111–126. With permission.)

Figure 66–5 Basal view of the asymmetrical bilateral cleft deformity demonstrating deviation of the columella toward the less complete side of the cleft deformity.

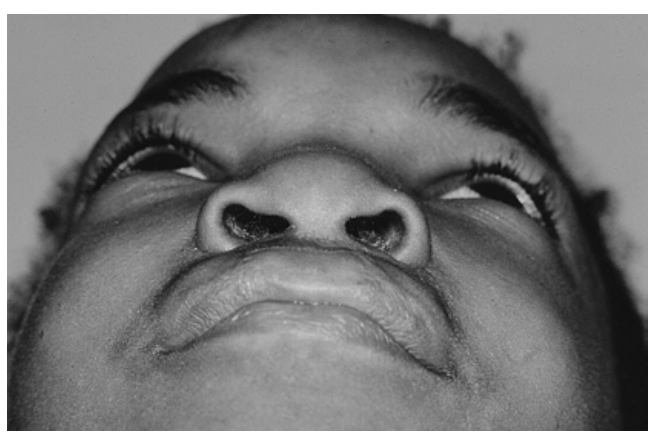

Figure 66–6 Basal view of a secondary bilateral cleft lip nasal deformity demonstrating the wide, bifid tip and short columella.

TABLE 66–3 Timing and Goals of Cleft Lip Rhinoplasty

Type of rhinoplasty	Timing of the procedure	Goals of the procedure
Primary	At the time of lip repair. Typically between 3 and 6 mo of age.	Close the nasal floor, actively reposition the alar base, and reorient the lower lateral cartilage while minimizing scarring, which will affect future procedures. Some surgeons will also attempt to realign the septum or increase columella length.
Intermediate	From the time of lip repair until the definitive rhinoplasty is performed. Typically 1 y to 14 y of age.	Stabilize and support the nasal base, lengthen the columella, reposition the septum if obstruction is severe, and continue to improve the nasal tip symmetry. Procedures are typically shorter and designed to provide enhancements that can be used in definitive rhinoplasty.
Definitive	After the completion of nasal and midface growth. Typically age 14 in women and 16 in men.	Restore symmetry and definition to nasal tip and base, realign and open the nasal airway, and prevent scarring and webbing from adversely affecting results.

Intermediate

Intermediate rhinoplasty refers to procedures performed from the time of the completion of lip repair up to the time of definitive rhinoplasty. These procedures are often grouped with the definitive repair and referred to as secondary rhinoplasty. Typically, the intermediate procedures are less involved and are meant to correct inadequacies that will allow symmetrical nasal growth and a more successful definitive procedure. More extensive procedures can be performed if the severity of the deformity warrants more aggressive intervention to prevent further mental or physical disability.

Definitive

Definitive rhinoplasty occurs after completion of nasal growth around age 14 years in women and 16 years in men. At this time, complete and aggressive restructuring of the internal and external nasal anatomy can be performed. The purpose of the surgery is to create symmetry and definition of the nasal base and tip, to relieve nasal obstruction, and to manage nasal scarring and webbing. The difficulty of the repair lies in the complex interaction of the original three-dimensional pathophysiologic process and the previous surgeries.

TECHNIQUES FOR THE REPAIR OF CLEFT LIP NASAL DEFORMITY

Nasal Base

The first step in the repair of the nasal deformity, whether unilateral or bilateral, is to establish a solid nasal base on which to build the remainder of the reconstruction. The first step in the creation of the base occurs with primary rhinoplasty. Closure of the nasal floor with the lip represents the beginning of the base. The next step is to correct the bone deficiency of the maxilla and premaxilla and restore the abnormal posteroanterior position of the alar base.[3] Although the timing of alveolar bone grafting is controversial, it is most commonly performed between the ages of 7 and 11 years, when one fourth to three fourths of the adult canine root is formed, and should be considered an intermediate rhinoplasty procedure.[24] Furthermore, augmentation of the nasal sill and base may be required at the time of the definitive rhinoplasty and can usually be accomplished with local tissue flaps.[25]

Unilateral Cleft Lip Nasal Deformity

Primary Rhinoplasty

Primary rhinoplasty at the time of cleft lip repair is the most significant positive change in the management of the unilateral cleft lip nasal deformity in the latter part of the twentieth century. The objectives of this surgery are to close the nasal floor, to actively reposition the alar base, and to change the configuration of the lower lateral cartilage.[13] The surgeon further seeks to minimize adverse scarring, which may affect future growth and the outcome of subsequent procedures.

The primary rhinoplasty is performed through the same incision used with the Millard advancement–rotation lip repair. Lateral dissection requires a complete alotomy with release of all attachments to the piriform aperture.[26] A lateral tunnel is then created with scissors dissection over the lateral crus up to the nasal dome (Fig. 66–7). A medial tunnel is also created from the original lip incisions with dissection superficial to the medial crus of the lower lateral cartilage. The subcutaneous tunnels free the lower lateral cartilage from the nasal skin–soft tissue envelope completely; the vestibular attachments are left undissected.[27] With these releases the objectives can now be accomplished. The floor of the nose is closed with the lip repair. If columella lengthening is needed on the cleft side, a back-cut onto the columella and rotation of the C flap into this area can be used.[23] The closure of the floor begins the placement of the alar base; to place it exactly in a symmetrical position with the contralateral ala, excision of skin inferiorly and laterally to the alar base is often required.[13] After the lip is closed and the alar base positioned, the lower lateral cartilage is molded to its new configuration. This can be accomplished with interdomal sutures[23,28] or the application of nasal bolster(s) (Fig. 66–8).[13,27] The purpose of the interdomal suture or

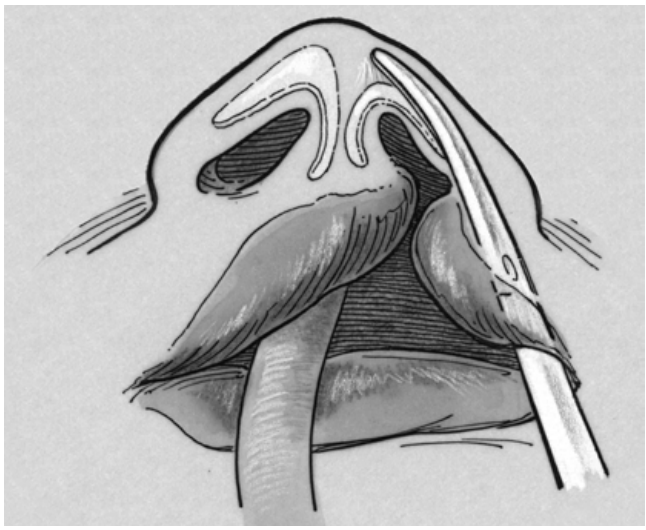

Figure 66–7 Basal schematic demonstrating the lateral dissection to release the attachments of the lower lateral cartilage. (From Sykes JM, Senders CW. Surgery of the cleft lip nasal deformity. *Oper Tech Otolaryngol Head Neck Surg* 1990;1:219–224. With permission.)

bolster is to recreate the dome of the lower lateral cartilage in a more lateral location. This is accomplished by stealing cartilage from lateral to medial to increase tip projection and enhance tip symmetry. The complete release of the nasal skin from the lower lateral cartilage prevents tethering of the tissue and an incomplete reorientation. If the bolster technique is used, the suture is paced through the cartilage into the subcutaneous tunnel to come out of the nasal skin on the noncleft side of the midline and tied with the necessary tension to cause a slight blanching of the external nasal skin (Fig. 66–9). The bolster(s) can be removed at 1 week postoperatively.

In cases where significant caudal septal irregularity exists, the septum can be repositioned onto the nasal spine at the time of primary rhinoplasty.[28] This has the added positive effect of increasing tip projection and enhancing base

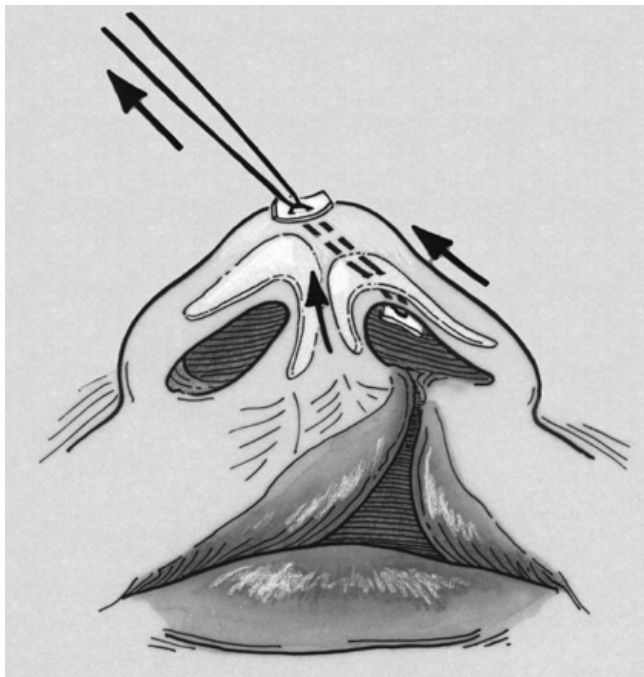

Figure 66–8 Basal schematic demonstrating the application of bolsters to reposition the cleft lower lateral cartilage. The vectors of force of the repositioning are displayed. (From Sykes JM, Senders CW. Surgery of the cleft lip nasal deformity. *Oper Tech Otolaryngol Head Neck Surg* 1990;1:219–224. With permission.)

symmetry. No significant removal of the septum and mucoperichondrium should be performed at this stage.

Intermediate Rhinoplasty

The use of intermediate rhinoplasty has decreased as surgeons have become more adept at primary rhinoplasty. Typically, in the unilateral cleft lip nasal deformity intermediate rhinoplasty serves to decrease the deformity and enhance the

Figure 66–9 Intraoperative photographs of primary cleft lip rhinoplasty at the time of lip repair. **(A)** Preoperative deformity. **(B)** Completed surgery. Note that the suture securing the bolsters is tightened until a slight blanch is seen.

result of definitive rhinoplasty. Aggressive surgery is rarely performed at this time due to the negative factors associated with scarring and growth retardation.

There are three situations that warrant the use of intermediate procedures for treatment of a unilateral deformity.[29] The first is severe nasal obstruction caused by caudal septal deviation. To correct this problem, the septum is repositioned over the nasal spine with very limited resection of tissue. The second situation involves a child with a deformity not addressed at the time of primary rhinoplasty. Limited tip rhinoplasty and alar repositioning as described for the primary rhinoplasty can be performed to enhance nasal symmetry. The third situation involves a child who is suffering severe emotional distress as a result of being ridiculed about the nasal deformity. For such a patient a more complex and complete procedure may be warranted. If grafting material is needed for this stage of the repair, strong consideration should be given to using banked, irradiated cartilage as a way of limiting the long-term effect on nasal growth.

Definitive Rhinoplasty

Definitive cleft lip rhinoplasty is performed after the nose and midface have reached full size. Both the original nasal deformity and previous attempts at correction contribute to the secondary deformity and to the difficulties encountered with the procedure.

The approach to rhinoplasty varies according to the requirements of the reconstruction. We use an open or external approach with or without an alotomy on the cleft side. The incision for the open approach has numerous configurations that reflect specific aspects of the reconstruction. The traditional inverted V incision can be modified to increase columella soft tissue with a V-Y closure,[30] or the incision can be made asymmetrically onto the nasal skin on the cleft side to recruit this skin inward to augment a superiomedial alar web (Fig. 66–10).[31] Finally, an evolution of techniques has been described related to the recruitment of tissue from the lip repair with a sliding chondrocutaneous flap.[2,32] This flap provides additional tissue to augment the vestibular lining and reduce the alar-columellar web, and when it is combined with the open rhinoplasty the chondrocutaneous flap can permit tip stability and refinement.

The lower one third of the nose is addressed in open-structure rhinoplasty by the complete evaluation of the lower lateral cartilage and the use of grafts to improve stability, enhance definition, and prevent wound contracture.[33] The first maneuver in the correction of the lower one third of the nose is septoplasty to relieve nasal obstruction and obtain grafting material. The septum can be accessed through a separate hemitransfixion incision or directly through the open approach. Adequate caudal and dorsal struts should be preserved while deviations in the cartilage and bone are corrected. To return the caudal septum to the midline, the surgeon often must remove a strip of cartilage inferiorly, allowing the septum to "swing" over the nasal spine (Fig. 66–11). This position can be maintained by suturing the cartilage to the spine.

The next step is to address the symmetry of the lower cartilages and to perform cephalic strip removal as necessary to correct asymmetries and reduce excessively large cartilages. A cartilaginous, columellar strut graft should then be placed between the medial crura of the lower cartilages. The lower laterals are sutured to the strut; advancement of the lower laterals onto the strut will enhance nasal projection (Fig. 66–12). Typically, the cleft side will have to be advanced more than the noncleft side to improve the flattening of the cleft lower lateral cartilage and enhance overall tip symmetry. The lower lateral cartilages are then divided and reconstituted. Division of the cartilages lateral to the dome increases the medial crural element and increases projection (Fig. 66–13). Once again, by vertically dividing the

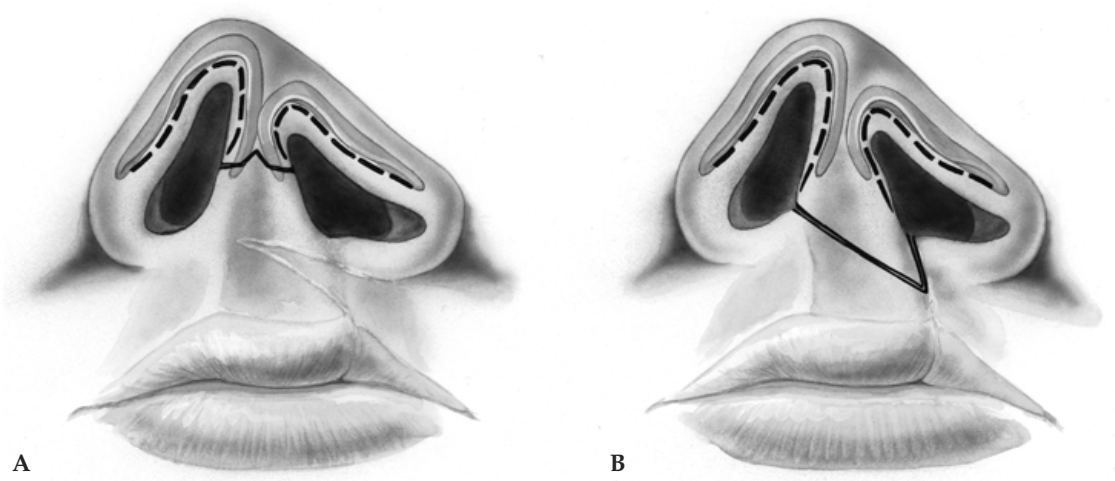

Figure 66–10 **(A)** Basal view of the secondary cleft lip deformity demonstrating modification of the standard external rhinoplasty incision. **(B)** Basal view demonstrating a modified Bardach incision. Closure of the incision in a V-Y fashion will recruit additional skin and soft tissue from the lip to the collumella. (From Sykes JM, Senders CW, Wang TD, Cook TA. Use of the open approach for repair of secondary cleft lip nasal deformity. *Fac Plast Surg North Am* 1993;1:111–126. With permission.)

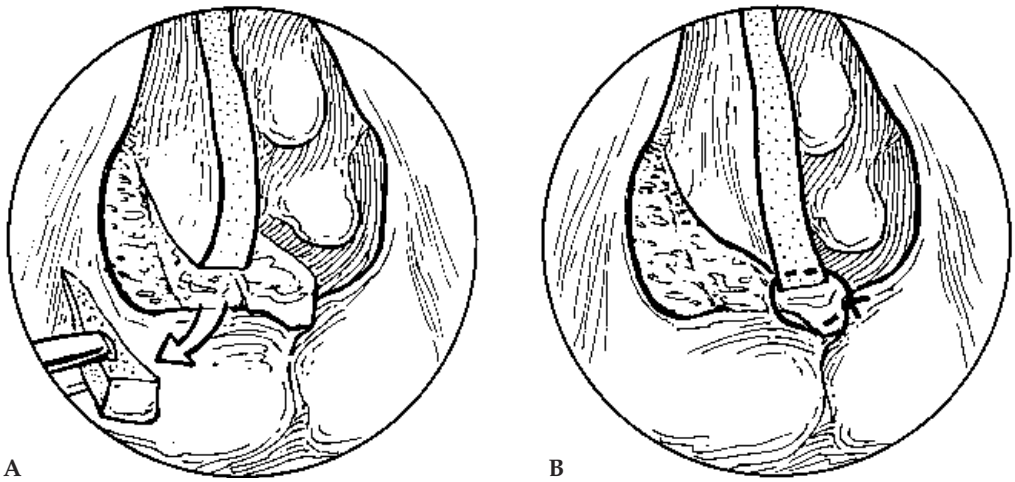

Figure 66–11 Coronal drawings demonstrating **(A)** the release of the septum to allow it to "swing" over the maxillary crest and **(B)** suture fixation of the septum to the maxillary crest. (From Jablon JH, Sykes JM. Nasal airway problems in the cleft lip population. *Fac Plast Surg Clin North Am* 1999;7:391–403. With permission.)

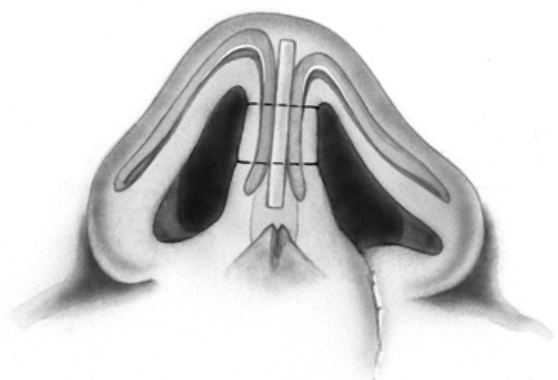

Figure 66–12 Basal view depicting the placement of the cartilaginous columellar strut and asymmetrical advancement of the lower lateral cartilages onto the strut. (From Sykes JM, Senders CW, Wang TD, Cook TA. Use of the open approach for repair of secondary cleft lip nasal deformity. *Fac Plast Surg North Am* 1993;1:111–126. With permission.)

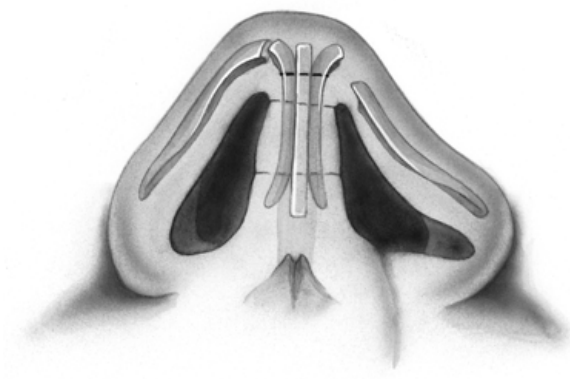

Figure 66–13 Basal view demonstrating asymmetrical division of the lower lateral cartilages to increase projection and symmetry. (From Sykes JM, Senders CW, Wang TD, Cook TA. Use of the open approach for repair of secondary cleft lip nasal deformity. *Fac Plast Surg North Am* 1993;1:111–126. With permission.)

cartilages at different points and removing different amounts of cartilage, enhanced symmetry can be obtained. If there is still significant introversion of the cleft lower lateral cartilage after these maneuvers, the lower lateral cartilage can be sutured to the upper lateral cartilage to reposition the alar rim more superiorly (Fig. 66–14). Finally, a cartilaginous tip graft can be added to camouflage irregularities and improve tip definition.

The obstruction at the external nasal valve caused by the introversion of the lower lateral cartilage and alar webbing is frequently improved by the approach chosen, the increased projection obtained with the strut and dome division, and the repositioning of the alar base. Additional strategies that can be used include Z-plasty over the web, excision of redundant tissue with primary closure, and placement of bolsters to retract the tissue and promote lateral scarring of the tissue similar to the bolsters used in primary cleft lip rhinoplasty.

The middle one third of the nose is addressed by stabilization of the upper lateral cartilage, frequently involving suturing of the upper lateral to the lower lateral. Moreover, if compromise of the internal nasal valve exists, the use of a unilateral, cartilaginous, spreader graft between the septum and the upper lateral cartilage can improve the cross-sectional airway and stability of the upper lateral (Fig. 66–15).

The upper one third of the nose is treated in a standard fashion with hump reduction as needed and medial/lateral osteotomies to reduce width and straighten the osseous pyramid (Fig. 66–16).

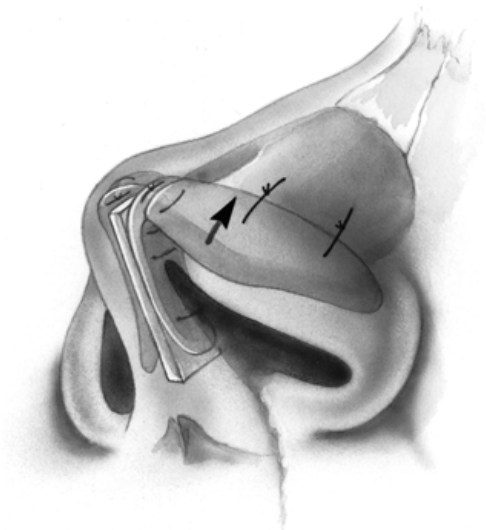

Figure 66–14 Oblique view demonstrating suture fixation of the lower lateral cartilage to the upper lateral cartilage to alleviate vestibular hooding. The arrow demonstrates the vector of force applied by the suture fixation. (From Sykes JM, Senders CW, Wang TD, Cook TA. Use of the open approach for repair of secondary cleft lip nasal deformity. *Fac Plast Surg North Am* 1993;1:111–126. With permission.)

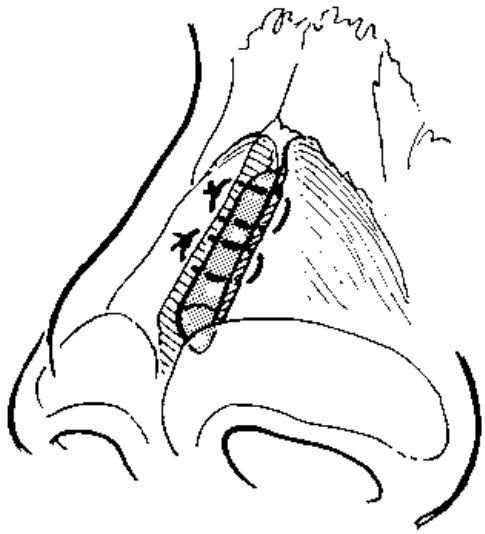

Figure 66–15 Oblique view depicting the use of the unilateral spreader graft to improve the dynamics of the internal nasal valve. (From Jablon JH, Sykes JM. Nasal airway problems in the cleft lip population. *Fac Plast Surg Clin North Am* 1999;7:391–403. With permission.)

Figure 66–16 **(A, C, E)** Preoperative anteroposterior, oblique, and lateral views of definitive cleft lip rhinoplasty. **(B, D, F)** Postoperative views.

Bilateral Cleft Lip Nasal Deformity

Primary Rhinoplasty

The role of primary rhinoplasty in the bilateral cleft nasal deformity is debatable. The repair of the bilateral cleft nasal deformity has been frequently described. Evolution of the techniques described has ranged from staged repairs to simultaneous reconstruction with labial repair. We only advocate primary cleft rhinoplasty in bilateral deformities when significant asymmetries are present. Other authors prefer a more aggressive tip rhinoplasty at the time of lip repair.[34,35]

The Mulliken[34] and Trott[35] repairs of the bilateral cleft nasal deformity seek to correct the deformity at the time of the lip repair. Both authors feel that the length of the columella is within the nasal tissue and do not attempt to recruit additional columella length from the prolabium.[36] The columella length is determined by active positioning of the alar cartilages, interdomal approximation, and excision of excessive tissue in the superior medial alar web. Their approaches vary, with Mulliken advocating a vertical, midline intradomal incision and Trott preferring a more standard open-incision approach. Long-term results have been good with both repairs, but definitive rhinoplasty is frequently required.

Intermediate Rhinoplasty

Intermediate rhinoplasty is used more often in the bilateral nasal deformity than in the unilateral deformity. The major goal of intermediate rhinoplasty is columella lengthening to provide additional tissue for use in a definitive repair. Intermediate rhinoplasty can be approached via a V-shaped incision or bilateral forked flaps (Fig. 66–17).[29] The lower lateral cartilages are freed from the nasal skin, and an interdomal stitch is placed to aid with nasal tip projection and enhance tip symmetry.

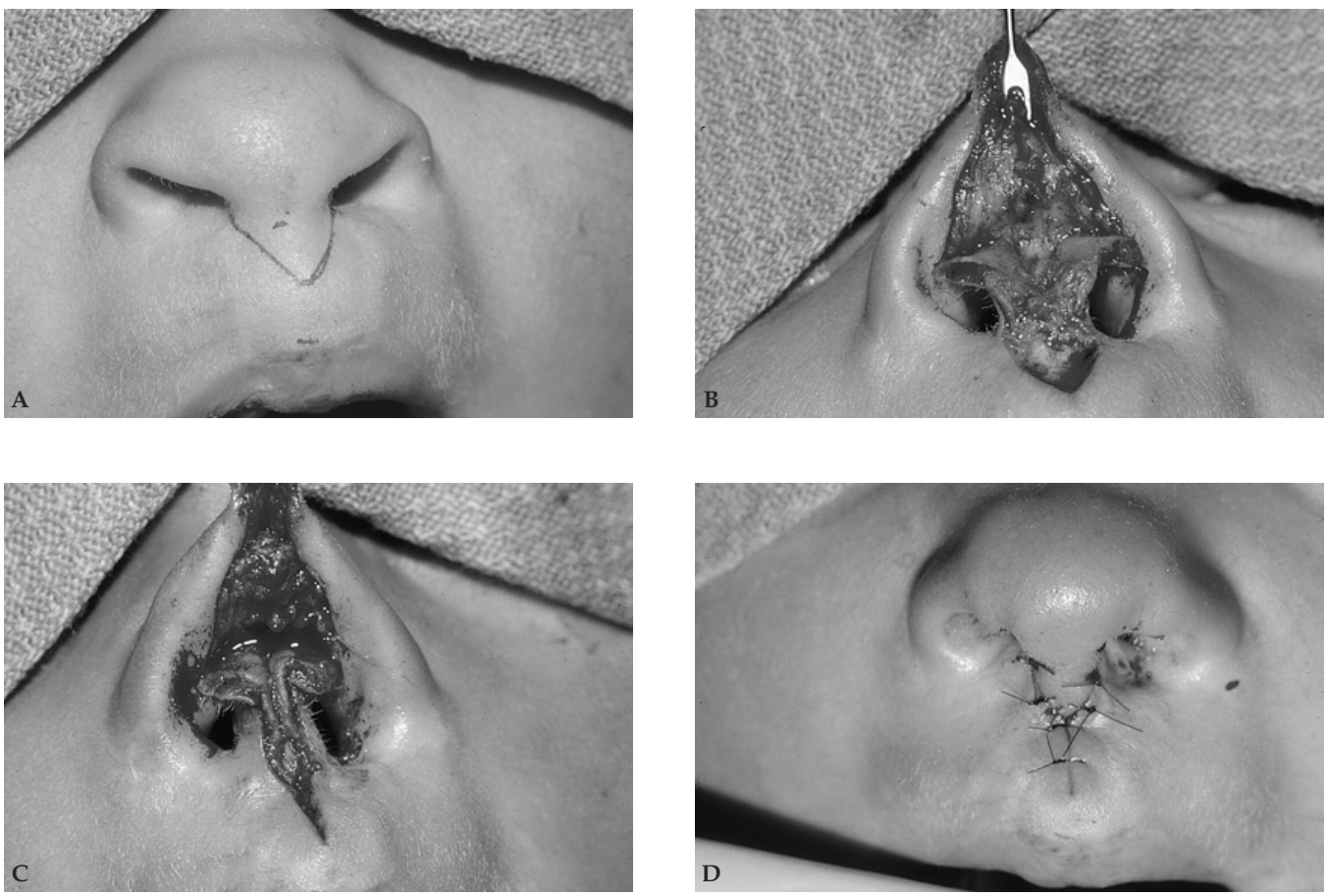

Figure 66–17 Intraoperative photographs of intermediate bilateral cleft lip rhinoplasty approached with a V incision **(A)**, which recruits skin from the lip into the columella. The splayed medial crura **(B)** are approximated with an intradomal suture to narrow the tip and improve symmetry **(C)**. The incision is then closed in a Y fashion **(D)**.

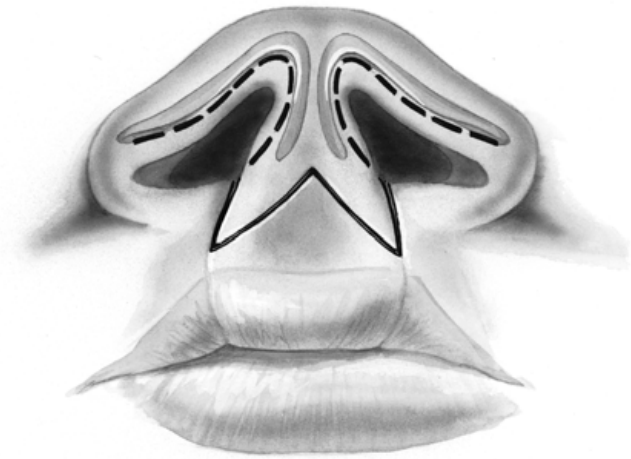

Figure 66–18 Basal view demonstrating bilateral forked flap incisions to approach the definitive bilateral cleft lip rhinoplasty. (From Sykes JM Senders CW, Wang TD, Cook TA. Use of the open approach for repair of secondary cleft lip nasal deformity. *Fac Plast Surg North Am* 1993;1:111–126. With permission.)

Definitive Rhinoplasty

The definitive rhinoplasty for the bilateral nasal deformity is similar to that for the unilateral deformity. This similarity is the result of the primary and intermediate procedures that produce a deformity that can be corrected with open-structure rhinoplasty after the completion of skeletal growth.

The approach can be done through a standard open rhinoplasty inverted V incision or by using forked lip flaps if additional columellar tissue is needed (Fig. 66–18). Septoplasty is done to correct any nasal obstruction and to obtain grafting material. The central concepts of the remainder of the lower one third of the repair include placing a cartilaginous tip strut, advancing the lower lateral cartilages onto the strut, dividing the lower lateral cartilages lateral to the dome to increase projection, reapproximating these cartilages to obtain symmetry, and placing a cartilaginous shield tip graft to further improve projection and definition and to camouflage irregularities (Fig. 66–19).

The goals of the middle one third of the reconstruction are to improve the stability of the upper lateral cartilages and to ensure adequate cross-sectional airway at the internal nasal valve. Suturing the upper lateral to the lower lateral will improve stability and decrease the introversion of the lower lateral cartilage. The use of spreader grafts is unusual but should be kept in mind if internal nasal valve collapse is present.

The upper one third of the nose is addressed with hump reduction as needed and medial/lateral osteotomies to improve the width and straightness of the nasal bones.

The final step is active repositioning of the alar bases if needed. A complete alotomy is needed to free tissue and give the surgeon the ability to place the alar base in a symmetrical position. The nasal floor must be reconstructed when the ala is moved. One side, both sides, or neither may be repositioned at the time of definitive repair (Fig. 66–20).

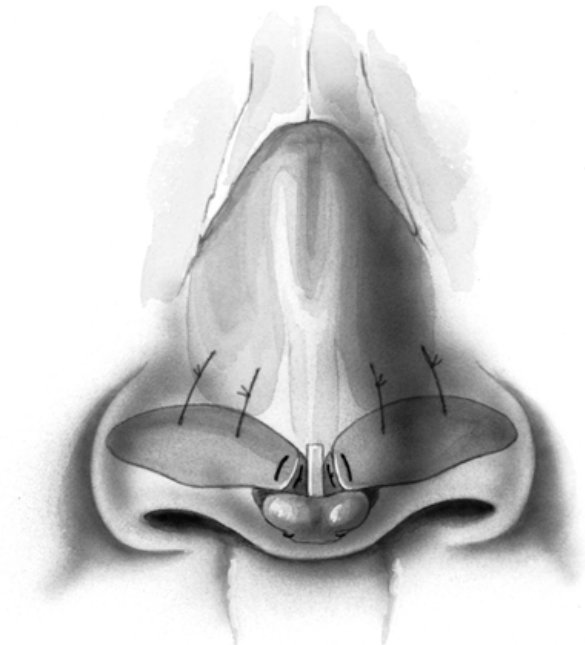

Figure 66–19 Anteroposterior view depicting the cartilaginous tip strut, the reconstituted lower lateral cartilages, the suture fixation of the lower lateral cartilages, to the upper lateral cartilages and the use of a cartilaginous tip graft. (From Sykes JM Senders CW, Wang TD, Cook TA. Use of the open approach for repair of secondary cleft lip nasal deformity. *Fac Plast Surg North Am* 1993;1:111–126. With permission.)

CONCLUSION

The cleft lip nasal deformity will likely continue to frustrate and challenge reconstructive surgeons for years to come. The concepts seem clear: restore symmetry and definition to the nasal tip and base, realign and open the nasal airway, and prevent scarring and webbing from compromising the results. In practice, however, the three-dimensional nature of the deformity and the involvement of all nasal layers make a dependable result elusive.

The more extensive use of primary rhinoplasty without the fear of halting midface or nasal growth has dramatically changed the secondary deformity, reduced the need for intermediate rhinoplasty, and improved the results obtained with definitive rhinoplasty.[29] Whether the next major advance will occur with in utero surgery or a new technique or concept in definitive rhinoplasty is unknown, but if we continue to study our results, refine our techniques and develop new ones, uncover new truths in models, and challenge accepted principles, we will work toward more consistent and better results that improve both the functional and aesthetic appearance of the cleft lip nasal deformity.

Figure 66–20 **(A, C, E)** Preoperative anteroposterior, oblique, and lateral photographs of definitive bilateral cleft lip rhinoplasty. **(B, D, F)** Postoperative views.

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Chapter 67

Orthognathic Surgery

Jonathan M. Sykes

The secret to facial beauty is balanced proportion of facial features. The overall attractiveness of the face is a composite of all of the anatomical elements, including skin, subcutaneous tissues, muscle, bone, and teeth. Facial plastic surgeons concern themselves daily with the achievement of this harmonious balance.

To achieve or approach an aesthetic ideal, the facial plastic surgeon must have a clear concept of proportion, a method to analyze deformities, and the ability to apply specific techniques to deformities. Although surgery of the nose involves correction of skeletal abnormalities, aesthetic surgery on the remainder of the face is mainly concerned with soft tissue deformities. In many instances, surgery of the soft tissues is sufficient; however, attention must often be paid to underlying skeletal deformities to correct many congenital and traumatic reconstructive problems.

Evaluation of facial deformities should include skeletal and soft tissue analysis. Soft tissue analysis can be done in an unstructured way through focused observation. It can also be achieved by careful study of consistent frontal and lateral photographs. Skeletal analysis involves evaluation of the facial bones and teeth. Generally, hard tissue analysis is easier to quantify. It is achieved by determining the patient's dental occlusion and through the use of cephalometric radiography.

After careful skeletal and soft tissue analysis, a detailed, systematic treatment plan is established. This involves using dental and bony models and is often the product of input from multiple specialty fields. Surgical correction of the specific dentofacial deformities is then performed and, hopefully, facial harmony is established.

DENTAL ANALYSIS

The establishment of balanced facial proportions begins with good dental occlusion. Occlusion is the relationship of the maxillary to the mandibular teeth. This relationship largely depends on the relative position and angulation of the teeth to each other. Malocclusion refers to a dental relationship that is less than optimal. It can result from dental or skeletal deformities or a combination of both.

In 1899, Angle developed a classification system to describe normal and abnormal dental occlusion.[1] The reference point in the Angle classification is the relationship of the maxillary to the mandibular first molar teeth. Each molar tooth has four grinding surfaces, called *cusps*. The surfaces adjacent to each cusp are referred to as *grooves*. Cusps adjacent to the tongue are called *lingual*, and those adjacent to the cheek are called *buccal*. Cusps located anteriorly, or toward the midline, are referred to as *mesial*, and those situated posteriorly or away from the midline are called *distal* (Fig. 67–1).

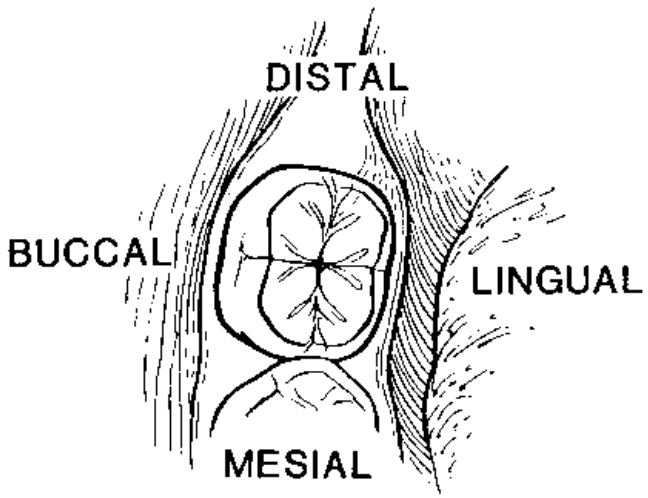


Figure 67–1 Orientation of molar cusp. (From Donald PJ. *The surgical management of structural dysharmony: a self-instructional package*. Washington, DC: American Academy of Otolaryngology–Head and Neck Surgery, 1985. With permission.)

There are three general categories of occlusion in the Angle classification system. In class I occlusion, the mesial buccal cusp of the first maxillary molar fits in the groove on the lateral or buccal surface of the first mandibular molar tooth (Fig. 67–2). However, this only represents the ideal relationship of the molar teeth. When the remainder of the teeth interdigitate perfectly, the occlusal relationship is said to be normal. Malocclusion can exist when the molar relationship is class I. This type of malocclusion is generally less severe and usually based on dental rather than skeletal deformities. Although the molar relationship is normal, crowding of the anterior teeth may occur. Another variation of class I malocclusion occurs when there is bimaxillary protrusion. In this situation the mandibular length is excessive, causing a protrusion of both upper and lower incisor regions.

Class II malocclusion is skeletally and dentally based. The mesial buccal cusp of the first maxillary molar is mesial, or in front of the first mandibular molar (Fig. 67–3).

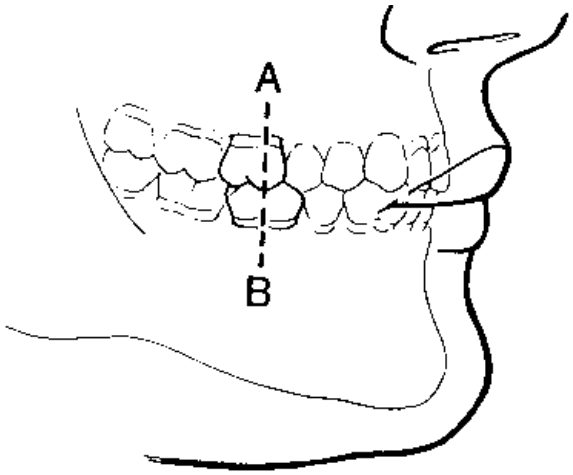


Figure 67–2 Schematics diagram of class I molar occlusion. The mesial buccal cusp of the first maxillary molar **(A)**. The buccal intercuspal groove of the mandibular first molar **(B)**. (From Donald PJ. *The surgical management of structural dysharmony: a self-instructional package*. Washington, DC: American Academy of Otolaryngology–Head and Neck Surgery, 1985. With permission.)

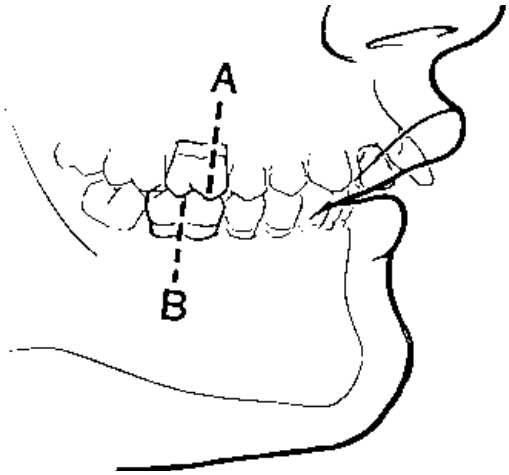


Figure 67–3 Schematic diagram of a patient with class II malocclusion. The mesial buccal cusp of the first maxillary molar **(A)**. The buccal intercuspal groove of the mandibular first molar **(B)**. (From Donald PJ. *The surgical management of structural dysharmony: a self-instructional package*. Washington, DC: American Academy of Otolaryngology–Head and Neck Surgery, 1985. With permission.)

There are two subtypes of class II occlusion. In the more common subtype, division 1, there is excessive overjet (anterior maxillary protrusion), and the maxillary incisors are quite protrusive. In division 2, there is a deep bite (overbite) with the maxillary incisors overlapping and covering the mandibular front teeth by more than the usual amount. There is a posterior tilting of the central incisors and a flaring of the lateral incisors. A deep bite is present, but overjet is not as pronounced (Fig. 67–4).

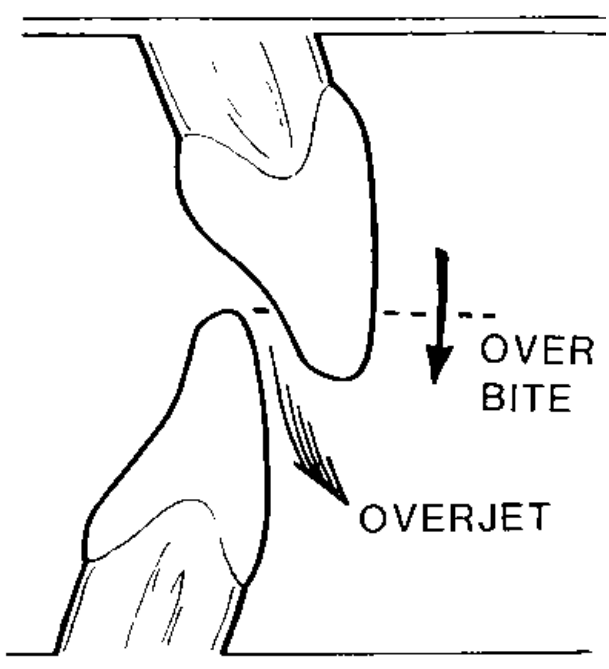


Figure 67–4 Relationship of the central mandibular incisor. The difference between overbite and overjet is indicated by the schematic diagram.

Class II malocclusion may arise from a lack of mandibular development. The resulting posteriorly positioned mandible is termed *retrognathia*. This condition often prevents the upper lip from completely covering the upper incisor teeth. Lack of complete lip seal exposes the upper incisors, rendering them more vulnerable to injury. A class II molar relationship may also arise from an abnormally protuberant maxilla.

The class III malocclusion is primarily skeletally based. It is characterized by a large protrusive mandible or an underdeveloped, retrusive maxilla. The mesial buccal cusp of the first maxillary molar is positioned distal to its ideal position (Fig. 67–5). Protrusion of the mandible is called *prognathism*.

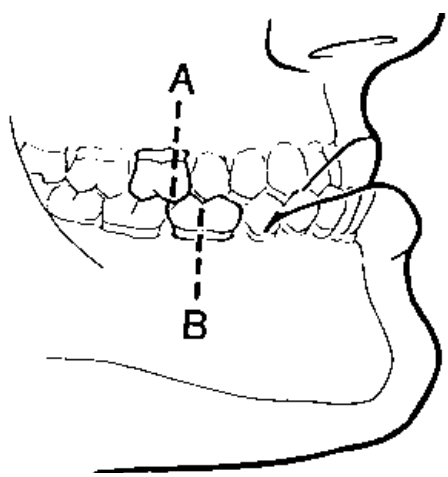


Figure 67–5 Schematic diagram of a patient with class III molar occlusion. The mesial buccul cusp of the maxillary first molar **(A)**. The buccal intercuspal groove of the mandibular first molar **(B)**. (From Donald PJ. *The surgical management of structural dysharmony: a self-instructional package*. Washington, DC: American Academy of Otolaryngology–Head and Neck Surgery, 1985. With permission.)

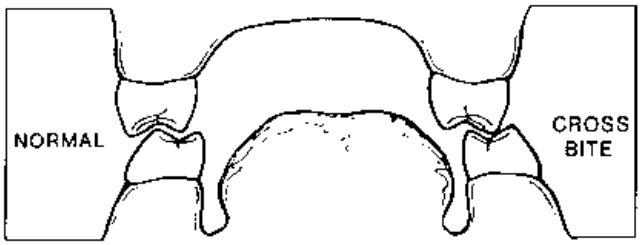


Figure 67–6 Schematic diagram of the coronal view of the oral cavity at the level of the first molar. (*left*) A normal molar relationship is shown with the maxillary buccal cusp related to the buccal surface of the underlying mandibular molar. (*right*) A lingual crossbite is indicated. (From Donald PJ. *The surgical management of structural dysharmony: a self-instructional package*. Washington, DC: American Academy of Otolaryngology–Head and Neck Surgery, 1985. With permission.)

In addition to anteroposterior malocclusions, suboptimal relationships can exist in a medial to lateral direction (Fig. 67–6). The ideal relationship occurs when the buccal cusps of the maxillary molar teeth are just lateral to the opposing mandibular buccal cusps. If the maxillary and mandibular molar cusps contact end-to-end or the maxillary buccal cusps are medial to their mandibular counterparts, a lingual cross-bite is present. If the maxillary teeth are more lateral than is ideal, a buccal cross-bite exists.

Malocclusion can thus result from dental or skeletal abnormalities or a combination of both. The cause of malocclusion may be congenital, traumatic, or a consequence of extirpative surgery for neoplastic disease. The dentofacial deformities produced may cause both cosmetic and functional problems. These include difficulties with speech, mastication, and swallowing. It is therefore imperative that the facial plastic surgeon carefully address the occlusal relationships when treating any facial deformity.[2]

SKELETAL ANALYSIS

The assessment of craniofacial dimensions is important in diagnosing structural facial dysharmony. Attempts have been made for years by artists, surgeons, and orthodontists to analyze and quantitate the proportions of the face. Cephalometry, the scientific measurement of the dimensions of the head, was first used in orthodontics to assess craniofacial growth. Another method for craniofacial analysis based on cephalometry is cephalometric radiography. Although cephalometric radiography was originally introduced into orthodontics during the 1930s, widespread acceptance of the method has only occurred during the last 20 years.[3] In 1931, Hofrath and Broadbent simultaneously and independently developed methods for the production of standardized cephalometric radiographs.[4] This standardization is achieved using a special head holder, known as a cephalostat, which holds the head in a fixed and reproducible position (Fig. 67–7).[5] The cephalostat stabilizes the head with three rods. One rod fits in each external auditory meatus, and a third rod rests passively on the inferior orbital rim or the nasofrontal suture. The radiograph taken is a true lateral view, with no head rotation in the sagittal plane. The cephalometric film should be taken with soft tissue technique to most clearly demonstrate the relationship between the soft tissues and the facial skeleton.[6] To further standardize the radiograph and to minimize distortion, a consistent subject-to-film distance and x-ray target-to-subject distance must be used.

Figure 67–7 The cephalostat holds the head in a fixed and reproducible position. Two rods are positioned in each external auditory meatus and a lucite bar rests passively at the nasofrontal angle. The x-ray cassette is positioned on the patient's left at a constant distance from the midline of the cephalostat and the head. (From Grayson BH. Cephalometric analysis for the surgeon. *Clin Plast Surg* 1989;16(4):10. With permission.)

The cephalometric radiograph obtained provides a two-dimensional outline of the lateral aspect of the craniofacial skeleton (Fig. 67–8). It can be traced onto a matte acetate sheet to provide a model on which various analyses may be performed. However, this radiograph is subject to image distortion. The acetate model is also subject to tracing error. The purpose of the cephalometric tracing is to provide objective data that assist in the diagnosis and treatment of facial skeletal deformities.

The cephalometric radiograph allows objective evaluation of bony and soft tissue morphology. To effectively use the lateral cephalometric tracing, standardized bony landmark points must be defined.[7] These skeletal landmarks may then be used to derive reference lines and angles.

Linear measurements may be obtained between any two points and angular measurements are made between three reference points. Various linear and angular analyses are then performed to aid in the diagnosis and treatment of dentoskeletal deformities.

Figure 67–8 The standard lateral cephalometric radiograph.

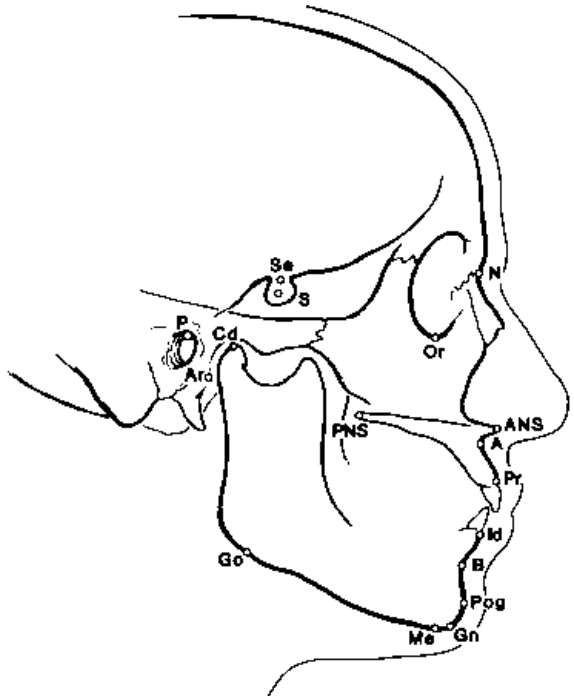


Figure 67–9 Schematic diagram of the commonly used skeletal reference points in cephalometric analysis. N, nasion; S, sella; A, subspinale; Pr, prosthion; B, supramentale; Id, infradental; Pog, pogonion; Gn, gnathion; Me, menton; Go, gonion; Cd, condylion; Ar, articulare; ANS, anterior nasal spine; PNS, posterior nasal spine; Or, orbitale; P, porion. From Rakowski T. *An atlas and manual of cephalometry radiography*. Philadelphia: Lea & Febiger, 1982. With permission.

Effective evaluation of the cephalogram depends on accurate definition and localization of bony landmarks. These points may be anatomical or anthropologic and are located on or in the skeletal structures. In contrast, radiologic or constructed reference points are secondary landmarks marking the intersections of x-ray shadows or lines. The points may be unilateral (in the sagittal plane) or bilateral. Bilateral points may be difficult to precisely determine and measure and therefore may result in slight loss of accuracy. The more commonly used skeletal reference points in cephalometric analysis are seen in the box on this page and Fig. 67–9.

These reference points can be used to construct numerous reference lines, as described in the box at right (Fig. 67–10). Different lines are used for different linear analyses, with one particular line representing the reference plane on which the whole analysis is based. The Frankfort horizontal plane is based on a line joining the superior border of the bony external auditory canal with the inferior border of the infraorbital rim. The Frankfort plane is used as a reference when orienting medical photographs of patients. This plane should be oriented parallel to the floor with the patient in the upright position. However, the Frankfort plane is not usually used for cephalometric analysis because it is based on points that are not midline. As such, they are subject to error. The line connecting the nasion *(N)* and sella *(S)* is midline and is often used as the reference plane on which most cephalometric analysis is based.

Identification of standardized bony reference points and tines allows linear and angular measurements to be determined. These measurements can be compared with normative reference values. Deviation from these normals allows quantitation of the skeletal abnormality.

Angles *SNA*, *SNB*, and *ANB* are relatively simple to determine and provide valuable basic information in analyzing the relationship of the maxilla and mandible. These angles

Cephalometric Reference Lines

S-N	sella–nasion—anteroposterior extent of anterior cranial base
N-A	nasion–height
P-O	Frankfort line (plane)—plane should be parallel to ground. A reference for photographic analysis
Me-Go	length of mandibular base
Cd-A	maxillary length
Cd-B	mandibular length
Pal	palatal plane (ANS-PNS)
Go-Me	extent of point A N-B nasion–point B
N-Id	nasion–infradentale N-Pog nasion–pogonion N-Pr nasion–prosthion
N-Go	nasion–gonion line, for analysis of the gonial angle
S-Go	posterior facial mandibular base (first measurement)
Go-Gn	extent of mandibular base (second measurement)
Cd-Go	length of mandibular ramus
S-Ar	lateral extent of the cranial base
FH	Frankfort horizontal—from porion (P) to orbitale (O)
S-Gn	Y axis

From Rakowski T. *An atlas and manual of cephalometry radiography*. Philadelphia: Lea & Febiger, 1982. With permission.

Cephalometric Bony Reference Points

N	nasion—The most anterior point of the nasofrontal suture in the median plane. The skin nasion *(n)* is located at the point of maximum concavity between nose and forehead.
S	Sella—The midpoint of the hypophysial fossa. The midpoint of the entrance of the sella *(Se)* represents the midpoint of the line connecting the posterior clinoid process and the anterior opening of the sella turcica.
Sn	Subnasal—A skin point. The point at which the nasal septum merges with the skin of the upper lip.
A	Point A, subspinale—The deepest point in the concavity of the maxilla. It is located between the anterior nasal spine *(ANS)* and the prosthion *(Pr)*.
Pr	Prosthion—The lowest, most anterior point on the alveolar portion of the premaxilla, between the upper central incisors.
B	Point B, supramentale—The most posterior point in the outer contour of the mandibular alveolar process, in the median plane. It is located between the *infradentale (Id) and the pogonion (Pog)*.
Id	Infradentale—The highest, most anterior point on the alveolar portion of the mandible, in the median plane, between the central incisors.
Pog	Pogonion—Most anterior point of the bony chin in the median plane.
Gn	Gnathion—This point has been defined in many ways. It is best identified as a point between the most anterior *(Pog)* and inferior *(Me)* point of the chin.
Me	Menton—The most caudal point in the outline of the symphysis (the lowest point of the mandible).
GO	Gonion—A constructed point, defined as the intersection of the lines tangent to the posterior margin of the ascending ramus and the mandibular base.
Cd	Condylion—Most superior point on the head of the mandibular condyle.
Ar	Articulare—The point of intersection of the posterior margin of the ascending ramus and the outer margin of the cranial base.
ANS	Anterior nasal spine—The tip of the bony anterior nasal spine in the median plane. It corresponds to the anthropolic acantion.
PNS	Posterior nasal spine—This is a constructed point, represented by the intersection of anterior wall of the pterygopalatine fossa and the floor of the nose. It marks the dorsal limit of the maxilla.
O	Orbitale—The most inferior point on the infraorbital rim.
P	Porion—The most superior point on the external auditory meatus.

Modified from Rakowski T. *An Atlas and Manual of Cephalometry Radiography*. Philadelphia: Lea & Febiger, 1982, with permission.

have a narrow range of normal values[3,8] (Fig. 67–11). If the angle *ANB* is greater than 4 degrees, a skeletal class II malocclusion is present. The maxillary versus mandibular contribution to this malocclusion may be determined by measuring the angles *SNA* and *SNB*. If *ANB* is greater than 4 degrees and *SNA* is greater than normal, the class II malocclusion is most likely secondary to maxillary protrusion. If *ANB* is greater than 4 degrees and *SNA* is less than normal, mandibular retrognathia probably exists.

Other important angles (Table 67–1) exist. The Frankfort mandibular plane angle is created by the intersection of Frankfort horizontal plane and the mandibular plane (from gonion to

TABLE 67–1 Cephalometric Angular Measurements

Points of the angle	Definition	Mean value (degrees)
N-S-Ar	Saddle angle	123 :f: 5
S-Ar-Go	Articular angle	143 :f: 6
Ar-Go-Me	Gonial angle	128 :f: 7
Ar-Go-N	Upper gonial angle	52 to 55
N-Go-Me	Lower gonial angle	70 to 75
SNA	Anteroposterior position of maxilla	82
SNB	Anteroposterior position of mandible	80
ANB	Difference between *SNA* and *SNB*	22
SN-MP	Angle between *SN* and mandibular plane	35
Pal-MP	Angle between palatal and mandibular plane	25
O-P	Intersecting Frankfort mandibular plane angle	20 to 29

From Rakowski T. *An atlas and manual of cephalometry radiography*. Philadelphia: Lea & Febiger, 1982.

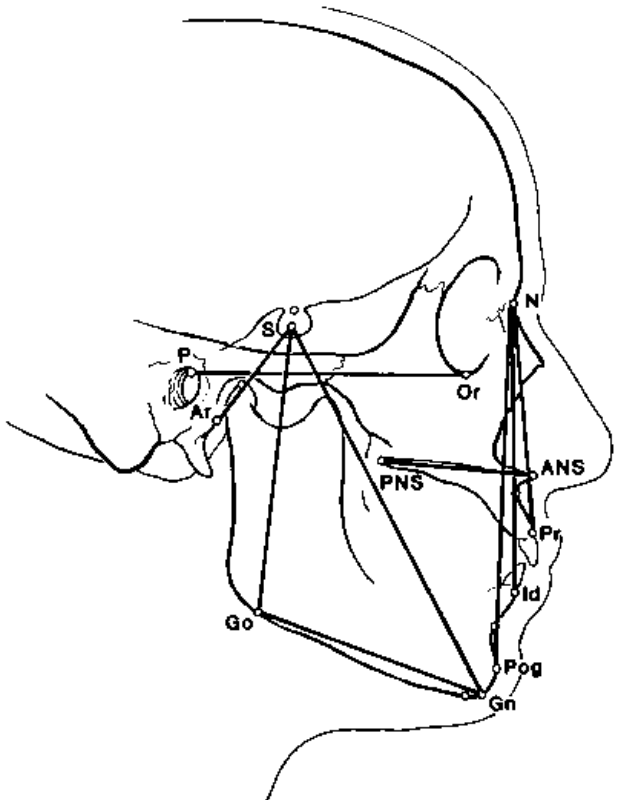


Figure 67–10 Commonly used skeletal reference lines in cephalometric analysis. S, sella; P, porion; Ar, articular; Go, gonion; PNS, posterior nasal spine; Or, orbitale; N, nasion; ANS, anterior nasal spine; Pr, prosthion; Id, infradental; Pog, pogonion; Gn, gnathion.

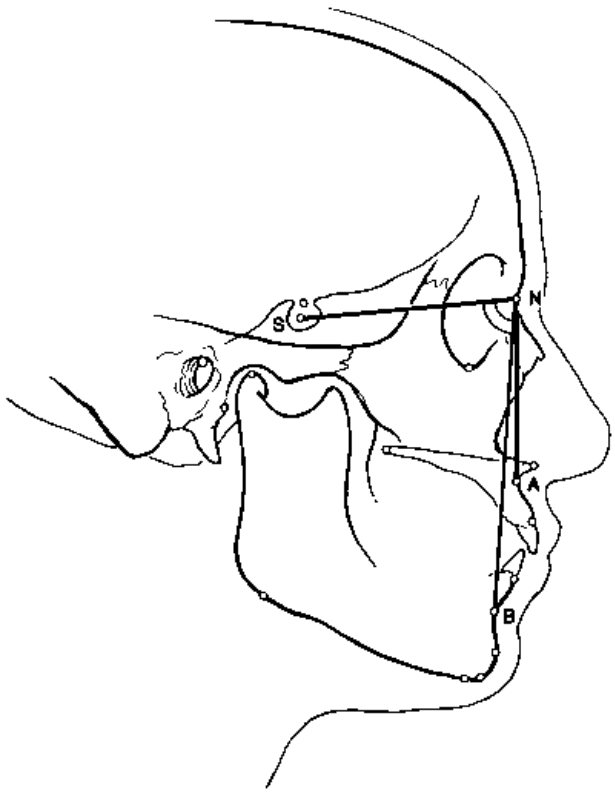


Figure 67–11 Cephalometric angular measurements. SNA, SNB, and ANB: these reference angles have a narrow range of normal values. S, sella; N, nasion; A, subspinale; B, supramentale.

menton). It is defined by Tweed[9] as 20 to 29 degrees and by Burston[10] as 23 degrees. It reflects the inclination of the mandibular plane. The saddle angle is the angle between the anterior and posterior cranial bases. The articular angle *(S-Ar-Go)* can be affected by orthodontic treatment. It is reduced in all cases of mandibular prognathism. The gonial angle *(Ar-Go-Me)* plays a role in growth prognosis of the mandible and is affected by the relationship between the body and the ramus. It indicates the direction of mandibular growth, with a large gonial angle indicating posterior condylar growth. The gonial angle may be divided into upper and lower (Fig. 67–12) gonial angles.[11]

Various linear distances have also been described (Table 67–2). Again, these lines are measured by identifying the two connecting points on the cephalometric radiograph. The mandibular base is determined by measuring the distance between the gonion *(Go)* and pogonion *(Pog)* when projected onto the mandibular plane. The maxillary base is measured from the posterior nasal spine *(PNS)* to point A. The distance from the sella *(S)* to the nasion *(N)* is the anteroposterior extent of the anterior cranial base.

A variety of analyses using the previously mentioned skeletal points, lines, and angles have been described. These include the Zimmer aesthetic plane,[12] the Holdaway ratio,[13] the Gonzales-Ulloa zero meridian line,[14,15] and others.[16] In all instances, these analyses represent an attempt to describe the normal relationship of the facial skeleton.

TABLE 67–2 Cephalometric Linear Measurements

Distance	Definition	Mean value (mm)
S-N	Anteroposterior extent of anterior cranial base	71
S-Ar	Extent of lateral cranial base	32 to 35
S-Go	Posterior facial height	
N-Me	Anterior facial height	
PNS-Point A	Maxillary base	
Go-Po	Mandibular base	

From Rakowski T. *An atlas and manual of cephalometry radiography*. Philadelphia: Lea & Febiger, 1982.

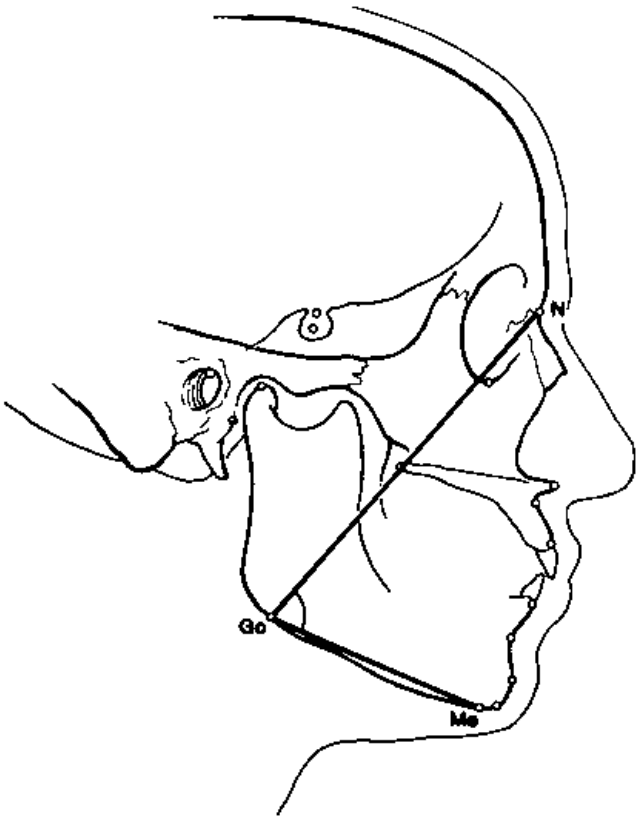


Figure 67–12 Schematic diagram of the lower gonial angle. This angle can be an indicator of the direction of mandibular growth. N, nasion; Go, gonion; Me, menton.

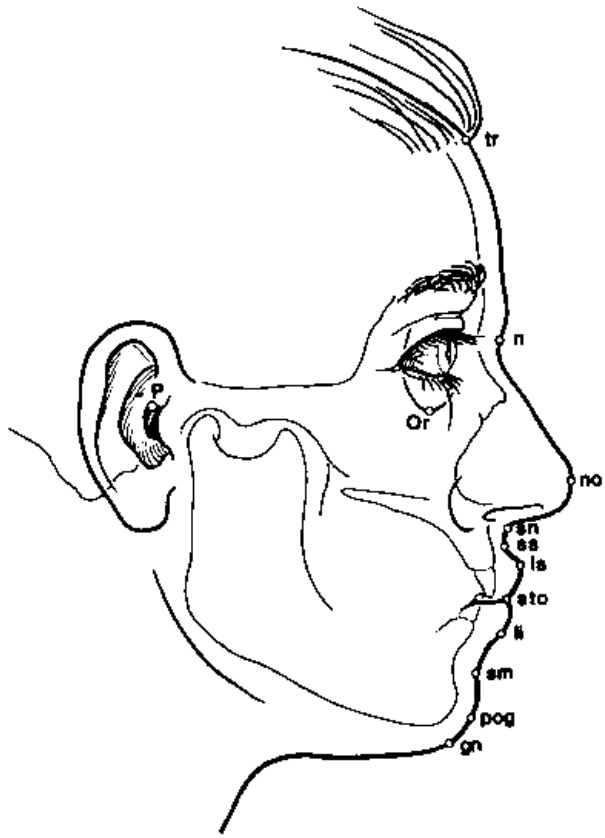


Figure 67–13 Schematic diagram of soft tissue reference points. In some instances, these points are soft tissue correlates of fixed skeletal reference points. For example, the nasion (n) is the soft tissue correlate of the skeletal nasion (N). In other cases, these soft tissue points have a more variable position, such as the trichion (tr) or the nasal tip (no). N, nasion; Or, orbitale; P, porion; Gn, gnathion; Pog, Pogonion.

SOFT TISSUE ANALYSIS

The overall form and structure of the human face is a product of many factors. Dental analysis and treatment directly address the relationship of the maxillary and mandibular teeth. Skeletal analysis demonstrates the relationship of the facial bones and illustrates any deformity in this relationship. However, dental and skeletal analyses alone are inadequate in evaluating and predicting facial form. Assessment of the soft tissues is crucial in preoperative facial analysis and in achieving harmonious facial balance after surgery.

Soft tissue analysis is the final determinant in evaluating the overall attractiveness of the face. It is the method used by the casual observer and therefore is generally more subjective and less easily quantified. However, the facial plastic surgeon must be able to set some standards of facial beauty; the casual observer also does this but in an unstructured manner. Successful correction of dentofacial deformities requires careful preoperative evaluation of soft tissues and accurate prediction of their response to skeletal surgery. Although the soft tissues are more difficult to standardize than dental or skeletal parameters, analysis may be performed by using fixed soft tissue reference points as described in the box at right (Fig. 67–13). These points are often direct correlates of associated bony reference points [e.g., n = soft tissue correlate to the nasion (N) or pog = soft tissue pogonion *(Pog)*.] However, they also represent soft tissue points that are variable in their location and have no fixed skeletal correlate [e.g. the trichion *(tr)* or hairline]. It is the variable thickness of the soft tissues (e.g., skin of the lips or nose) and

Soft Tissue Reference Points

tr	trichion (hairline)
n	skin nasion
no	nasal tip
sn	subnasal
ss	subspinale (concavity of upper lip)
Is 1	abrale superius (border of upper lip)
Sto	stomion (central point of interlabial gap)
Li	labrale inferius (border of lower lip)
sm	submentale (labiomental fold)
pog	skin pogonion
gn	skin gnathion

From Rakowski T. *An atlas and manual of cephalometry radiography*. Philadelphia: Lea & Febiger, 1982. With permission.

the relative position of nonfixed points (e.g., the trichion) that determine the overall facial structure and appearance.

The soft tissue reference points can be used to determine various lines and to calculate various angular measurements. This can be done in a similar manner to the cephalometric bony linear and angular measurements. The soft tissue points can also be used to analyze vertical facial height (Fig. 67–14).[6] In this analysis, the distance from the trichion to the gnathion may be subdivided into thirds by the nasion and subnasal soft tissue points. Because hairlines are variable, the upper third of the face is not usually a reliable measurement. However, the middle and lower thirds of the face are reliable and should approximately form a 1:1 ratio. Ratios greater than 1 indicate vertical maxillary excess, foreshortening of the lower third of the face, or a combination of these elements. A vertical height ratio of less than 1 signifies a large lower facial third or vertical maxillary deficiency.

The lower third of the face may be further subdivided into two segments (Fig. 67–15). This allows further analysis of the soft tissues of the upper lips, lower lips, and chin.[17] The position and posture of the lips is determined by the dental and skeletal support and must be included in any complete evaluation of the lower third of the face. The upper lip length [from subnasal *(sn)* to stomion superius *(stos)*] should be approximately one half of the lower lip length [from stomion inferius *(stoi)* to gnathion *(gn)*]. When the ratio of the upper to lower lip is smaller than 1:2, the vertical height of the lower lip and chin is excessive and a vertical reduction genioplasty may be indicated. Various other analyses have been developed for evaluating lip and chin position.[18–19] These analyses illustrate wide variation in the normal relationship between the teeth, lips, and chin. Lip and chin projection are perhaps best evaluated by drawing a vertical line from subnasal *(sn)* to pogonion *(pog)* (Fig. 67–16).

To accurately correct facial deformities, the facial plastic surgeon must understand the amount of soft tissue change gained by a given bony alteration. It is certainly clear that soft tissue responses to skeletal surgery vary in different regions of the face. It is the accurate prediction of these responses that determines the final aesthetic result.

In portions of the face where the overlying soft tissues are relatively thin, larger, and more predictable, soft tissue changes are usually obtained for a given bony alteration.[20] Additionally, different procedures on a given facial skeletal area may produce

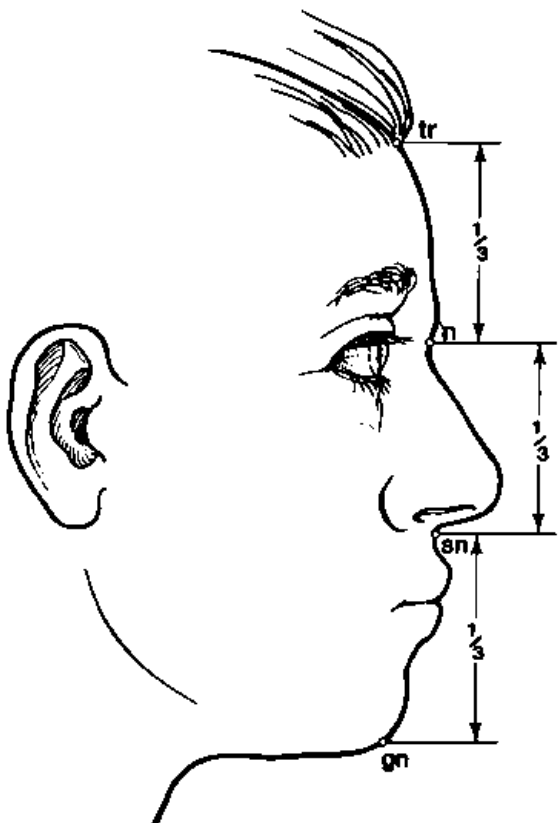


Figure 67–14 Vertical facial height. Balanced facial proportion allows the face to be broken up into three relatively equal thirds. The upper facial third, from the trichion (tr) to the nasion (n), is the most variable as in individuals hairline is often quite variable. A 1:1 ratio should exist between the middle and lower facial thirds. See chart on page 852 for abbreviation explanations.

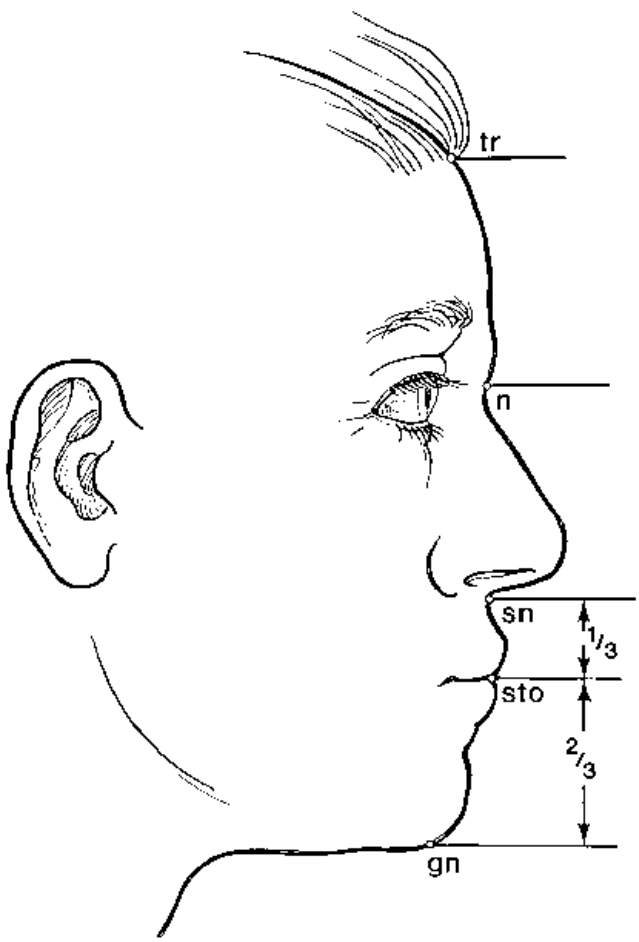


Figure 67–15 Lower facial height. A ratio of 1:2 should exist between the height of the upper lip and height of the lower lip and chin. See chart on page 852 for abbreviation explanations.

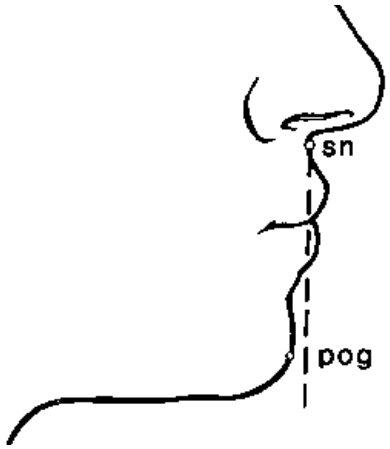


Figure 67–16 Schematic diagram of anterior chin projection. Projection is best evaluated by dropping a vertical line from the lower lip perpendicular to the Frankfort horizontal. Pog, pogonion.

different soft tissue responses. For instance, mandibular advancement procedures increase the soft tissues in a 1:1 ratio at the chin and approximately a 0.8:1 ratio at the lower lip.[21,22] When augmentation genioplasty is used for less significant microgenia, the soft tissue response at the pogonion is approximately 0.8:1.[22] When augmentation genioplasty is used as an adjunct to mandibular advancement, the additional soft tissue advancement as a result of the genioplasty is only a 0.4:1 response.[22] Similar response ratios of soft tissue to bony changes can be measured for mandibular setback surgery, and maxillary advancement and setback surgery (Table 67–3).[20] Although these ratios are not absolute, they can be used as a guide to predict the particular soft tissue response to surgery on a particular portion of the facial skeleton.

The overall appearance after correction of a facial deformity is therefore a result of both the skeletal correction and the redraping of the overlying skin soft tissue envelope. This fact has been well understood by surgeons who perform cosmetic rhinoplasty, where changes in the infrastructure of the nasoskeleton may be minimized or accentuated depending on the relative skin thickness.

TABLE 67–3 Soft Tissue Changes after Maxillofacial Surgery

Procedure	Response ratio of soft tissue to bone
Mandible setback:	
Pogonion *(Pg)*	1:1
Inferior labial sulcus *(Si)*	9:1
Labrale inferius *(Li)*	8:1
Labrale superius *(Ls)*	2:1
Mandible advancement:	
Pogonion *(Pg)*	1:1
Labrale inferius *(Li)*	8:1
Labrale superius *(Ls)*	Variable
Chin advancement alone:	
Pogonion *(Pg)*	8:1
Chin advancement with mandibular advancement:	
Pogonion *(Pg)*	4:1
Chin setback alone	
Pogonion *(Pg)*	25:1
Menton *(Me)*	33:1
Maxilla setback:	
Subnasale *(Sn)*	5:1
Labrale superius *(Ls)*	5:1
Maxilla advancement:	
Subnasale *(Sn)*	5:1
Labrale superius *(Ls)*	5:1
Maxilla-superior repositioning:	
Lip shonened	2:1
Maxilla-inferior repositioning lip lengthened	Variable

From Lehman JA. Soft tissue manifestations of aesthetic detects of the jaws: diagnosis and treatment. *Clin Plast Surg* 1987;14:4.

PHOTOGRAPHIC ANALYSIS

Consistent and reproducible photographs are essential when planning surgical correction of any facial deformity. They are an integral part of the preoperative soft tissue analysis. Photographs function as useful teaching aids for both patients and residents. They also provide accurate preoperative and postoperative medicolegal documentation. Photographs also give the surgeon a macroscopic view of the relationship between the individual's facial skeleton and the overlying soft tissues. Most importantly, however, photographs provide the surgeon with a visual record, which can be retrospectively analyzed. It is through such periodic critical assessment that surgical procedures are modified.

The most important aspect of useful medical photography is consistency. A 35-mm camera with a microscopic lens in the focal length range of 80 to 110 mm should be used. The Frankfort horizontal plane must be used religiously as a guideline when taking full-face portrait views. This plane can be constructed by connecting the porion (the superior aspect of the external auditory canal) with the orbitale (the most inferior point on the infraorbital rim). All photographs should be taken with this line parallel to the ground.

At least five full-face portrait views should be obtained. These include a posteroanterior, two lateral, and two oblique views. In addition, a submental-vertex (basal) view and close-up views of the occlusion from the posteroanterior and lateral orientation should be obtained.

TREATMENT PHILOSOPHY

Diagnosis and treatment of the patient with dentofacial deformities must occur in an orderly, systematic fashion. A careful medical and dental history and physical examination must be performed. This should include the patient's individual needs and expectations from orthognathic surgery. Specific concentration should be placed on the relative importance of

functional versus cosmetic correction expected by the patient. After completion of the basic examination, photographic and radiographic analysis is obtained. Lastly, dental study models are constructed. These models may be mounted on an articulator, allowing analysis of static occlusion and the dynamic relationship between the maxillary and mandibular teeth.

After performing a thorough dental, skeletal, and soft-tissue analysis, a complete problem list is compiled. This complete problem list should include all medical or systemic problems, dental occlusal problems, and problems relating to the facial skeleton. In addition, any soft tissue abnormalities are identified. The problem list may then be prioritized according to the severity of each particular deformity.

A systematic treatment plan for the patient with facial dysharmony may then be formulated. This may require the cooperative efforts of many disciplines, including facial plastic surgeons, oral surgeons, dentists, and orthodontists. In most cases, more than one management plan is possible. The option chosen should be a product of the patient's desires and expectations from treatment and the surgical team's abilities and experience. The surgical options and final treatment plan must be thoroughly discussed with the patient. This is crucial because most management plans for dentofacial deformities involve complex and lengthy treatment, requiring significant patient cooperation and commitment. For instance, a patient with mandibular retrognathism may be ideally treated by combined orthodontic and orthognathic surgical treatment. However, after understanding the treatment and postoperative care, the patient may choose to have orthodontic treatment only. Alternatively, the patient may not complain of problems with occlusion and may only be concerned with cosmetic improvement of the retrusive mandible. In this instance, treatment with either a sliding genioplasty or an alloplastic chin augmentation may be appropriate.

It is imperative to discuss the risks, benefits, and limitations of potential treatment options with the patient. The patient, understanding the treatment plans and their limitations, may then make an informed decision regarding which management choice to pursue.[23]

Dental Treatment

As a general rule, all routine dental care should be completed before initiating orthodontic treatment or orthognathic surgery. This is important because most orthodontic treatments or intermaxillary fixations place considerable demands on the teeth and periodontal tissues. Dental caries, periapical abscesses, or other intraoral inflammatory diseases must be treated. Fillings and extractions should also be completed. To facilitate orthodonture, temporary restorations may be necessary before placement of an orthodontic appliance. Placement of crowns or missing teeth is usually postponed until orthodontic and orthognathic treatment is completed.

Treatment of temporomandibular joint syndrome is usually begun before any orthodontic treatment. This may include analgesics or anti-inflammatory medication. It also may include dental splints to decrease pain and spasm. Pretreatment of these problems allows better evaluation of the patient's occlusion and facilitates more accurate treatment planning.

Preoperative Orthodontic Treatment

In most instances, preoperative orthodontic treatment is necessary to align the dental arches. This can minimize the occlusal deformity and often decreases the amount of movement necessary during orthognathic surgery. Preoperative orthodonture usually requires 12 to 18 months of treatment. It may require dental extractions to accommodate tooth movements and eliminate crowding.

The orthodontist should work closely with the maxillofacial surgeon to anticipate the postoperative position of the dental arches.[24–26] Careful dental analysis should occur, and the portion of malocclusion secondary to dental versus skeletal components should be identified. Plaster dental models are constructed (Fig. 67–17), and these models are placed on an articulator (Fig. 67–18). An articulator consists of two metal platforms that are hinged on one end to simulate the temporomandibular joint. This enables the two models to slide on each other. The amount of movement necessary to achieve class I

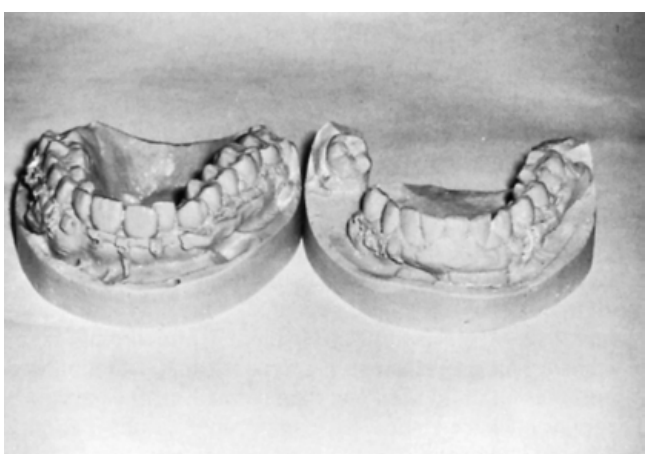


Figure 67–17 Plaster dental study models.

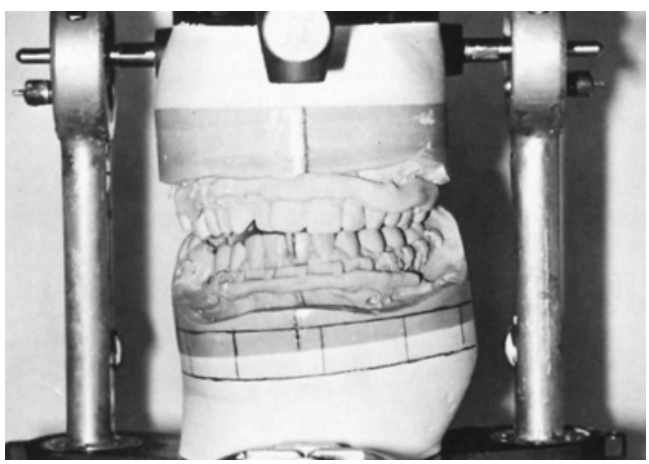


Figure 67–18 Anteroposterior view of plaster dental models mounted on an articulator.

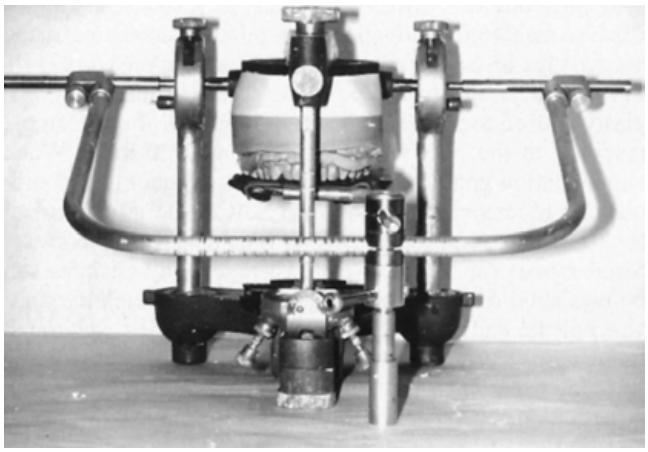


Figure 67–19 Plaster dental model of the maxilla mounted on a facebow. Once mounted on the facebow, the model of the maxilla may be tilted in any direction to allow improved analysis and treatment.

occlusion can be determined. A facebow may also be used to improve the analysis of the occlusion (Fig. 67–19). This consists of a metal mount that is placed on the maxillary component of the articulator. This allows further examination of the relationship of the maxilla to the anterior cranial base. This improves analysis and treatment of the asymmetrical or obliquely oriented bite. Finally, a plan is made by the orthodontist to establish the maximal preoperative occlusal relationship.

Preoperative Workup and Model Surgery

After maximal preoperative occlusal relationships are obtained, the plaster dental models are mounted and the amount of surgical correction is determined. An acrylic, interocclusal wafer splint is finished to be used during surgery. This splint provides an exact template on which the maxillary and mandibular dental arches may fit at the time of surgery.

If a single-jaw surgery is to be performed, a single interdental wafer splint is placed at the conclusion of the jaw movement. The patient is then placed in maxillomandibular fixation (MMF) with the wafer splint in position. If surgery involves both the maxilla and mandible, two splints are fabricated prior to surgery (Fig. 67–20). The first splint (intermediate) is placed to indicate the position of the maxilla after movement but prior to mandibular osteotomy. The second splint (final) is used to identify the occlusion and jaw position after both the maxillary and mandibular osteotomies and movements. This final splint remains in place after repositioning of the entire maxillomandibular complex.

The interdental wafer splint is constructed to indicate the horizontal (anteroposterior) and transverse new position of both jaws after osteotomy and repositioning. However, the interdental splint does not dictate the new vertical (superior–inferior) position of the jaws. The vertical dimension is determined during presurgical planning and is accomplished by ostectomy (for shortening) and bone grafting (for lengthening) prior to final bony movement.

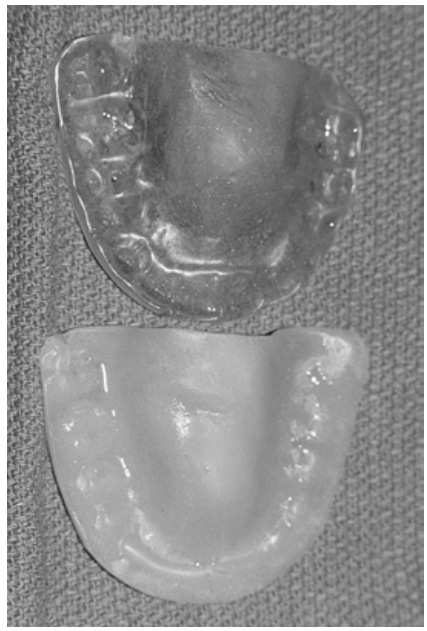


Figure 67–20 Fabricated dental splints for patient undergoing two jaw orthognathic surgery. The intermediate splint (*above*) is used after osteotomy, movement, and fixation of the maxilla and prior to mandibular osteotomy. The final splint (*below*) is used after both jaws are osteotomized, moved, and fixated.

In cases of complex maxillary osteotomies, a splint with full palatal coverage (rather than a wafer splint) is constructed. The full palatal coverage splint enhances stability after bony osteotomy and movement. This type of splint would be used in a patient with maxillary transverse constriction. After a paramedian palatal split, a full palatal coverage splint would be placed.

The initial plan for correcting any dentofacial deformity should include the type of surgery, the amount of jaw movement planned, and whether the deformity is best treated with one- or two-jaw surgery. This treatment plan should specifically address the patient's problem list and will dictate surgical treatment.

Mandibular Prognathism

Various surgical procedures exist for correction of mandibular prognathism, including the vertical-subcondylar osteotomy and the sagittal-split osteotomy. The vertical-subcondylar osteotomy may be performed through either an intraoral or extraoral approach, whereas the sagittal-split osteotomy is usually done intraorally. Each approach and technique has specific advantages and disadvantages. The procedure chosen should be individualized for the specific needs of the patient.

The vertical-subcondylar osteotomy was first performed by Caldwell and Letterman in 1954.[28] Several modifications of the original procedure, which was performed through an external incision, have been made.[27–29] The major advantage of the vertical-subcondylar osteotomy is in avoiding injury to the inferior alveolar nerve. It may be performed through an

intraoral or external incision. The intraoral approach has the advantage of avoiding the external cervical scar and the associated potential injury to the marginal mandibular branch of the facial nerve. However, the intraoral approach is technically more difficult. The more oblique the angulation of the mandibular rami in relation to the sagittal plane, the easier the exposure through the intraoral approach. It is performed through a mucosal incision in the gingivobuccal sulcus from the base of the coronoid to the second bicuspid. Care should be taken to avoid the buccal fat pad. Incision of the periosteum over the anterior aspect of the ramus is accomplished, and the periosteum is elevated posteriorly. The antilingular process is then carefully identified. This landmark is crucial because it is opposite the lingula, which is the entrance of the inferior alveolar neurovascular bundle on the medial aspect of the mandible.

The oblique osteotomy line is carefully marked from the sigmoid notch to the angle of the mandible. This line should be posterior to the antilingular process to avoid injury to the neurovascular bundle. The mandible is then scored with a cutting burr and the osteotomy completed with a reciprocating saw. After the osteotomy is performed bilaterally, the proximal segments are reflected laterally and the distal segment is allowed to recess medially (Fig. 67–21).

Occlusion is checked and the interocclusal wafer splint placed. Intermaxillary fixation is applied and maintained for 6 to 8 weeks. Sometimes rigid fixation of the mandibular segments is used, alleviating the need for intermaxillary fixation.

The external approach for vertical-subcondylar osteotomy has the disadvantage of a cervical scar and the potential for injury to the marginal mandibular branch of the facial nerve. It is the preferred approach for setbacks of greater than 10 mm and for asymmetrical setbacks. It is performed through a 3-cm cutaneous incision in the relaxed skin tension lines approximately one finger breadth below the angle of the mandible. Exposure and subperiosteal dissection are carried out in a similar manner to the intraoral approach.

The sagittal-split osteotomy was first introduced by Obwegeser and Trauner in 1955.[30–32] Modified by Dal Pont in 1961,[33] it is a versatile procedure for correction of mandibular deformities because it can be used for both advancement and setback of the mandible. It is especially satisfactory when used in prognathic patients with an open-bite deformity. It is also well suited for rigid fixation.

A risk of the sagittal-split osteotomy is inferior alveolar nerve injury. The procedure is also associated with avascular necrosis of the proximal bony segment. The teeth adjacent to the sagittal fracture line may also be compromised and lost.

The sagittal-split osteotomy is done intraorally through a mucosal incision similar to that of the vertical-subcondylar osteotomy. Subperiosteal dissection is carried out on both the medial and lateral surfaces of the mandible. The lingula and mandibular foramen are identified on the medial surfaces of the mandible. A horizontal osteotomy is made on the medial cortex 5 mm above the lingula. A vertical osteotomy is then made through the lateral cortex in the region of the second molar tooth. The osteotomies are connected along the oblique line, and separation of the medial and lateral segments is accomplished using a heavy osteotome as a lever. The inferior alveolar neurovascular bundle remains medially with the distal segment. A vertical segment of bone is then removed from the anterior aspect of the proximal lateral bony segment. The width of the segment to be removed should equal that of the setback to be achieved (Fig. 67–22).

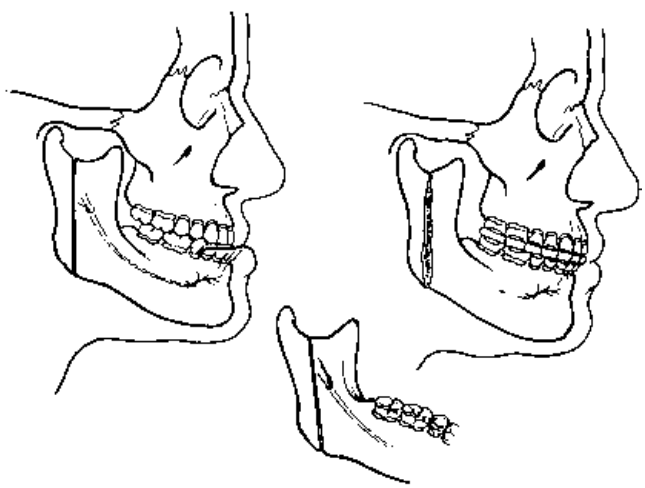


Figure 67–21 Schematic diagrams of the vertical subcondylar osteotomy. The oblique osteotomy line is made from the sigmoid notch to the angle of the mandible. This osteotomy is posterior to the inferior alveolar neurovascular bundle. After bilateral osteotomies are performed, the proximal segments are reflected laterally and a mandibular setback is accomplished.

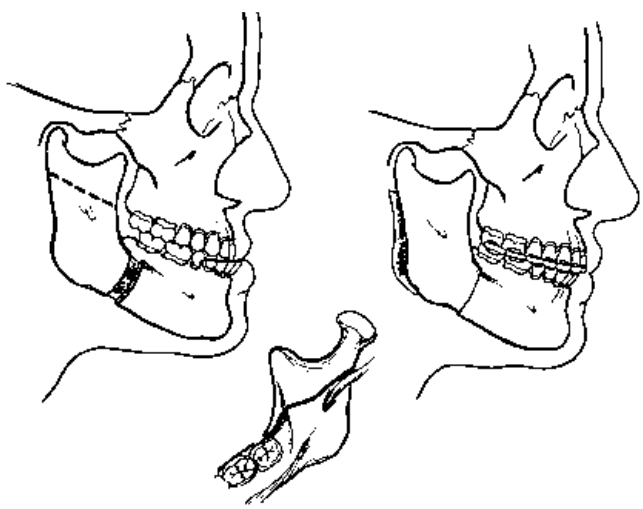
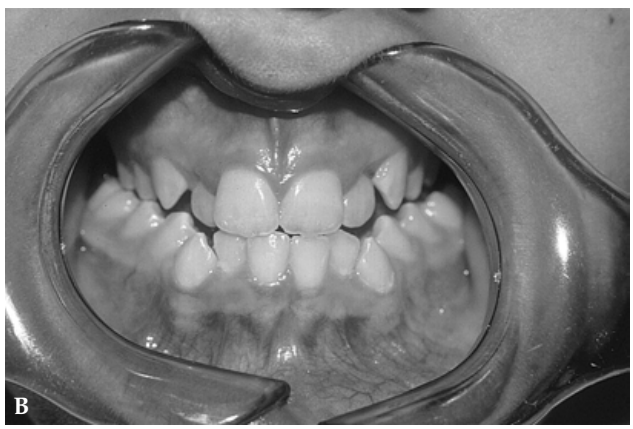


Figure 67–22 Schematic diagrams of the sagittal-split osteotomy. This osteotomy consists of a horizontal osteotomy on the medial cortex 5 mm above the lingula. A second vertical osteotomy is made through the lateral cortex in the region of the second molar tooth. The sagittal split is completed by connecting the two osteotomies along the oblique line. The inferior alveolar neurovascular bundle remains medially with a distal segment.

The contralateral osteotomy is then accomplished in a similar manner, and occlusion is obtained with a wafer occlusal splint. The proximal segments are carefully positioned in each glenoid fossa. Intermaxillary fixation is again placed for 6 to 8 weeks.

The sagittal-split osteotomy is a versatile procedure for mandibular deformities. The distal (i.e., tooth-bearing) segment may be retruded, advanced, or rotated to close an anterior open bite (Fig. 67–23A–L). It is also the procedure of choice in patients requiring two jaw surgeries. The wide surface contact between the proximal and distal segments ensures rapid bone healing; delayed union and nonunion are extremely rare. The main disadvantage of this procedure is the incidence of permanent anesthesia of the lower lip, with reports as high as 45%.[34]



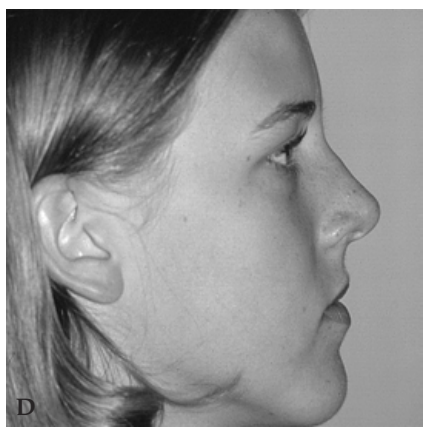


Figure 67–23 **(A, B)** Full-face and occlusion views of a 15-year-old patient with class III malocclusion, bilateral cross-bite, maxillary hypoplasia, and mandibular prognathism. **(C–G)** The same patient after 15 months of orthodontic therapy and prior to two jaw orthognathic surgery. Note that the orthodontic therapy has straightened the teeth and corrected malrotations but has accentuated the class III malocclusion. *(continues on next page)*

Figure 67–23 *(continued)* **(H–L)** Six months after two-jaw orthognathic surgery including Le Fort I maxillary osteotomy, bilateral sagittal split, ramus oteotomy of the mandible with setback, and rotation of the mandible.

Mandibular Retrognathism

Retrognathism, or mandibular deficiency, defines a group of conditions in which the mandible is small, retruded, or both. The occlusion in retrognathism is class II and this malocclusion is generally skeletally based. There are many reasons for this condition, and it may be associated with many syndromes (e.g., Nager's or Treacher Collins).

Many procedures have been developed for treatment of retrognathism. The sagittal-split osteotomy[33] is the most commonly used technique for correction of mandibular deficiency. This procedure allows for correction of significant bony retrognathism; in addition, correction of the soft tissue pogonion generally follows the bony alteration at a 1:1 ratio.

The technique for sagittal-split osteotomy has been well described. A gingivobuccal-sulcus incision is made from the pterygomandibular raphe to the second molar tooth. Subperiosteal dissection is accomplished on both the lateral and medial surfaces of the mandible. Care is again taken to avoid entering the buccal fat pad. The channel retractor is placed along the medial aspect of the ramus to expose the bone above the lingula.

A horizontal bony incision is made with the Lindemann side-cutting burr through the medial cortex of the ramus. This bony cut is made superior to the mandibular foramen, with care taken to protect the inferior alveolar neurovascular bundle. The vertical lateral osteotomy is performed at an oblique angle in the region of the second or third molar. The two osteotomies are joined on the anterosuperior margin with a reciprocating saw.

A thin osteotome is used to complete the sagittal split. The osteotome should angle toward the buccal cortex of the mandible, hugging the medial surface of the lateral bony table. This helps avoid injury to the inferior alveolar nerve. A similar procedure is performed on the contralateral side. The distal segment is then positioned with the condyles of the proximal segments held in the glenoid fossae. An acrylic wafer splint is again used to position the dental arches, and intermaxillary fixation is performed. If internal rigid skeletal fixation is used, intermaxillary fixation is not necessary (Fig. 67–24A–G).

Temporary or permanent injury to the inferior alveolar nerve is a recognized complication of sagittal-split osteotomy. Permanent lower-lip anesthesia has been reported in 2 to 45% of cases.[34] Relapse of some or all of the mandibular retrusion is also a known complication. Relapse is usually secondary to pull of the suprahyoid musculature. It may also result from improper positioning of the condylar head in the glenoid fossa at the time of mandibular advancement.

Some patients may have normal occlusion before surgery but a suboptimal aesthetic relationship between the chin and

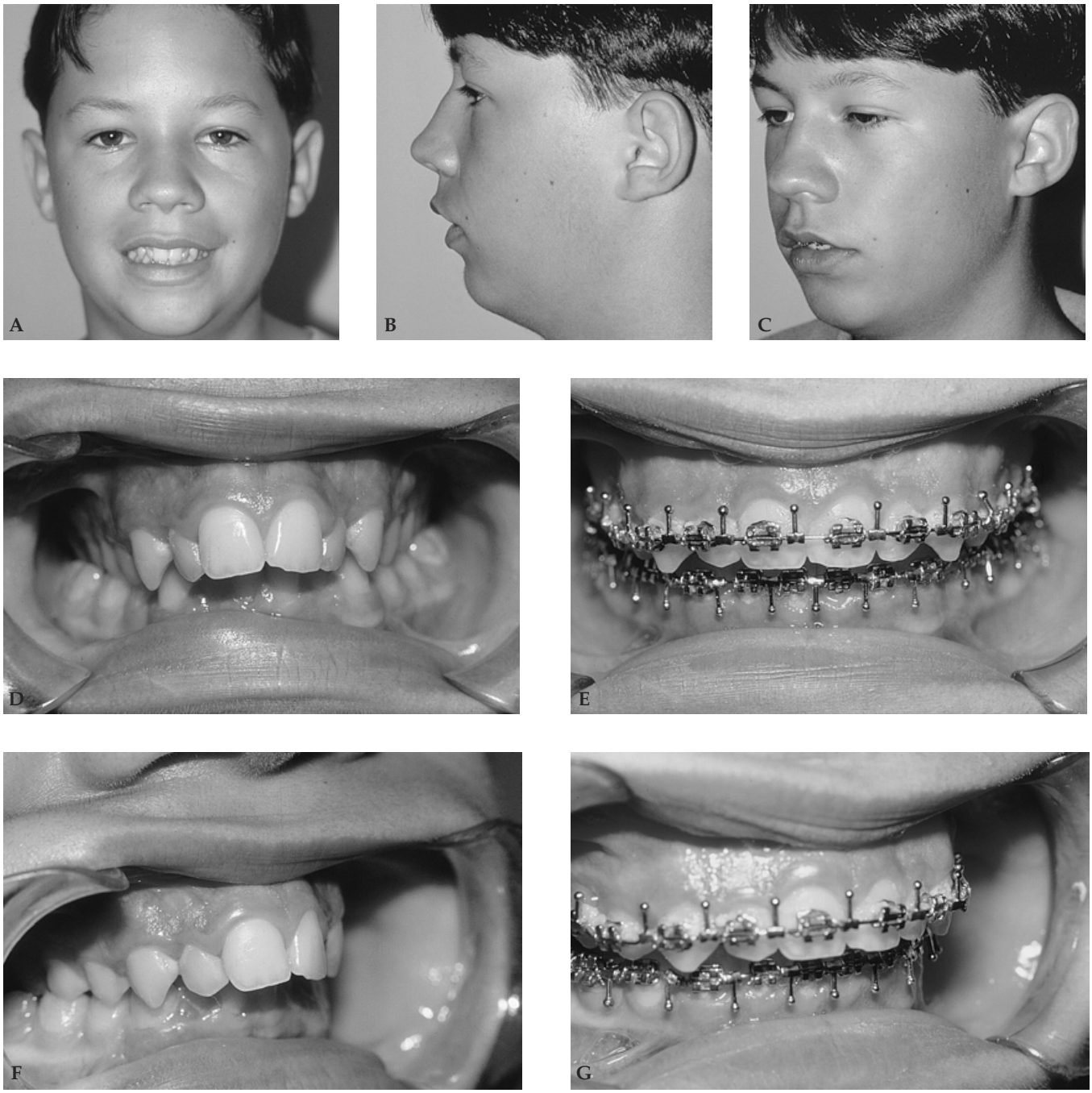


Figure 67–24 **(A–C)** A 15-year-old boy with class II malocclusion maxillary constriction, and retrognathia. **(D, F)** Preorthodontic occlusal views of the patient. **(E, G)** Postorthodontic two jaw occlusal views after 12 months of orthodontic therapy. The patient ultimately underwent mandibular advancement and advancement genioplasty.

the remainder of the face. This can be determined by dropping a vertical line from the mucocutaneous (vermilion) border of the lower tip (see Fig. 67–16). The soft tissue pogonion should almost reach this vertical line in men and is located just posterior to the vertical line in women. If the soft tissue pogonion falls significantly behind this line, microgenia may be diagnosed. In patients with mandibular retrusion and a normal occlusal relationship, osseous genioplasty or chin augmentation may be performed to improve facial harmony. The decision to perform genioplasty versus placement of an

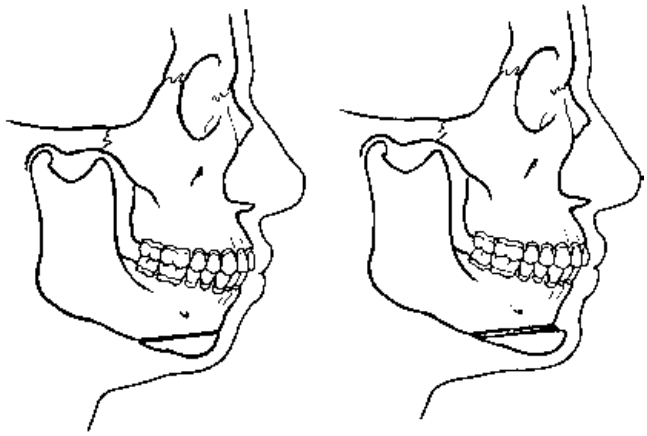


Figure 67–25 Schematic diagram of a sliding genioplasty and anterior chin advancement.

Figure 67–26 **(A)** Preoperative lateral photograph of a patient with mild class II malocclusion, retrognathia, and moderate to severe microgenia. **(B)** Postoperative lateral photograph of the patient after sliding genioplasty and anterior chin advancement.

alloplastic chin implant has been the subject of significant controversy. The choice should be made by the patient based on the surgeon's comfort with each procedure and the patient's specific deformity.

Horizontal sliding genioplasty has the advantage of achieving excellent aesthetic results without the potential risks of an alloplastic chin implant. It is performed through an intraoral gingivobuccal incision extending from one bicuspid to the other. A horizontal incision is made below the tooth roots and subperiosteal elevation is accomplished. The mental nerves and inferior mandibular border are not usually exposed. A horizontal incision is outlined anterior to the emergence of the mental nerves. Horizontal incision is made with a series of burr holes and these are connected with a sagittal saw or osteotome. The distal segment may then be repositioned anteriorly (Fig. 67–25).

The amount of anterior chin advancement is limited by the need to maintain good bony contact between the proximal mandible and the advanced distal segment. In extreme cases a bony onlay graft may be necessary to achieve adequate advancement. Stabilization of the bony segments may be accomplished with interosseous wiring or with lag-screw rigid fixation, Bell and Dann[21] demonstrated a 0.8:1 ratio of soft tissue response to skeletal change after sliding genioplasty (Fig. 67–26).

Chin augmentation has the advantage of being technically simple and entirely reversible. It may be performed through an intraoral or an external (submental) incision. A pocket is made centrally just above the periosteum to accommodate the implant. The implant may be tucked under the periosteum laterally to assist in fixation. Implants may be made of a variety of alloplastic materials, including silicone, Silastic, and porous materials such as Proplast (Vitek, Houston, TX). They may also be homografts (e.g., irradiated rib cartilage) or autografts (e.g., calvarial bone). Chin augmentation is often a useful adjunctive procedure to rhinoplasty or surgical rejuvenation of the lower two thirds of the face (Fig. 67–27).

Maxillary Retrusion

Facial imbalance may also result when the middle third of the face is positioned suboptimally. The maxilla may be maldeveloped or malpositioned. It may be normal in architecture but malpositioned anteriorly or posteriorly (maxillary retrusion). Maxillary retrusion may also be associated with maxillar hypoplasia. Maxillary retrusion may be associated with either normal occlusion or class III malocclusion. It may also be present with a normal mandible or simultaneous mandibular malposition.

Diagnosis of midface retrusion may be difficult when the occlusion is normal or when there is simultaneous mandibular deformity. Cephalometric radiography is essential for diagnosis. An *SNA* angle of less than 79 degrees with a normal *SNB* angle establishes the diagnosis of maxillary retrusion. It is important to analyze not only the position of the skeleton but also its particular contour in patients with suspected maxillary retrusion. The maxillary deformity may be present inferiorly only, with abnormal angulation of the maxillary alveolar shelves. The entire maxilla may be hypoplastic or retruded, requiring attention to both the inferior and superior aspects of the maxilla.

Figure 67–27 **(A)** Preoperative anteroposterior view photograph. **(B)** Postoperative anteroposterior photograph of the patient 6 months after rhytidectomy, blepharoplasty, and alloplastic chin augmentation. **(C)** Preoperative left lateral photograph. **(D)** Postoperative result. Left lateral view 6 months after surgery. **(E)** Preoperative left oblique view. **(F)** Postoperative left oblique view.

When maxillary hypoplasia exists and occlusion is normal, onlay grafting is appropriate. Augmentation may be performed with autologous cranial or iliac bone or may be achieved with alloplastic materials. Maxillary and premaxillary augmentation is a useful adjunct to facelift and rhinoplasty surgery.

In patients with retrusion of the inferior aspect of the maxilla, a standard Le Fort I osteotomy is indicated (Fig. 67–28).[33] This is a horizontal cut through the walls of the maxillary sinuses and the nasal septum, coupled with separation of the maxilla from the pterygoid plates. A gingivolabial-sulcus incision is made from the level of one second molar tooth to the opposite second molar. Periosteal elevation over the anterior nasal spine, pyriform aperture, and face of the maxilla is then accomplished. A decision must be made regarding the exact level at which to make the horizontal Le Fort I osteotomy. The osteotomy is started in the lateral wall of the pyriform aperture. The medial and lateral walls of the maxillary sinuses are cut, with the lateral cuts extending to the pterygomaxillary fissure. A curved osteotome is positioned in the pterygomaxillary fissure inferiorly and driven medially to separate the alveolar segment from the skull base. The maxilla is then down-fractured and mobilized.

Advancement of the maxilla into the predetermined position is then accomplished. An acrylic, occlusal wafer

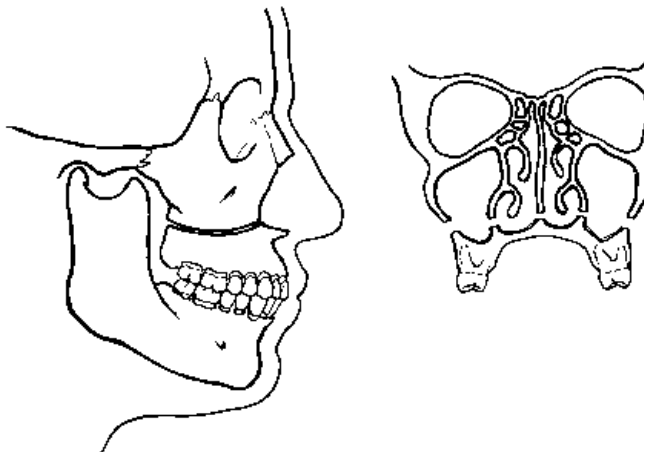


Figure 67–28 Schematic diagram of a standard Le Fort I osteotomy of the maxilla. This osteotomy consists of cuts through the maxillary sinus, nasal septum, and pterygoid plates. This versatile osteotomy can be used for retrusion, advancement, or intrusion of the maxilla.

Figure 67–29 Intraoperative view of a patient undergoing rigid fixation of the maxilla after Le Fort I maxillary osteotomy and advancement. The plate used is a T-shaped, stepped plate for fixation of the maxilla.

splint is used, and the maxilla is wired to the mandible. The mandibular–maxillary complex may then be moved as a single unit. It is crucial to ensure that the mandibular condyles are well seated in the glenoid fossa before fixation of the maxilla. The maxillary segment may then be stabilized using miniplate rigid fixation.[7] Miniplates should be applied at the thickest portion of the maxilla at the pyriform aperture and zygomatic buttresses (Fig. 67–29). An alternative method of fixation is to use intermaxillary wires, with the acrylic occlusal splint as a guide. Controversy exists regarding posterior stabilization of the maxillary segments with bone grafts to prevent relapse of the retrusion. Some surgeons believe that bone grafts help maintain the alveolar segment in their advanced position.

Vertical Maxillary Dysplasia

The vertical maxillary component in the analysis and treatment of dentofacial deformities has become more important during the past 20 years.[35] Vertical maxillary excess is characterized by a short upper lip and excessive incisor show at rest. An anterior open bite may be present. Vertical maxillary deficiency is characterized by an apparent excess of upper-lip length, with a lack of incisor display at rest. The ideal lip position at rest shows approximately 2 to 3 mm of upper incisor. In both forms of vertical maxillary dysplasia, this relationship is disturbed.

Treatment of vertical maxillary dysplasias is usually accomplished using Le Fort I osteotomies. When the vertical dimension of the maxilla is excessive, superior positioning of the maxilla (maxillary intrusion) is accomplished. Bone may then be removed from the lateral aspect of the piriform rim to accommodate maxillary intrusion[20] (Fig. 67–30). Treatment of maxillary deficiency (short-face syndrome) is accomplished by downfracture of the maxilla and placement of interpositional bone grafts. In both instances, adequate bone contact must be maintained after osteotomy to ensure good bony healing.

Transverse Maxillary Deficiency

Maxillary constriction was first described by Kole in 1959.[36] The maxillary corticotomy, in which the cortex alone is cut, aids in expansion of the palate. After corticotomy, the contour of the maxilla may be changed by using a palatal expander with a jackscrew appliance (Fig. 67–31). Surgically assisted rapid expansion is an alternative to segmental (multiple-piece) Le Fort osteotomies for correction of transverse maxillary deficiency.

SUMMARY

The goal in plastic and reconstructive surgery is to maximize form and function. The convergence of aesthetic and reconstructive concerns is most obvious in the patient with dentofacial deformities. With this in mind, the maxillofacial surgeon attempts to achieve balanced facial proportion. Consideration must be given to the teeth and how they relate to the bones that house them, and, most importantly, to the soft tissues that drape over this skeletal framework. Evaluation of dentofacial deformities should occur in a careful, systematic fashion, including dental, skeletal, and soft tissue analysis. Surgical correction is then performed and facial harmony reestablished.

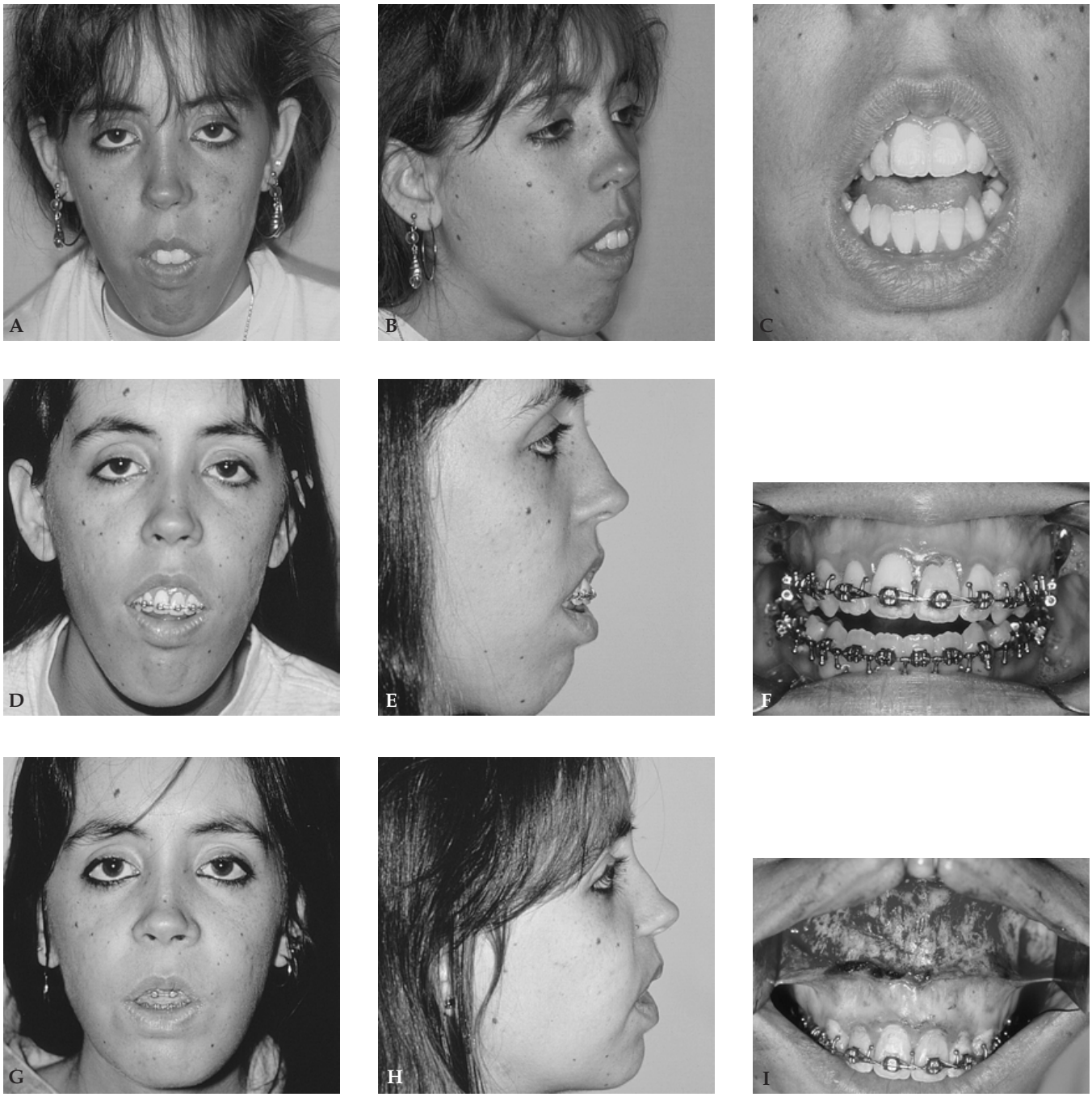


Figure 67–30 **(A–C)** Preorthodontic photographs of an 18-year-old patient with myotonic dystrophy, severe vertical maxillary excess, and premature posterior contact of the occlusion. The patient has a severe open-bite deformity and labial incompetence. **(D–F)** An 18-year-old patient with myotonic dystrophy after preoperative orthodontic therapy in preparation for Le Fort I maxillary osteotomy with impaction. **(G, H)** Frontal and lateral photographs of the same patient after Le Fort I maxillary osteotomy with impaction and genioplasty with shortening of the chin. **(I)** Reveals intraoperative view of the maxilla showing a severely excessive maxilla in vertical dimension.

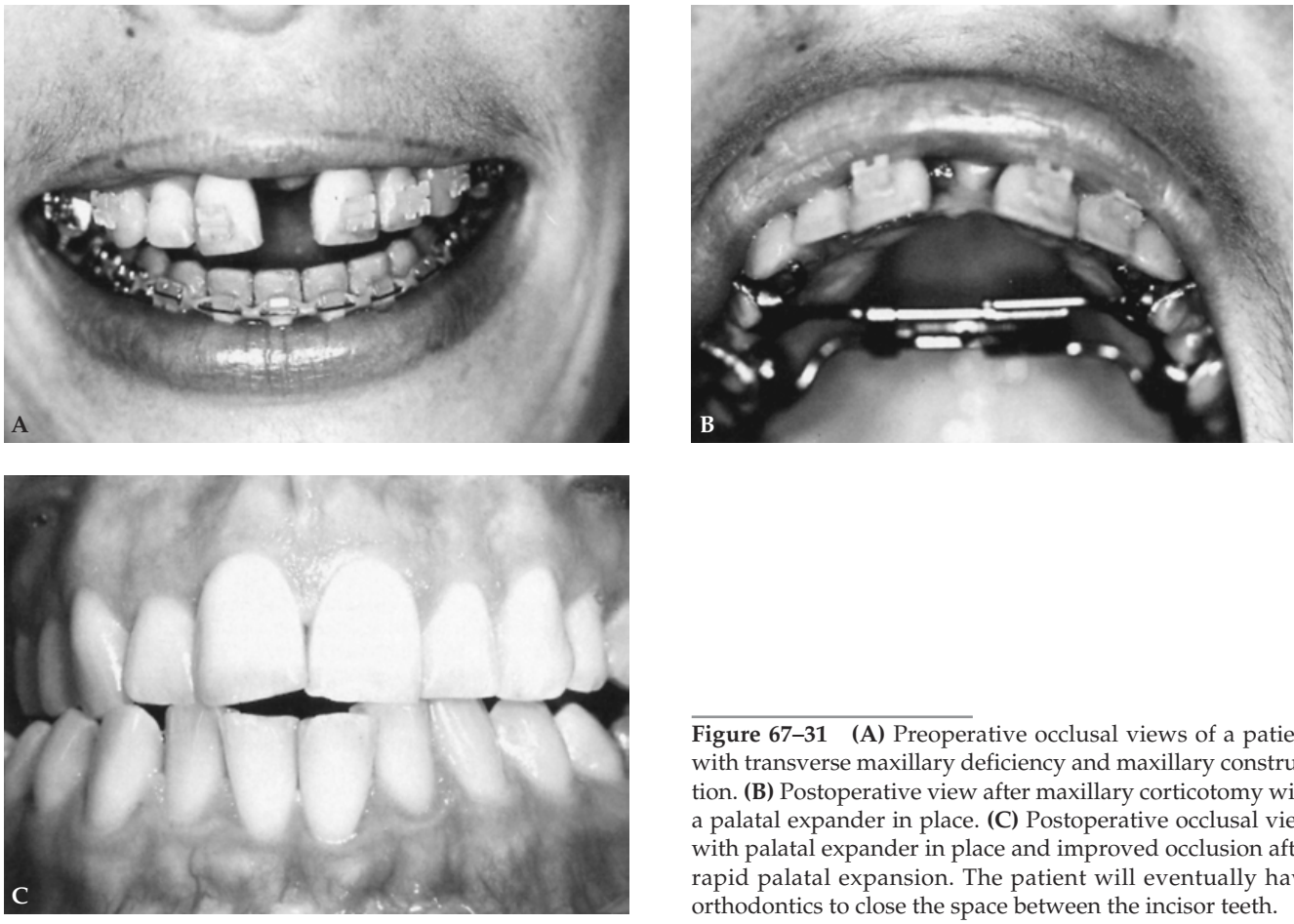


Figure 67–31 **(A)** Preoperative occlusal views of a patient with transverse maxillary deficiency and maxillary construction. **(B)** Postoperative view after maxillary corticotomy with a palatal expander in place. **(C)** Postoperative occlusal view with palatal expander in place and improved occlusion after rapid palatal expansion. The patient will eventually have orthodontics to close the space between the incisor teeth.

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Chapter 68

Hemifacial Microsomia: Classification and Management Protocols

Karin Vargervik

The mandible, the temporomandibular joint (TMJ), and the outer and middle ear structures are derived from the first and second branchial arches. Disruption of cell migration or proliferation such as could occur by a vascular insult have been implicated as etiologic factors in hemifacial microsomia (HFM), which is the most commonly occurring congenital anomaly affecting these structures.[1] Animal models mimicking clinical findings in humans have been developed by various experimental methods.[2–4]

HFM is primarily a unilateral congenital birth defect with involvement of several skeletal, neuromuscular, and other soft tissue components of the first and second branchial arches. The condition includes a wide spectrum of craniofacial anomalies and may also have ocular, renal, spinal, and cardiac components. Dysmorphologists and others have created a variety of terms to describe the broad spectrum of phenotypes, but HFM remains the most widely used name. Other terms include oculoauriculovertebral (OAV) spectrum, craniofacial microsomia, otomandibular dysostosis, and lateral facial dysplasia.[5–7] Oculoauricolovertebral dysplasia may be considered a separate category of HFM, also referred to as Goldenhar syndrome. The additional characteristics of this type are epibulbar dermoids and cervical spine abnormalities. There is also a higher incidence of oronasal clefting in this type, and most likely there are specific etiologic factors causing this constellation of birth defects. HFM is the second most common congenital craniofacial anomaly after cleft lip and palate. The most frequently quoted incidence estimate is 1 in 5600 live births.[6,8] There seems to be agreement that there is male predominance of 3:2 and a right side predominance of 3:2 as well.[9] For an extensive overview of the very heterogeneous phenotypes in this spectrum, the reader is referred to the work of Cohen et al[5] and Peterson-Falzone.[7] In the mildest form of HFM, the only clinical manifestation may be ear tags with or without malformed ears. The most severe cases may present with malformed ears, temporal bone involvement including missing glenoid fossa, malformed or absent joint structures and mandibular ramus including both coronoid and condylar processes (Fig. 68–1).

CLASSIFICATION BY PHENOTYPE

Tenconi and Hall[10] distinguished between the classic type, microphthalmic type, bilateral asymmetrical type, complex with limb deformity type, frontonasal type, and Goldenhar type. The "infant of diabetic mother" type was recently added.[11–13] Of the 67 individuals included in the Tenconi and Hall study, 14.9% had some type of cardiac malformation, 5.9% had renal system malformations, 17.6% had microcephaly, and 13.3% had developmental delay. Cervical spine abnormalities were not assessed by them, but our finding and those of others indicate that close to 50% have some type of cervical spine abnormality.[14–17]

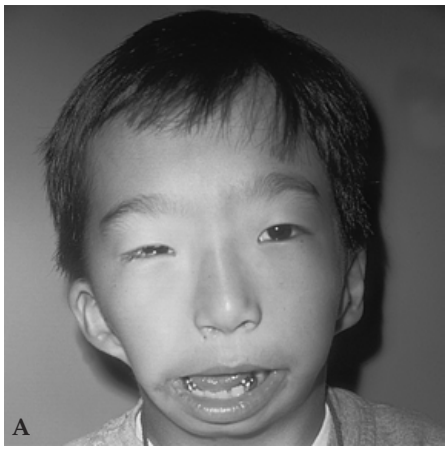
The OMENS classification represents an attempt to include all of the prominent features of HFM: O = orbit, M = mandible, E = ear, N = facial nerve, and S = skeletal. Each entity is graded from 1 to 3 according to severity. Others have suggested that additions, such as the presence of noncraniofacial involvement, be annotated by an asterisk (OMENS*).[18–20]

The SAT classification system addresses only three main features: S = skeletal, A = auricle, and T = soft tissue.[21] In this system, there are five levels of skeletal deformity (S1 to S5), four levels of auricular deformity (A0 to A3), and three levels of soft tissue deformity (T1 to T3). As an example, they indicate that an individual with minimal deformity might be classified as S1A0T1 whereas an individual with severe deformity would be S5A3T3. It does not appear that this classification system has clear advantages over the OMENS system, and it falls short of including all of the most essential elements.[20]

CLASSIFICATION BY MANDIBULAR INVOLVEMENT

In this chapter, the emphasis will be on the mandibular and temporomandibular bone and joint malformations and malfunctions. The classification system we use is an amalgamation of the classifications described by Pruzansky,[22] Kaban and co-workers,[23] and Harvold, Vargervik, and coworkers.[24,25] Describing middle and lower face involvement, it is based on discrete findings of the presence or absence of critical elements of the mandible and temporomandibular joints and consists of types I, IIA, IIB, and III.

In type I, all parts of the affected side of the mandible and the attached muscles are present but are hypoplastic to varying degrees (Fig. 68–2). The glenoid fossa is usually missing, and translatory joint movement is minimal. Rotational movement of the condyle is usually not impaired, resulting in hinge movement on the affected side. During jaw opening, the mandible shifts to the affected side as translatory movement occurs on the



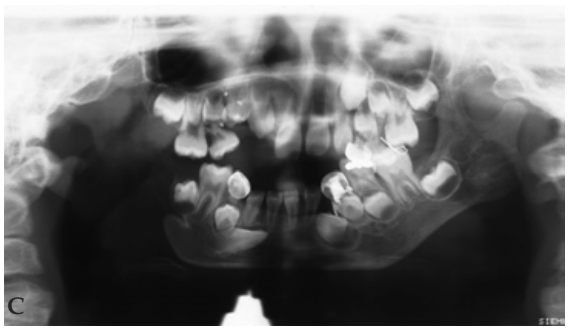
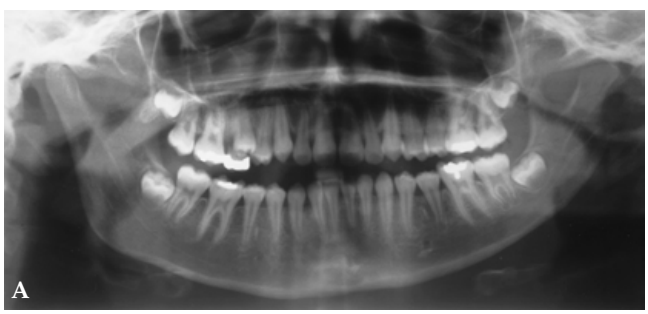


Figure 68–1 **(A)** Goldenhar type of malformation with bilateral epibulbar dermoids, right macrostomia, chin deviation to right, deficient soft tissue development on right, mild ear deformity. **(B)** The lateral headfilm shows mandibular and cervical spine malformations. **(C)** The panoramic radiograph demonstrates bilateral mandibular involvement with type I malformation on the left side and type III on the right, with the entire mandibular ramus missing.



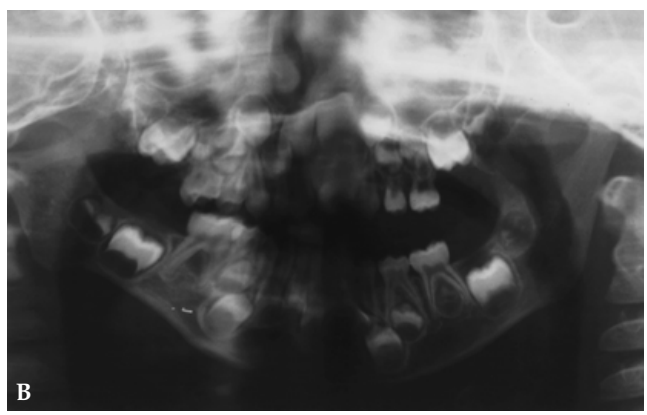


Figure 68–2 **(A)** Left side type I, right side normal. **(B)** Right side type I with a very underdeveloped ramus, but all parts present.

contralateral side only. Frequently, the contralateral condyle moves excessively during maximum jaw opening.

Type IIA is characterized by a cone-shaped, anteriorly and medially displaced condyle, missing glenoid fossa, but presence of all masticatory muscles with varying degrees of hypoplasia (Fig. 68–3). The jaws and face are usually highly asymmetrical. In type IIB, the condyle is missing along with the lateral pterygoid muscle (Fig. 68–4). The coronoid process is usually small and the temporal muscle hypoplastic. Jaw and facial asymmetry are usually quite marked.

Type III represents congenital absence of the entire ramus of the mandible and most of the masticatory muscles (Fig. 68–1C). The mandible can be guided freely into various positions as the movements of the affected side are not limited by either joint structures or muscles and ligaments. All joint structures are missing, and frequently the temporal region is flat or even concave, resulting in a poor platform for the ear, which usually is affected and requires reconstruction. Tables 68–1 and 68–2 summarize the morphologic and functional characteristics of HFM.

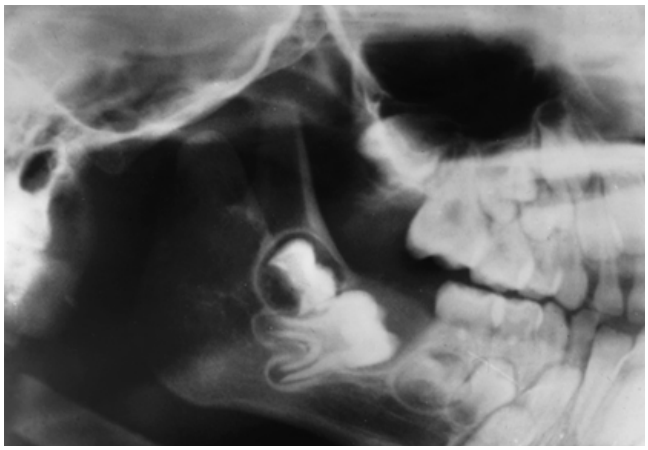


Figure 68–3 Type IIA mandible with cone-shaped, anteriorly displaced condylar process.

NORMAL MANDIBULAR GROWTH

In the embryo, mandibular bone formation starts in association with Meckel's cartilage and around the developing tooth buds. The osseous areas expand, coalesce, and become the body of the mandible. The neuromuscular and vascular networks are well established before bone formation starts and are presumably prerequisites for osteogenesis. During these early stages of development, the mandibular structures are carried forward by the growing Meckel's cartilage. The various muscle masses become attached to or included in the developing bone, probably by the same mechanisms by which muscle reattachment occurs.[26] The posterior muscles extending into the temporal region provide the environment for development of the ramus with the condylar and coronoid processes. The condylar process and the developing TMJ structures in association with the lateral pterygoid muscle presumably take over the propulsive action, which up to

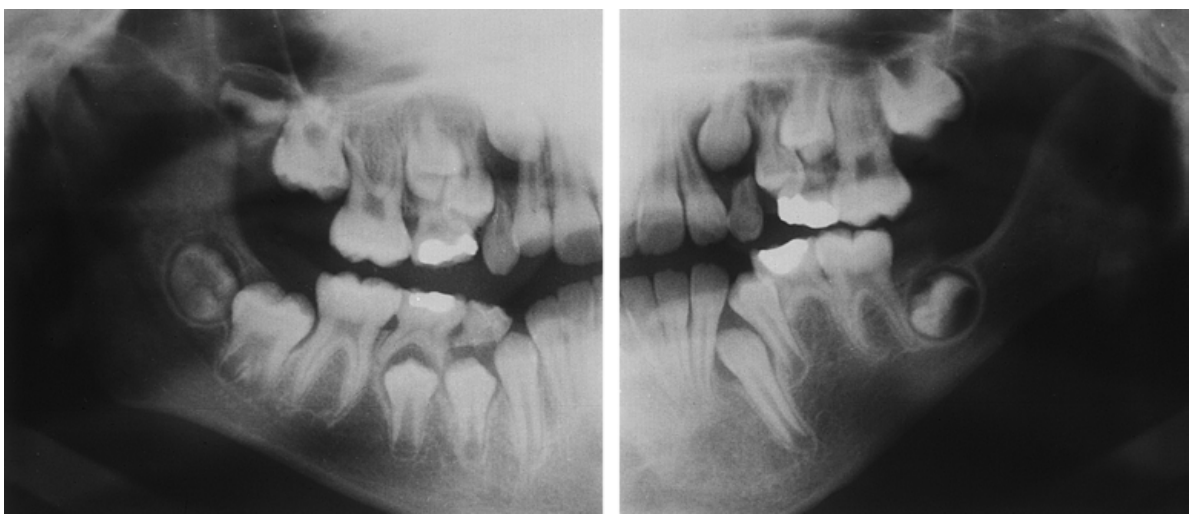


Figure 68–4 Type IIB mandible with only one ramus extension.

TABLE 68–1 Morphologic Characteristics of the Mandible and Associated Muscles in Hemifacial Microsomia

	Bony characteristics				Muscle characteristics		
Mandibular type	Glenoid fossa	Condyle	Coronoid process	Gonial area	Masseter and med. pterygoid	Lateral pterygoid	Temporalis
I	Absent	Present but small	Present	Present to varying degree	Present but small	Present	Present but small
IIA	Absent	Cone-shaped and displaced	Present	Present	Present	Present	Present
IIB	Absent	Absent	Present	Absent	Rudimentary	Absent	Present
III	Absent	Absent	Absent	Absent	Rudimentary or absent	Absent	Rudimentary

TABLE 68–2 Functional Characteristics of Hemifacial Microsomia

Mandibular type	Jaw movements			Other		
	Rotation	Translation	Deviation on opening	Palate elevation	Facial nerve involvement	Hearing
I	Unrestricted	Usually none	Toward affected side	Less on affected side	Varies	Loss on affected side
IIA	Unrestricted	None	Toward affected side	Less on affected side	Varies	Loss on affected side
IIB	Unrestricted	None	Toward affected side	Less on affected side	Varies	Loss on affected side
III	Unrestricted	None	Toward affected side	Less on affected side	Varies	Loss on affected side

that point has been provided by Meckel's cartilage. This new propulsive mechanism continues postnatally throughout the growth period and presumably functions by sensorimotor feedback, primarily from the joint structures.[27] It appears that the periodic proliferation of condylar cartilage toward the glenoid fossa elicits activity in the lateral pterygoid muscle, which advances the condyle, thereby maintaining the optimal joint space. The various areas of the mandible remodel as the jaw is brought forward relative to its muscles and other structures. Bone apposition, which replaces cartilage in the interface between condylar cartilage and bone, appears to occur only when the cartilage is proliferating.[28] The condylar cartilage is therefore a controlling factor during growth.

GROWTH IN HEMIFACIAL MICROSOMIA

In patients with HFM, the very structures that are essential to mandibular growth are affected; therefore, impairment of mandibular growth is always present, varying in degree according to the primary tissue deficiencies. Characteristically, in most individuals with HFM, the affected side of the mandible and the associated muscles grow less than the contralateral side. However, it is interesting to note that even in type III where the entire ramus is missing, the length of the mandibular body increases as bone forms around each successively developing tooth bud. This side of the mandible is gradually brought forward to a small degree, presumably by the presence and function of the tongue and tissues in the floor of the mouth. Because the main propulsive factors in advancing the mandible (condylar cartilage and lateral pterygoid muscle) are rudimentary or missing, it is understandable that jaw and facial asymmetry may increase rather than improve with growth.

OVERALL MANAGEMENT

The overall team management for a child with HFM involves attention to respiration, hearing, speech and language development, psychosocial issues, and management of associated problems, such as cervical spine fusions, scoliosis, epibulbar dermoids, and other eye problems. Every child with HFM should have a renal sonogram, cardiac evaluation, spinal radiographs, CT scans of ear structure, ophthalmology consultation, and management and intervention as needed.

TREATMENT OF STRUCTURAL MALFORMATIONS AND DEFICIENCIES

Phase I: Early Treatment Intervention for Jaw Asymmetries

Our rationale for early treatment has been that some of the secondary unfavorable adaptations to deficient growth of the mandible could be prevented and that, where condylar and coronoid structures exist (types I and IIA), additional bone apposition could be achieved by providing a substitute for the normal advancing mechanisms.[29–32] A functional appliance of the activator type, with or without a buccal shield, has therefore been used routinely in our HFM patients as an initial treatment phase. Generally, this treatment is started at the time of the eruption of the 6-year molars. The expectations from this treatment phase include increased length of the mandible on the affected side and reduced vertical development of the maxilla on the contralateral side, resulting in an open bite (Fig. 68–5).

Phase II: Mandibular Surgery

The second treatment phase is surgical lengthening or reconstruction of the affected mandibular ramus. If done during the mixed dentition stage, it is often possible to avoid a surgical procedure on the maxilla by minimizing the secondary growth inhibition on the affected side.[25,30,33] The exceptions are situations where the maxillary dental midline is severely deviated from the facial midline and orthodontic correction of the dental midline discrepancy is impossible, or where the vertical maxillary development on the contralateral side is excessive. It is generally not possible to correct a severely canted maxillary occlusal plane until an open bite has been created by surgical repositioning of the mandible. If maxillary surgery is anticipated due to severity of maxillary involvement, both jaw pro-

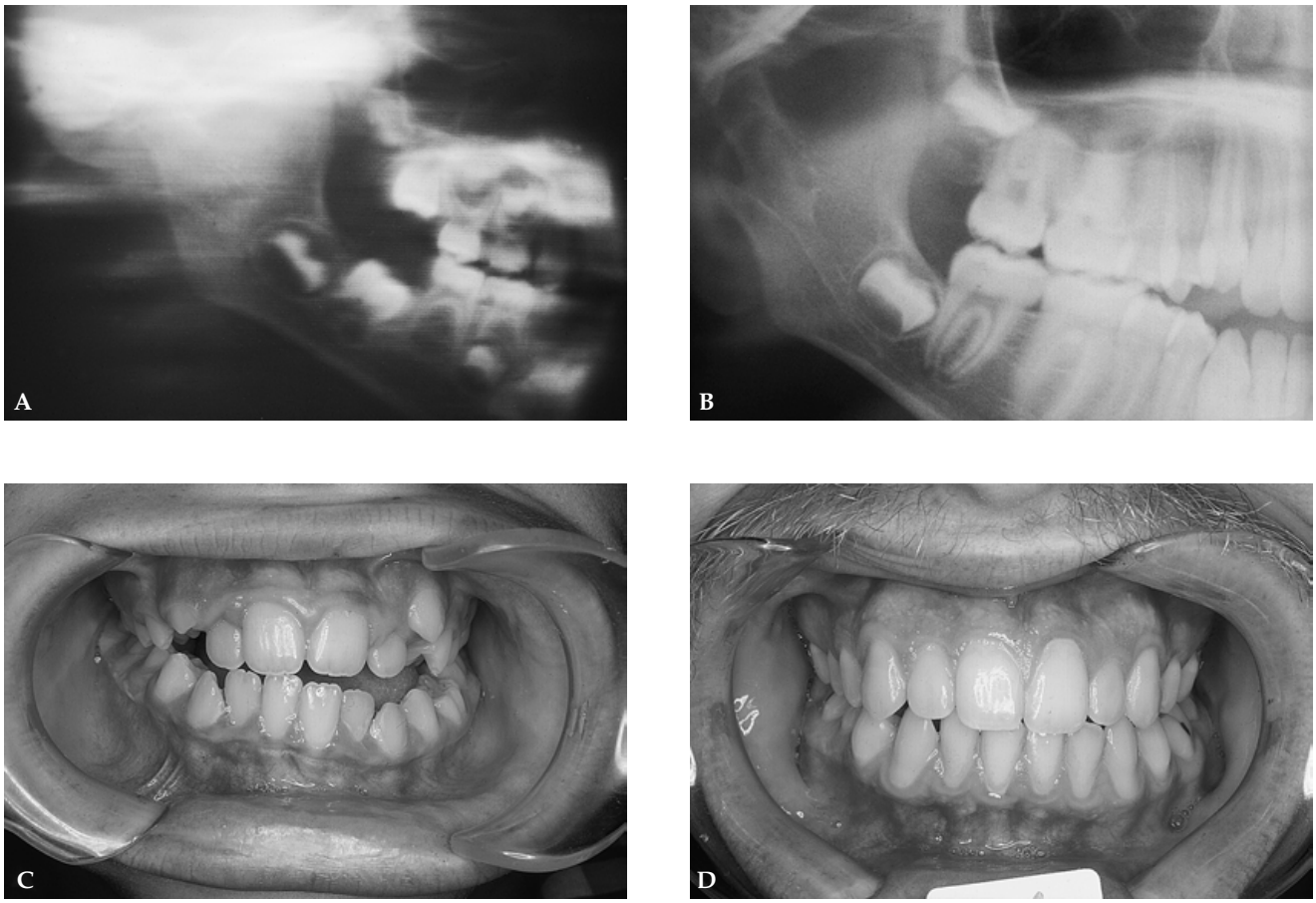


Figure 68–5 **(A)** Age 6 years. Treatment with a functional appliance was started when the 6-year molars erupted. **(B)** Age 14 years. Note size increase and condylar development. **(C)** Open bite on contralateral side after functional appliance use. **(D)** Final occlusion after right mandibular lengthening and orthodontic treatment.

cedures can be postponed until most of the child's growth is complete. The more general growth there is remaining in the youngster, the higher the probability that the asymmetry will redevelop due to less growth on the reconstructed side than on the contralateral side of the mandible. A transplanted costochondral graft may also grow excessively, thereby creating an asymmetry to the opposite side. Following the mandibular surgery, the position of the mandible relative to the maxilla is secured by a bite registration splint and interarch fixation wires. Depending on the type of mandibular surgical procedure, the length of the fixation may vary from 2 weeks, if rigid or semirigid fixation was achieved, to 6 weeks if the entire mandibular ramus has been reconstructed. Following removal of the interarch fixation wires, the splint is attached to the maxilla with elastics to allow removal for cleaning. Lightweight guiding elastics are placed to the mandible to ensure precise and controlled mandibular movements into the splint.[25,30] This is a period for reattachment of muscles and ligaments, retraining of the neuromuscular system to a new position of the mandible, and formation of new bone as the bone graft is gradually replaced and remodeled. This very important adjustment period should last for several weeks. The progression of new bone formation and remodeling is monitored by panoramic radiographs. Continued growth of the reconstructed ramus/condyle unit is still unpredictable, and many factors are involved.[34,35]

Lengthening of the affected manibular ramus by distraction has become popular lately.[36–38] Because this technique has both advantages and disadvantages, at this stage cases should be selected with care. When distraction osteogenesis can be applied in such a way that significant muscle lengthening is achieved, the approach will have a major advantage over other lengthening procedures in selected cases.

Phase III: Closure of Open Bite on the Affected Side

The postsurgical treatment phase blends into the next phase if it is expected that the unilateral maxillary underdevelopment can be corrected without a surgical procedure. The open bite created by lengthening of the affected mandibular ramus is protected by a maxillary bite plate. Auxiliary springs are placed on this plate for active extrusion of the maxillary teeth on the affected side.

Figure 68–6 **(A)** Before starting treatment, age 12 years. **(B)** After mandibular and maxillary reconstruction, orthodontic treatment, and soft tissue augmentation. **(C)** Final occlusion.

Phase IV: Orthodontic Treatment

Full orthodontic treatment is started after eruption of the permanent teeth and after most of the jaw growth is completed. Standards for treatment outcome are the same for these patients as they would be for any other orthodontic patient. It is very important not to resort to interarch elastic mechanics that may contribute to redevelopment of the jaw asymmetry. It should be recognized that it may be very difficult, if not impossible, to correct unfavorable dentoalveolar adaptations completely. This is a particular challenge in the presence of an asymmetrical palate and tongue.

ADDITIONAL SURGICAL PROCEDURES

Reconstruction of a malformed or missing ear usually requires three surgical procedures, which are generally started at about age 6 years. Additional surgical procedures are often needed to correct bony chin asymmetry, nasal septal deviation, and soft tissue deficiency. The asymmetrical genioplasty and nasal septal reconstruction are done simultaneously. As the very last procedure, soft tissue augmentation may be indicated. If the soft tissue asymmetry is mild, the transferred tissue may be a double dermis graft obtained from the buttock.[24] However, if more tissue bulk is needed, a muscle flap transfer by microvascular procedures may be the choice[39] (Fig. 68–6). Tables 68–3 and 68–4 summarize treatment interventions in HFM.

TABLE 68–3 Sequential Treatment Procedures in Hemifacial Microsomia

- Ear reconstruction (three procedures, starting at age 6–7)
- Presurgical jaw orthopedic treatment (phase I)
- Mandibular surgery (phase II)
  - Lengthening/reconstruction of ramus with or without bone graft
  - Interarch fixation with splint
  - Controlled jaw movements with splint and guiding elastics
- Closure of open bite (phase III)
  - Extrusion of maxillary teeth
  - Alternatively, surgical correction of maxilla
- Orthodontic treatment (phase IV)
- Additional surgical procedures (optional phase V)
  - Asymmetric genioplasty and nasal septal reconstruction
  - Soft tissue augmentation

TABLE 68–4 Treatment Procedures for Hemifacial Microsomia by Age and Type

Type	0–6 yr	6–12 yr	12–14/15 yr	>15 yr
I	Team evaluations Hearing aid if needed Ear tag removal Monitor eruption of teeth	Team evaluations Monitor eruption of teeth Treatment phases 1, 2, 3. May postpone phase 2 (mandibular surgery) if response to phase 1 (jaw orthopedic treatment) is favorable. Stages 1, 2, 3 ear reconstruction.	Team evaluations Phase 4 treatment (treatment phases 1, 2, 3 if not done previously)	If needed: Asymmetric genioplasty Rhinoplasty Soft tissue augmentation
IIA	Same as for I	Same as for I Mandibular surgery almost always necessary	Same as for I	Same as for I
IIB	Same as for I	Same as for I Mandibular surgery always necessary	Same as for I	Same as for I
III	Same as for I and Macrostomia and ramus reconstruction if functional impairments dictate	Same as for I Ramus reconstruction always necessary	Same as for I	Same as for I

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Chapter 69

Velopharyngeal Inadequacy

Marshall E. Smith, Steven D. Gray, and Judy Pinborough-Zimmerman

VELOPHARYNGEAL ANATOMY AND FUNCTION

The velopharynx comprises the structures that separate the nasopharynx from the oropharynx. *Velum* is a generic anatomical term for *covering* or *veil*, which usually refers to the velum palatinum or soft palate and uvula. These and adjacent pharyngeal structures work in concert to create a valve that opens for nasal breathing and closes for speech and swallowing. Normal velopharyngeal function varies depending on the type of activity or speech produced. Different patterns have been found in velopharyngeal closure for speech, blowing, whistling, swallowing, and gagging.[1] Greater velopharyngeal movement appears to accompany swallowing rather than blowing and phonation.[2] Physiologically, velopharyngeal movements in swallowing appear to be different from blowing and speech production. Physiologic differences in movement between speech and nonspeech activities are consistent with the clinical observation that patients who are able to obtain complete velopharyngeal closure with swallowing (i.e., do not have nasal regurgitation of food) may have inadequate or variable closure during speech.

In speech production, the velopharynx can be viewed as an articulator in the same way that the jaw, tongue, oral cavity, lips, pharynx, and larynx all work in concert to produce the various sounds of speech. Normal velopharyngeal function varies according to the characteristics of the speech produced. Factors such as vowel height, consonant type, proximity of nasal sounds to oral sounds, utterance length, speaking rate, and tongue height can affect velopharyngeal patterns of opening and closing.

High vowels tend to be associated with greater velar height than low vowels. For example, velar height generally is higher for the high vowels /l/ and /u/ than for the low vowel /ah/.[3] No consistent differences have been found, however, for the front/back or tense/lax features of vowel sounds.[4] Magnitude of velar elevation has been found to be generally greater during production of the /s/ sound than during production of low vowel sounds.[3,5]

During production of oral consonants and vowels, the velopharyngeal mechanism is generally closed, separating oral from nasal cavities. This directs acoustic energy and airflow out of the mouth. There may be incomplete closure during vowel production, particularly if the vowel production is in proximity to a nasal consonant. The English language has three nasal sounds: /n/, /m/, and /ng/. Low-level activity is seen during the production of these nasal consonants, usually somewhere between a relaxed and complete closure position. The velopharyngeal port therefore changes its relatively open and closed states depending on the balance of oral versus nasal consonants occurring in the speech stimuli (Fig. 69–1). Normal velar function may vary widely in velocity and displacement with the demand of the speaking situation. Velar displacement generally decreases with increased speaking rate.[6] The degree of velar elevation, however, is not significantly influenced by speech loudness.[7] Individuals achieve competent closure of the velopharyngeal port through a variety of sphincteric patterns utilizing muscles of the soft palate and pharynx. Muscles contributing to the function of the velopharyngeal sphincter include the five muscles composing the substance of the soft palate: the tensor veli palatine, levator veli palatini, musculus uvulae, palatoglossus, and palatopharyngeus. A sixth muscle, the superior constrictor of the pharynx, is also influential in velopharyngeal closure.[8]

During speech, the velopharyngeal port closes when the velum moves in a posterior superior direction toward the posterior pharyngeal wall and the lateral pharyngeal walls move medially. In some individuals, the posterior pharyngeal wall may move anteriorly. Normal velopharyngeal closure involves variability in movement. Table 69–1 presents a summary of the muscles involved in velopharyngeal function—their origination, attachment, function, and innervation.

The back and upward movement of the velum has been attributed to the action of the levator veli palatini (LVP) muscle, the main muscle mass of the soft palate and the major elevator of the velum.[9] There is individual variability in the angle of velar insertion of the LVP relative to the cranial base.[10] Contraction of the palatoglossal and palatopharyngeal muscles probably serves to pull downward on the velum, thereby opposing the upward pull of the levator.[3] The palatopharyngeus also serves to stretch the velum laterally to increase available velar area and shape for contact.[10] Subtle adjustments in velar height have been attributed to the palatopharyngeus when the velum is in the elevated position.[4] Bulk to the dorsal side of the velum has been attributed to the musculus uvulae.[11]

Although the contribution of lateral pharyngeal wall movement to closure varies among individuals, it generally has been found to occur during speech and is related to the

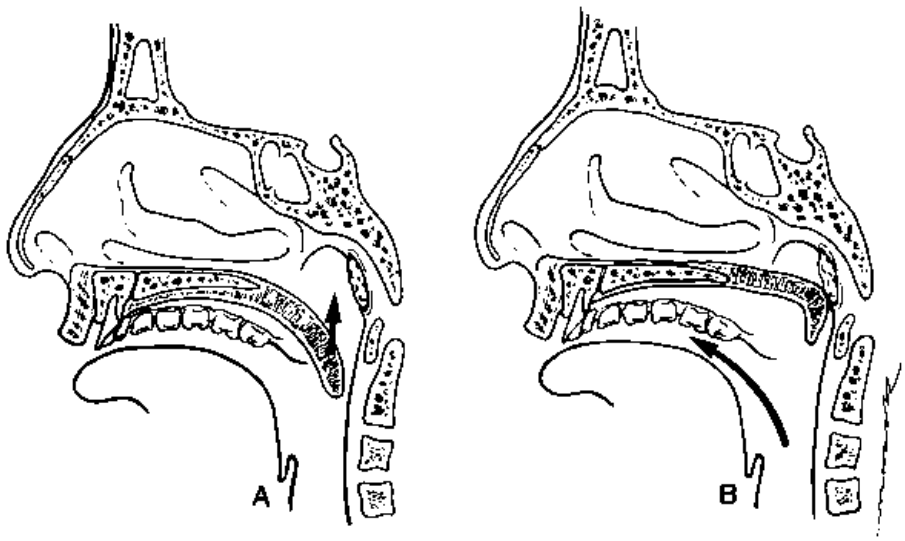

Figure 69–1 For pressurized speech sounds the flow of air must be channeled to the oral structures. This is done by raising the palate and sealing off the nose from the oral cavity. Velopharyngeal incompetence occurs when the velopharyngeal port is not sealed and leakage of air into the nasal cavity occurs, as shown in part A. Part B shows competency.

speech context. The greatest pharyngeal movement has been reported to be at the level of the full length of the velum and hard palate well below the levator eminence.[9] It has been suggested that lateral movement is a result of selective contraction of the uppermost fibers of the superior constrictor muscle. Laterally, the superior constrictor merges with fibers of the palatopharyngeus, so that an active role of this muscle in lateral wall movement is described.[12]

Passavant's ridge is a transverse elevation of the posterior pharyngeal wall seen during speech and swallowing in some individuals that has been associated with active lateral pharyngeal wall motion. It is felt to be due to contraction of the uppermost fibers of the superior constrictor, with merging fibers of the palatopharyngeus.[10] In some individuals it is the primary pharyngeal structure located on the posterior pharyngeal wall at the level of the velum. However, variations have been seen in the way Passavant's ridge is positioned relative to the velum. Findings suggest that in approximately one third of observed patients Passavant's ridge is one of the primary pharyngeal structures at the level of the velopharyngeal closure.[13] Velopharyngeal closure may or may not be assisted by the presence of Passavant's ridge in some individuals.

In summary, six muscles of the soft palate and pharynx are involved in velopharyngeal closure. Normal closure varies among individuals and is expressed by the varying contributions of the velum and the lateral and posterior pharyngeal walls. Types of velopharyngeal closure vary from individual to individual.[14,15] Open and closed states of the velopharyngeal port are relative to the demands of speech.

CAUSES OF VELOPHARYNGEAL DYSFUNCTION

There has been considerable discussion in medical and speech literature regarding the terminology used to describe dysfunction of the velopharyngeal mechanism. Definitions summarized by D'Antonio and Crockett are applied.[16] When referring to any type of abnormal velopharyngeal function, the term *velopharyngeal inadequacy* is employed. This can be separated into three etiologic categories: velopharyngeal insufficiency, (VPI), velopharyngeal incompetence, and velopharyngeal mislearning. *Insufficiency* encompasses structural defects that result in insufficient tissue to accomplish closure. A common example of this is cleft palate. *Incompetence* describes impairment of motor control due to neurologic dysfunction, such as paresis/paralysis. Causes of incompetence include skull base surgery or tumors around the jugular foramen and vagus nerve, or central nervous system impairment due to stroke, especially involving the brain stem. *Mislearning* includes etiologic factors that are independent of structural defects or neuromotor pathologies (i.e., functional).

Congenital anatomic conditions affecting velopharyngeal function are most commonly attributable to clefting of the palate and associated anomalies. Cleft palates occur in approximately 1 of every 750 live births.[17] The incidence of VPI following repair of the cleft palate varies depending partly on how a particular research group is defining VPI. However, it appears that about 20 to 50% of children with cleft palates have perceptible hypernasality or nasal escape. Many of these patients can be successfully treated with speech therapy. Others require surgical intervention.

TABLE 69–1 Muscles of the Velopharyngeal Mechanism

Muscle	Origination	Attachment	Function	Innervation
Tensor veli palatini	Vertical portion arises from the scaphoid fossa at the base of the internal pterygoid plate, from the spine of the sphenoid, and from the outer side of the cartilaginous portion of the eustachian tube	Terminates in a tendon that winds around the hamular process	Tenses the soft palate; opens the auditory tube during swallowing	Mandibular branch of the trigeminal nerve
Levator veli palatini	Arises from the undersurface of the apex of the petrous portion of the temporal bone and from the inner surface of the cartilaginous portion of the eustachian tube; found to occupy the intermediate 40% of the length of the soft palate[106]	Fibers spread out in the soft palate where they blend with those of the opposite side	Acts as a sling when contracted to pull the velum in a posterosuperior direction[107]; major elevator of the velum[108]; positions the velum[109]	Pharyngeal plexus derived from the glossopharyngeal and vagus nerves and the facial nerve[110]; course of the facial nerve is through the greater petrosal nerve[111]
Musculus uvulae	Palatal aponeurosis in a circumscribed area posterior to the hard palate[112]	Inserts into the uvula	Adds bulk to the dorsal surface of the soft palate	Pharyngeal plexus; pharyngeal plexus derived from the glossopharyngeal and vagus nerves and the facial nerve[110]
Palatoglossus	Has a fan-shaped attachment from the anterior surface of the soft palate[113]	Courses through loose connective tissue within the anterior faucial pillar and has a tapering termination in the side of the tongue[113]	Elevates the tongue upward and backward to constrict the pillars and probably lowers the velum[114]; positions the velum[109]	Pharyngeal plexus composed of branches from the glossopharyngeus and vagus cranial nerves and from the sympathetic trunk
Palatopharyngeal	Arises from the soft palate	Inserts with the stylopharyngeus into the posterior border of the thyroid cartilage	Adducts the posterior pillars, constricts the pharyngeal isthmus, narrows the velopharyngeal orifice, raises the larynx, and lowers the pharynx[115]; positions the velum[109]	Pharyngeal plexus
Superior constrictor	Arises from the lower third of the posterior margin of the internal pterygoid plate and its hamular process	Inserts into the median raphe	Medial movement of the lateral aspects of the pharyngeal walls[107]; high levels of activity are related to laughter[108]; may function to draw the velum posteriorly[108]; pulls the posterior wall and posterolateral angle anteriorly[109]	Pharyngeal plexus derived from the glossopharyngeal and vagus nerves and the facial nerve[110]

Palatal clefting can be considered on a continuum ranging from overt cleft palate to submucous cleft to occult submucous cleft. A submucous cleft is defined by a bifid uvula, muscular diastasis of the soft palate, and notching of the posterior border of the hard palate (loss of the posterior nasal spine). The bifid uvula and muscular diastasis are generally identifiable on visual inspection. The notch in the hard palate requires palpation for identification. The presence of a bifid uvula alone does not constitute a submucous cleft palate but rather serves as a harbinger; therefore, further inspection is warranted. Bifid uvulas have an incidence of 1 in 80 Caucasians.[17] Weatherley-White et al examined 10,836 school-age children and determined the incidence of submucous clefting to be 1 in 1200.[18] Only 1 in 9 was symptomatic for VPI. An occult submucous cleft suggests that the usual triad of submucous cleft signs is not present.[19] In the occult submucous cleft palate, there is absence of the musculus uvulae and diastasis of the levator palatini muscle. On the nasoendoscopic view, this finding is recognized as an absence of the bulge from the contraction of the musculus uvulae that is typically present on the nasal surface of the soft palate during speech (Fig. 69–2). Many children with VPI but no obvious cleft have been identified as having occult submucous cleft.

Occult submucous clefts or submucous clefts predispose children to VPI because of abnormal musculature of the velopharyngeal sphincter.[20] Consequently, these children may acquire VPI when changes to the anatomy of the velopharynx occur, such as an adenoidectomy or even involution of the adenoid pad.[21–23] For this reason, a preoperative evaluation for adenoidectomy should include a careful inspection of the palate, both visually and with palpation.[24]

VPI may occur following adenoidectomy even in children without a submucous cleft palate, but its occurrence in relatively healthy children can be hard to predict.[25] Huge adenoids may assist in easy velopharyngeal closure. When such adenoids are removed, considerable palatal motion may be required to obtain closure. Short palate, a relatively deep nasopharynx, and palatal hypotonia may all be factors in the development of VPI following adenoidectomy. Ren and colleagues showed that postadenoidectomy VPI is often associated with enlarged tonsils or remaining prominent adenoid tissue.[22] Incomplete removal of adenoid tissue can be a cause of VPI. If there is concern that the child's palate may not be capable of making the complete excursion back to the new position of the posterior pharyngeal wall, then a partial adenoidectomy can be performed. This has been described in various ways, but generally a superior half adenoidectomy is performed either with suction electrocautery or using a Thompson-Sinclair adenoid forceps. If postadenoidectomy VPI exists, then our current recommendations are for a 3- to 6-month trial of speech therapy. Useful adjuncts to this therapy are biofeedback using nasometry and occasionally C-PAP therapy for those with touch-closure VPI findings.[26–28] VPI due to hypertrophic tonsils has also been described. Observing tonsil interference with velopharyngeal closure on nasal endoscopy makes the diagnosis. The treatment is a tonsillectomy.[29–31]

Many conditions or syndromes other than those associated with clefting can result in or predispose children to VPI. Furthermore, any condition that can affect the timing of the palate with speech, such as developmental delays, mental retardation, or traumatic brain injury, may result in velopharyngeal inadequacy. In the pediatric age group, velocardiofacial syndrome and Down syndrome warrant special comment.

Velocardiofacial Syndrome

Velocardiofacial syndrome (VCF) is diagnosed with increasing frequency. This is a result of increased awareness of the syndrome, as well as the availability of chromosome testing for diagnosis. This condition has characteristic facies: prominent nose, retruded mandible, cardiovascular anomalies, possibly cleft palate, and often learning disabilities.[32,33] Inheritance is autosomal dominant with variable expressivity. Failure to thrive in infancy is present in about 25%, and about 35% have short stature. Obstructive sleep apnea may also occur. Mental disability is experienced by nearly all. Childhood- or adult-onset schizophrenia has been reported.[34]

Facial appearance is fairly characteristic, comprising a long face with vertical maxillary excess, malar flatness, and mandibular retrusion. Robin's sequence may be present. The nose is usually prominent with a square nasal root and narrow nasal passages.

Cardiac anomalies are present in more than 80% of patients. Ventricular septal defect is the most common, but other cardiac anomalies, such as right-sided aortic arch, tetralogy of Fallot, and aortic valve disease, are also found. Of significant consequence for the otolaryngologist is that the internal carotid arteries can be medially displaced along the posterior pharyngeal wall.[35] When considering velopharyngeal surgery in VCF patients, it is critical to consider internal carotid location. Often this is visible with nasoendoscopic examination. Radiographic techniques to precisely map the location related to the proposed surgery may be required.[36]

Diagnosis of VCF can be difficult. Finkelstein et al, reporting on 21 patients with VCF, found that only 11 (52%) had typical manifestations.[37] Fortunately, genetic testing for

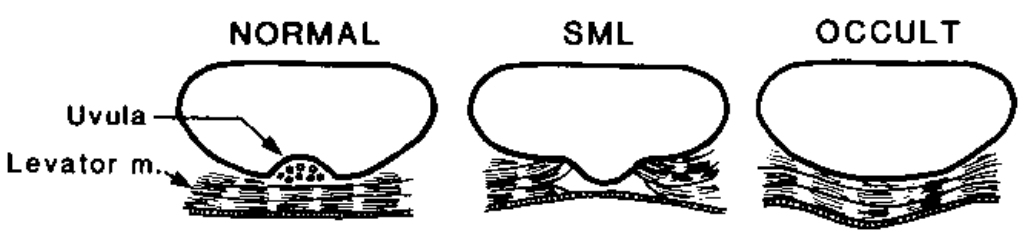

Figure 69–2 Nasal endoscopic view of the soft palate.

these patients is now possible. Microdeletions of the q11 region of chromosome 22 have been found in VCF patients. This is the same area in which microdeletions found in DiGeorge's syndrome occur. The microdeletions in some patients with VCF syndrome have encompassed the DiGeorge chromosome locus.[38] The otolaryngologist providing care for such patients should recognize the possibility that features of both syndromes may coexist.

Down Syndrome

Down syndrome (trisomy 21) occurs in 1.5 in 1000 births and is associated with mental handicaps, hearing loss, and muscular hypotonia.[39,40] All of these can be risk factors for development of VPI. A review of 74 tonsillectomies and adenoidectomies in children with Down syndrome identified two children with postoperative VPI.[41] These authors point out the risk of possible VPI development in children with known hypotonia and known articulation problems. Considering their predisposing factors, it is somewhat surprising that postadenoidectomy VPI does not occur more often. The narrow oropharynx and velopharynx and the shallow skull base at the adenoid site (platybasia) seen in Down syndrome may offset these predisposing factors.

ASSESSMENT

Evaluation of velopharyngeal dysfunction involves perceptual, instrumental, and physical examinations of the patient. The perceptual assessment of hypernasality and nasal emissions is aided by use of a commercially available instrument called the Nasometer (Kay Elemetries, Inc., Lincoln Park, NJ). This device measures the acoustic energy coming from the mouth and nose during production of standardized sentences or phonemes, and calculates the ratio of oral to nasal sound energy or nasalance. The subject's speech is then compared with normative data to assess the degree of hypernasality or hyponasality. Elevated nasalance scores on passages containing only oral sounds are significantly correlated to listener judgment ratings of hypernasality.[42] Reduced nasalance scores on passages containing primarily nasal sounds are correlated to listener judgment ratings of hyponasality.[43] In children with hypernasality, nasometric scores are also significantly correlated to aerodynamic estimates of velopharyngeal area and to nasoendoscopic findings.[42,44] Clinical judgment is important in interpretation because degrees of mixed resonance or imprecise articulation can affect results. When velopharyngeal inadequacy for whatever cause may be present, a direct examination of the velopharyngeal structures is indicated.

Two methods are advocated for velopharyngeal assessment: nasopharyngoscopy and multiview videofluoroscopy.[45] Each method has benefits and drawbacks. Nasopharyngoscopy allows a direct view of structures. This is very helpful in revision cases where prior pharyngoplasty has been done. But the procedure has some drawbacks as follows: (1) occasionally, patients may be uncooperative; (2) endoscopic images may be prone to distortion; and (3) vertical level assessments may be relatively difficult.[46] Fluoroscopy is well tolerated and is felt to give a better view of lateral pharyngeal wall motion than endoscopy. However, ionizing radiation is required and the speech samples are necessarily brief. As with nasopharyngoscopy, experience and skill in performance of the study and interpretation of the images is needed. The availability of nasopharyngoscopy in cleft palate teams has increased from 8 to 90% during the last two decades.[47] We recommend its use in most cases.

Nasopharyngoscopy

Flexible nasopharyngoscopy is an effective way of viewing the velopharyngeal orifice. The contribution of the pharyngeal walls can be visualized, and a fairly accurate analysis of the closure patterns and deficiencies of velopharyngeal motion can be obtained. The motion of the velopharyngeal walls during closure has been classified into various patterns. Skolnick et al described three shapes of the persistent gap following closure: coronal, sagittal, and circular.[48] Croft et al studied closure patterns in both normal subjects and those with VPI.[49] They did not find a significant difference in the prevalence of particular closure patterns in normal subjects as opposed to those with VPI. Using both multivideofluoroscopic views and nasoendoscopy, Croft et al further refined these closure patterns. They include coronal (seen in about 55% of normal subjects), sagittal (in 10 to 15%), circular (10 to 20%), and circular with Passavant's ridge (15 to 20%) (Fig. 69–3).

Nasopharyngoscopy is usually performed so that both video and audio can be recorded. Most children, when properly prepared, can tolerate nasopharyngoscopy. Topical anesthesia

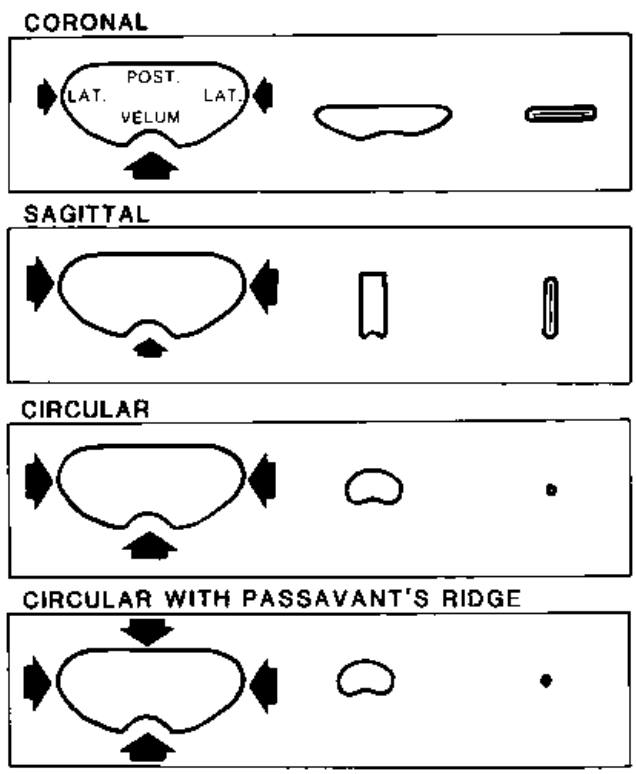

Figure 69–3 Velopharyngeal closure patterns. Note that these descriptive patterns are based on the shape of the gap as it closes.

is used for the nose, and systemic sedation is neither required nor advisable in nearly all cases. A speech pathologist is generally in attendance to assist in the speech examination. Both nasal chambers can be examined, followed by the nasopharyngeal area during speech. Despite the shortcomings of nasopharyngoscopy, it has been reliable in assessing VPI and is the standard method for viewing the nasopharyngeal area.

When the velopharyngeal mechanism is dysfunctional, nasopharyngoscopy includes an additional descriptive method. Besides describing the velopharyngeal closure pattern, the relative contributions of the pharyngeal walls are rated. Although absolute measurements of the velopharyngeal gap or pharyngeal wall motion have been performed, these are difficult in a clinical setting. In 1988, an international working group proposed rating pharyngeal wall contribution to closure as a ratio of motion from one wall to the other.[46] Therefore, pharyngeal wall motion is graded by the degree of movement of that wall to the opposite wall. If complete closure occurs to the opposite wall, then a ratio of 1 is given. If motion toward the opposite wall is only halfway, then a ratio of 0.5 is given. In this way pharyngeal wall dysfunction and resultant gaps in closure can be described (Fig. 69–4).

The vertical level of closure is an equally important anatomic location. In performing reconstructive velopharyngeal surgery, one would like to take advantage of already existing velopharyngeal motion. Videofluoroscopy or nasopharyngoscopy can be used to identify the point of maximal pharyngeal wall motion. This level of closure should be ascertained for each individual. This has generally been done using multivideofluoroscopy. Using this method, Finkelstein et al evaluated Passavant's ridge. They found that it exists in about 40% of individuals and is formed by fibers of the superior constrictor muscle.[32] Using the torus tubarius as a landmark, they found that the upper limit of lateral pharyngeal wall motion was approximately 1 cm below the torus. The vertical length of closure can be variable. It can be fairly short, making it necessary to be precise about the vertical level of any reconstructive sphincter, or it can be longer, in which case precise placement may be less critical.[8]

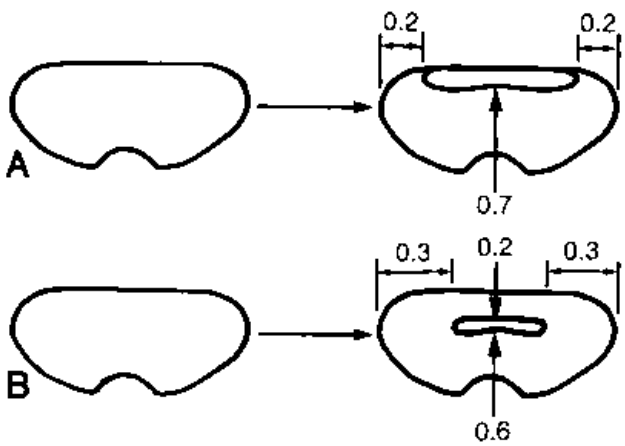

Figure 69–4 Describing velopharyngeal closure patterns is performed by first naming the type of closure pattern involved and then showing with arrows the amount of motion present in each wall. A ratio of movement for the wall being described to the opposite wall is obtained. In part A this would be described as a coronal closure pattern with the velum showing 0.7 motion and the two lateral pharyngeal walls showing motion rated at 0.2. In part B this would be rated as a circular closure with posterior wall motion. One could also argue that this is a coronal closure. It would be a very unusual closure pattern but is used here for descriptive purposes. In this case, the anterior wall shows 0.6 motion, both lateral pharyngeal walls show 0.3, and the posterior wall shows 0.2 with a resultant small corona-shaped gap.

NONSURGICAL TREATMENT

Successful treatment of velopharyngeal dysfunction depends on careful evaluation of both velopharyngeal function and speech. It is also influenced by the type and severity of defect; patient's age, cognitive ability, and motivation; availability of services; and expertise of service providers.[5,50] Integration of services provided by an interdisciplinary team of specialists is frequently required to develop and implement effective treatment plans. Treatment decisions must be based not only on subjective practitioner impressions but should also include data provided by objective procedures, such as nasopharyngoscopy, videofluoroscopy, aerodynamic or nasometric studies, and in-depth articulation analysis.[4]

For individuals who do not have the basic anatomy or function necessary to obtain adequate velopharyngeal closure for speech, surgical treatment is generally recommended.[51] Such patients often present with consistent lack of velopharyngeal closure with varied speech demands and have hypernasality measurements in the moderate to severe range.

Nonsurgical treatment options may be utilized prior to, in conjunction with, or in lieu of surgery. These options include, but are not limited to, prosthetic dental management, speech therapy, biofeedback treatment utilizing instrumentation, and resistance exercises performed while positive air pressure is introduced into the nasal cavities. To date, however, research data about the efficacy of these treatment options and factors affecting outcome are limited. For the last 30 years, prosthetic devices have been used successfully to assist with inadequate velopharyngeal closure.[52,53] These devices are particularly helpful when there are contraindications to surgery for significant velopharyngeal dysfunction, when dysfunction is secondary to neuromuscular involvement, or when velopharyngeal movements are poorly timed.[54,55] There are two basic types of prosthetic devices, obturators, and palatal lifts.

An obturator is a device designed and constructed by a prosthetic dentist to substitute for missing or incomplete tissue; dental wires or bands attach it to the teeth.[56] Usually, the obturator used to improve velopharyngeal function is a thin acrylic plate that extends back to the pharyngeal area.

Customized fabrication and fitting of the obturator require the use of data provided by nasopharyngoscopy, aerodynamic measurements, videofluoroscopy, or nasometric studies.[27,57–60] A gradual reduction in obturator size has been advocated for some patients; usually, this involves adjusting the size of the original obturator. It is postulated that as the size of the obturator is gradually reduced,

velopharyngeal function may improve and, in some cases, eliminate the need for the obturator or for surgical intervention.[52,54]

Unlike obturators, palatal lifts are designed to elevate the soft palate when the length of the palate is adequate. Lifts are particularly useful in patients with limited or no dynamic palatal movement. It is unclear at this time whether palatal lifts improve the neuromuscular ability of the velopharynx.[55] Use of obturators or palatal lifts can be difficult in young children, particularly if cooperation or cognitive ability is compromised.

Hypernasality, nasal emissions, and articulatory/phonologic deficits can be the result of mislearning rather than VPI. These problems respond well to speech treatment, particularly phoneme-specific nasal emissions occurring with a select group of sounds. *Surgical intervention is contraindicated in these cases*. For children, diagnostic speech therapy is often recommended prior to physical management, particularly in cases of borderline, mild, or inconsistent hypernasality.[59,60] Speech or language treatment is strongly recommended for children with severe articulatory/phonologic deficiencies or limited expressive language. Compensatory articulation error patterns, such as glottal stops, restrict airflow below the velopharyngeal valve.[61,62] Radiographic or nasopharyngoscopic observation of the velopharyngeal mechanism is appropriate for children who are able to demonstrate correct articulatory placement for some oral consonant sounds and who have enough language to provide a varied speech sample.

Diagnostic speech therapy frequently involves use of a Nasometer. This biofeedback device has proven effective in the reduction of nasality levels in some patients.[5,47] Treatment utilizing the Nasometer encourages such strategies as ear training, promoting a lower posterior tongue placement, increasing loudness, speaking at a lower pitch, using a more open mouth posture, controlling the type of consonants and vowels used in speech training, and lowering the rate of speech.[51,58] The duration of any speech therapy designed to reduce hypernasality should be carefully monitored. If continued improvement in hypernasality is not demonstrated within 3 to 6 months, speech therapy to reduce hypernasality should be discontinued and other treatment options explored.[60]

Video-recorded nasopharyngoscopy is used with success in biofeedback therapy for adults with VPI.[28,63] A case study involving an older child demonstrated correction of phoneme-specific nasal emissions using nasopharyngoscopy.[28] Nasopharyngoscopy biofeedback therapy may prove to be a useful tool in training some children to achieve better velopharyngeal function, but further research is necessary.

A new therapy for hypernasality uses continuous positive air pressure (CPAP), which is introduced into the nasal cavities during speech production.[26] It is theorized that in cases where hypernasality is related to physiologic limitations, resistance training might strengthen muscles involved in velopharyngeal closure. It has been demonstrated that as positive air pressure is delivered to the nasal cavities, levator veli palatini muscle activity increases.[64] Therapy can take place in the patient's home—a major treatment advantage. Preliminary case reports suggest that CPAP therapy is useful for patients with mild to moderate hypernasality, regardless of the underlying etiologic factors.

SURGICAL TREATMENT

Palatoplasty

In a patient with overt cleft of the palate, repair of the cleft palate, usually done before 1 year, is expected to prevent VPI in most cases. These success rates average 80%.[64a] The indications and techniques are covered in another chapter in this text. In treatment of VPI, an additional point to be made here is that palatoplasty may also be used in older children. Indications for this include (1) submucous cleft palate and (2) previously repaired cleft palate wherein an intravelar veloplasty was not performed. The technique of choice in these situations is the double opposing Z-plasty described by Furlow.[65] The success rate with this procedure both in primary cleft palate repair and in submucous cleft treatment has been excellent, as reported by a variety of centers.[66,67]

Pharyngoplasty

The principle behind surgical improvement of velopharyngeal competence is to narrow the velopharyngeal opening and essentially to create a partial nasopharyngeal stenosis. The key word is *partial* because an adequate airway must be maintained for nasal breathing and sleep to take place. Procedures have been developed to obturate the middle of the velopharyngeal area or the lateral portion of the velopharynx. Hynes first described an operation that obturated the lateral part of the velopharynx.[68] His goal in designing this was to construct a sphincter that would be dynamic. He felt that raising lateral flaps of superior origin would lead to a neuromuscular flap that would contract. Nearly two decades later, Orticochea reported using lateral-based flaps for the treatment of VPI.[69] According to his description of the Orticochea pharyngoplasty, he used the posterior tonsillar pillars as donor flaps and also created a recipient site by raising a small inferior pharyngeal flap. Again, nearly a decade later, Jackson modified the Orticochea technique.[70] It is essentially the latter version of the pharyngoplasty that has gained so much popularity. The posterior tonsillar pillars are still used as donor flaps to be sutured across the nasopharynx. However, an inferior pharyngeal flap is not created. Instead, the transverse incision is made higher in the nasopharynx, and a small superior pharyngeal flap can be created if needed. Further modifications of this technique have been made. Most have centered on obtaining an adequate superior placement and covering raw tissue areas. Several studies have assessed the success of a sphincter pharyngoplasty to improve VPI. In 1984, Riski et al reported correction of hypernasality in 78% of patients.[71] In 1992 a more complete evaluation of the sphincter pharyngoplasty had similar success rates, although during the study the surgical technique changed.[72] An objective study was performed by Witt et al who found that nasal resonance improved in 79% of patients.[73] In their study, sphincter pharyngoplasty was done to correct hypernasality in patients exhibiting all velopharyngeal closure patterns, rather than selecting certain patients for other techniques. This study also appropriately documented potential problems with all types of velopharyngeal obturating surgery. They found that 30% of their patients were judged to be hyponasal postoperatively. Sloan et al compared a modified Hynes pharyngoplasty with placement of inferiorly and superiorly

based pharyngeal flaps and concluded that the sphincter pharyngoplasty was a better technique for management of VPI.[74]

Indications

A sphincter pharyngoplasty is considered when the nasal endoscopy study shows velopharyngeal insufficiency associated with good velar movement but poor to absent lateral wall motion.[71] A sphincter pharyngoplasty may also be indicated for those with poor motion of any of the pharyngeal walls, including the velum. Such persons have a relatively adynamic sphincter, and typically their velopharyngeal port is described as a black hole because there is no light reflection of the sphincter during nasoendoscopic examination.[75] Because the sphincter pharyngoplasty pulls the lateral pharyngeal walls medially and because the flaps are sewn across the back wall, both the lateral and posterior portions of the velopharyngeal port are obturated. The degree of obturation can be varied by adjusting the thickness of the flaps, the snugness or tightness with which the flaps are sutured together, and the extension of the flaps toward the uvula. The possibility of modifying the sphincter based on individual variations in VPI pattern is an appealing aspect of this procedure.[76] When needed, revisions of sphincter pharyngoplasty are generally successful.[77,78]

Technique

Proper patient preparation includes the surgeon's review of the nasoendoscopy tape and videofluoroscopic results, if applicable. If possible, a recording of the nasoendoscopic examination should be present in the surgical suite so that this may be reviewed at the time of operation. The potential necessity of a tonsillectomy or adenoidectomy should also have been previously determined from the nasal endoscopy study. If positioning and placement of the sphincter will be through the adenoid pad, an adenoidectomy should have been performed. Placement of a sphincter pharyngoplasty through the adenoid can increase the difficulty of the operation. We prefer to do an adenoidectomy approximately 8 weeks prior to placement of the sphincter pharyngoplasty. A tonsillectomy can be done prior to or at the time of pharyngoplasty. In doing this tonsillectomy, care is taken not to injure the posterior tonsillar pillars and to keep scarring of the palatopharyngeal muscle to a minimum. Use of extensive electrocautery should be avoided.

Following intubation with an oral RAE endotracheal tube, a Dingman or Davis mouth gag is used to obtain adequate exposure of the posterior tonsillar pillars. Exposure to the nasopharynx is obtained by use of a uvula retractor. With the soft palate retracted superiorly, the proper vertical level for the sphincter pharyngoplasty is determined by comparing anatomic landmarks found videofluoroscopically or nasoendoscopically with those directly visibile or palpable during surgery. After the site has been determined it is injected with a vasoconstrictive agent such as 1% lidocaine with 1:200,000 epinephrine. The posterior tonsillar pillars are likewise mildly injected to improve hemostasis. A no. 15 blade is used to make an incision along the anterior surface of the posterior tonsillar pillar. The posterior tonsillar pillar is detached inferiorly just above the inferior pole of the tonsil. A combination of a no. 15 blade and lower lateral crural right-angle scissors is used to elevate the palatopharyngeal muscle superiorly. The posterior incision, which is close to the junction of the lateral and posterior pharyngeal wall, is carried superiorly to the level of the desired vertical placement across the nasopharynx. Then the palatopharyngeus flaps are elevated up to nearly this level. The anterior incision does not extend as superiorly as the posterior incision. In fact, the anterior incision of the palatopharyngeal muscle usually does not extend even as high as the superior pole of the tonsil because as a result of so doing the reconstructed velopharyngeal port can become quite narrow (Fig. 69–5). The blood supply to the flap may also be disrupted.[79]

As the anterior pillar incision extends superiorly and toward the uvula, the reconstructive port becomes narrower. If the intent is to keep the velopharyngeal port open and at the same time create significant obturation of the lateral and posterior portion of the nasopharynx, this anterior incision can be extended across the back of the tonsillar pillars and curved up along the posterior and superior (nasal) surface of the soft palate/pharynx. This extension allows for more superior elevation of the palatopharyngeus flap without necessarily constricting the velopharyngeal port.

With the two palatopharyngeal muscles elevated, an incision is made across the nasopharynx at the desired level of sphincter placement. This usually requires a palatal retraction with the uvula retractor. The palatopharyngeus flaps are sutured transversely across the nasopharynx. These flaps can either be sutured end-to-end or in an overlapping fashion, and to the nasopharyngeal mucosal flaps with 4-0 Vicryl. (It is usually adequate to sew the posterior pillar edge to the inferior edge of the nasopharyngeal mucosa. Partial dehiscences that yield necklace bands usually function adequately.) If a very snug sphincter is created, then an obstructive breathing pattern may occur in the immediate postoperative state. In this case, a soft nasal trumpet is placed through the sphincter and kept there until the following morning.

Posterior Pharyngeal Flaps

An operation designed to obturate the midline of the velopharyngeal port is termed a pharyngeal flap procedure. In this procedure, a flap of tissue is pedicled superiorly or inferiorly to the posterior pharyngeal wall and sutured to the palate. Through the years, success has been reported using both inferiorly and superiorly based pharyngeal flaps. Placement in the midline divides the velopharyngeal port into two smaller lateral ports. Mobile lateral pharyngeal walls are needed for ports to be open during breathing and closed during speech. Posterior wall and velar motion are relatively unimportant when choosing this procedure.

In the last decade, preoperative nasopharyngoscopy has facilitated better preoperative planning. More attention has been focused on the proper vertical placement of flaps.[80] One of the criticisms of inferiorly based pharyngeal flaps is that the flap is tethered inferiorly and that with additional scar contracture the flap will be pulled from optimal position.[81] For this reason, in the United States, the trend has been toward superiorly based pharyngeal flaps.

Pharyngeal flaps have been effective in reducing hypernasality. Morris et al studied 65 subjects, over half of whom

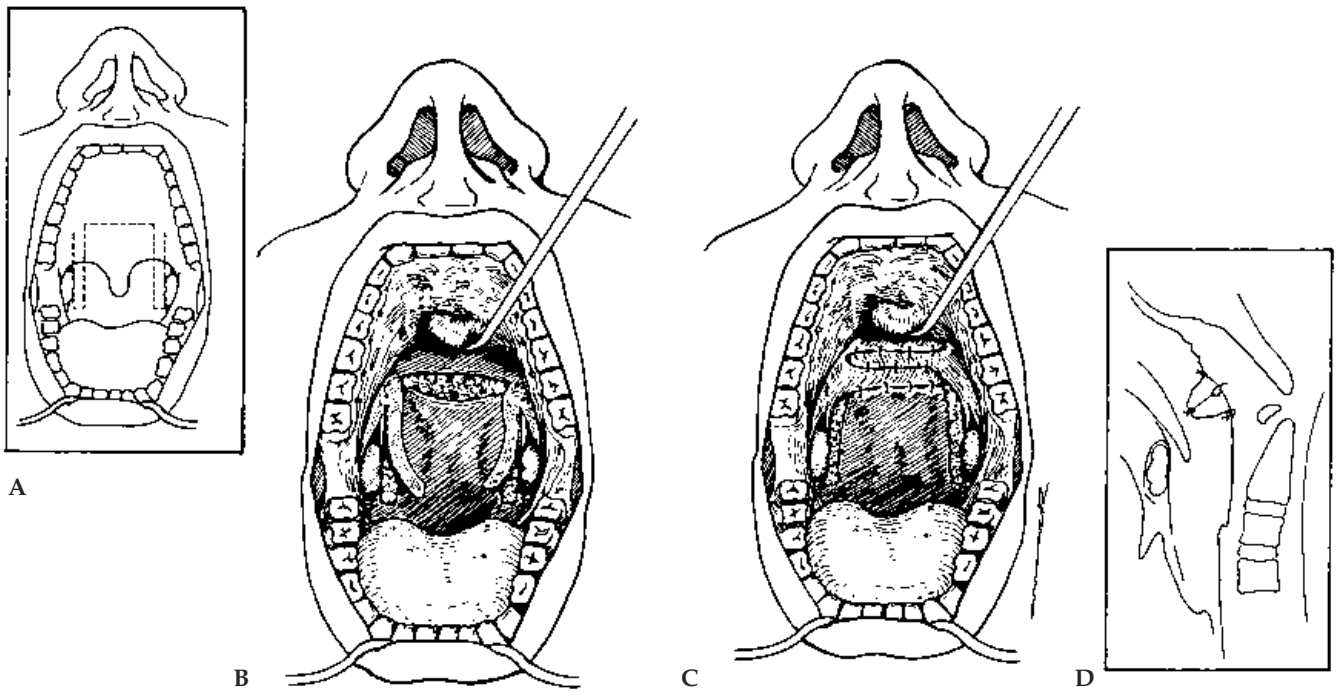

Figure 69–5 Sphincter pharyngoplasty technique. **(A)** The height or vertical level of the sphincter usually must be placed in relation to the pharynx. The soft palate is retracted. *Broken lines* represent an approximation of the surgical incisions, although this is difficult to represent two-dimensionally. **(B)** The soft palate is retracted superiorly, and the posterior tonsillar pillars (palatopharyngeal muscle) have been elevated. Note that the anterior incision stops at the superior pole but may extend further vertically and medially along the nasal surface of the soft palate toward the uvula if the surgeon desires a narrow, tight port. Note also that the medial or posterior incision for the flaps extends up to the horizontal incision so that the flap can be easily rotated. **(C)** Flaps have been sutured into the sphincter position overlapped. The flaps may also be sutured end-to-end. This illustration better demonstrates that the sphincter could be closed by pulling the flaps in more tightly, by creating a larger posterior wall ridge (harvesting larger and thicker flaps), and by extending the anterior incision medially along the nasal side of the soft palate (this step is usually not needed and can lead to severe narrowing of the port). **(D)** Lateral view following pharyngoplasty. Note that the sphincter is in the nasopharynx, above the soft palate. (From Gray S, Pinborough-Zimmerman J. Diagnosis and treatment of velopharyngeal incompetence. *Fac Plast Surg Clin North Am* 1996;4(3):405–412. With permission.)

had had their surgery more than 10 years previously.[82] Eighty-three percent showed normal velopharyngeal function, and 66% showed normal or near-normal speech production. Eight of the 65 subjects had surgical revision of the flap. One required reduction in the size of lateral ports; the other 7 had either flap takedowns or lateral port enlargements performed. Likewise, Hirschberg reported a series of 500 cases involving pharyngeal flaps wherein 90% of patients demonstrated improvement in hypernasality and 74% showed improvement in speech.[83] It was also emphasized that the best speech results were obtained when the width of the flap was appropriately matched with the relative motion of the lateral pharyngeal walls. Matching the width of the flap to obturate the remaining gap area, which is determined by maximal medial motion of the lateral pharyngeal walls, is termed "tailoring of the pharyngeal flap."[84] The theory of tailor-made flaps is a good one. In practice, achieving consistent, precise millimeter dimensions in the lateral ports due to the many forces of scar contracture is probably unrealistic. Variation of scar contracture between individuals leads to some of the complications that are reported regarding pharyngeal flaps.

Numerous long-term studies have thoroughly documented the drawbacks and benefits of this procedure.[85] Sleep apnea is a reported complication of pharyngeal flap placement.[86,87] Sleep apnea is more likely to occur in the early postoperative period, and within 3 months obstructed sleep problems should be substantially resolved.[88,89] In a long-term follow-up, Morris et al obtained electrocardiograms (ECGs) on 33 of the 65 subjects in the pharyngeal flap study.[82] Those chosen for ECG monitoring had complained of sleep difficulty or had a history of snoring. No subjects had clear findings of right ventricular hypertrophy, which can be a pathologic response to obstructive sleep apnea. Their conclusion was that although symptoms of nasal airway obstruction, when present, are rarely serious enough to cause pathology. Nocturnal

respiratory obstruction that results in nocturnal awakening and daytime hypersomnolence after a pharyngeal flap procedure may be present in the absence of sleep apnea.[90] Its long term significance on patients' well-being is not known.

Indications

The indication for a pharyngeal flap procedure is presence of relatively good lateral wall motion but with a central persisting gap. Patients with a sagittal closure pattern would also be candidates for this procedure.

Technique

The procedure is performed by placing a Dingman mouth gag and injecting the posterior pharyngeal wall and the palate with 1% lidocaine and 1:200,000 epinephrine. Two different techniques can be used for insetting the pharyngeal flap to the palate. One, termed a fish-mouth technique, essentially consists of by-valving the soft palate (separating nasal mucosa from oral tissue) to create a pocket into which the pharyngeal flap is pulled and sutured.[91] The pocket is usually placed just superior and anterior to the edge of the soft palate on the nasal side. This technique has not yielded consistent results.[92] The other technique involves splitting the palate and has been well described by Hogan[93] and Crockett et al.[94] Both of these articles describe adjustments to the lateral ports.

The width of the flap is determined from previous nasoendoscopic or videofluoroscopic procedure. The superiorly based flap is elevated a little higher than the level ascertained to be appropriate for maximum medial motion of the lateral pharyngeal walls. With scar contracture, the flap usually descends a couple of millimeters. The fish-mouth technique or the palatal splitting technique is used to sew the flap into position. Prior to suturing the flap, small endotracheal tubes are placed in both ports to assist in postoperative breathing and to provide guidance on lateral port size.

Postoperatively, after the small endotracheal tubes have been removed, the patient should be monitored for obstructive apnea. The tubes may be left in place the first night, and the patient should not be discharged from the hospital until indications are clear that serious obstructive apnea is not present. Parents should be cautioned that if obstruction seems to be worsening, the patient should be brought back to the hospital for monitoring and reevaluation.

Augmentation of the Posterior Pharyngeal Wall

The concept of augmenting the posterior pharyngeal wall in an effort to improve velopharyngeal competence has received and will continue to receive attention for a number of reasons: (1) the majority of persistent velopharyngeal gaps are continuous with the posterior pharyngeal wall; (2) in many VPI patients the velum or soft palate has relatively good motion; (3) the risk of inducing hyponasality and nasal obstruction is lower; and (4) the procedures are relatively easy to perform. The concept of simply bringing the posterior pharyngeal wall forward to correct the gap is appealing. However, in practice, many posterior pharyngeal wall augmentation techniques have failed to meet expectations. Currently, one of the best techniques to augment the posterior pharyngeal wall is a sphincter pharyngoplasty because a large shelf of tissue is placed across the posterior pharyngeal wall. However, this section focuses on techniques that augment the posterior wall.

Various materials have been used to augment the posterior wall either by injection or implantation.[95–97] Tissue implants, such as cartilage and fascia, have been used.[98–101] The most common injectable material used for treatment of marginal VPI over the last few decades has been Teflon.[102] Smith and McCabe injected Teflon into the posterior pharyngeal wall, thus creating a transverse ridge.[103] Disadvantages of Teflon include (1) the fact that it is not approved by the Food and Drug Administration for this indication and (2) the fact that migration may occur within the pharynx due to growth of the neck, or even elsewhere in the body. One inadvertent carotid artery injection with Teflon has occurred. Obviously, it is important to palpate the posterior wall for great vessels prior to any sort of posterior pharyngeal wall procedure. An anecdotal advantage of Teflon injection is that as the Teflon migrates and the posterior wall bulges less, the velopharyngeal sphincter may gradually adapt to maintain competency, much like sphincter improvement with obturator reduction. However, if this does not occur, the Teflon will move to a position below the plane of velar closure, resulting in reoccurrence of hypernasal symptoms; this has also been noted anecdotally.

Because of the theoretical advantages of posterior wall augmentation, there is renewed interest in the use of posterior wall tissue to create a shelf or ledge along the posterior wall. In this procedure, a superiorly based pharyngeal flap is lifted and buckled to create a ridge across the posterior wall.[104,105] Results obtained with this procedure have been mixed. Witt et al reported experience with 14 patients and concluded that the procedure was ineffective.[104] On the other hand, Gray et al also reported 14 patients who had the same procedure.[105] Improvement in hypernasality by either perceptual assessment or nasometry was seen in 12 of 13 assessed. Only one patient had revision surgery. Though not statistically significant, the procedure was felt to be more effective in younger patients, postadenoidectomy VIP patients, and nonsyndromic patients in this series. In comparing this report with that of Witt et al, it appears that the patients in Gray's series had smaller (<1 mm) gaps, whereas those in Witt's had somewhat larger gaps (up to 20%).

Indications

Posterior wall augmentation is indicated when there is a very small central midline gap and velopharyngeal closure could be made complete by simply bringing forward the posterior wall. Occasionally, a patient may achieve velopharyngeal closure that is not tight enough, whereupon pressure causes leakage of the air through the velopharyngeal port. This condition is referred to as a "touch closure" problem because the pharyngeal walls touch but do not achieve competent closure. Under these conditions, a small augmentation of the posterior pharyngeal wall is enough to provide a competent seal. If significant augmentation of the posterior pharyngeal wall is required, then a sphincter pharyngoplasty is usually a better alternative. Posterior wall augmentation works best for small central or off-center gaps in the area of 1 to 2 mm or for touch closure problems.

Technique

Posterior wall augmentation using a buckled or folded pharyngeal flap is relatively easy to perform. A superiorly based pharyngeal flap is raised and then folded on itself at the level of maximum pharyngeal wall motion in the area of the

velopharyngeal port. A superiorly based pharyngeal flap is elevated to prevertebral fascia such that the constrictor muscle is present within the flap. Flap width is determined by ascertaining the width of the gap to be obturated and making the flap slightly larger. The flap shrinks once elevated; therefore, a wider flap than anticipated is usually required (Fig. 69–6).

The lateral incisions are made first and carried through the constrictor muscle until the white fascia is encountered posteriorly. At this point, a right-angle elevator can be used to elevate the remaining muscle off the fascia. The flap is detached inferiorly at about the level of the inferior pole of the tonsil. The flap is elevated superiorly to slightly above the level of the desired augmentation. When the flap is elevated above the level of augmentation, the buckle of the flap will be correctly positioned. The flap can then be sutured on itself or to the posterior wall so that the fold is in the desired location vertically. Usually three or four sutures are placed across the inferior edge of the flap to hold it in proper position, and then one or two sutures are placed on the lateral aspects of the folded flap for stability and to close any dead space between the two layers of the flap.

Drawbacks to this procedure include (1) variability in flap atrophy and (2) inadequate closure of large posterior gaps. Even when a large buckled flap is created, large folded flaps are functionally not very useful because a large buckle has a tendency to flap (move up and down) depending on air pressure in the vocal tract. For this reason, small gaps of 1 to 2 mm can be closed successfully, but large gaps are inconsistently closed because a large folded flap is not vertically stable.

SUMMARY

In conclusion, treatment of VPI requires careful evaluation by a team of professionals consisting of a speech–language pathologist and a surgeon with expertise in speech disorders. Patient care should be individualized. Surgical care requires preoperative assessment of the velopharynx by nasoendoscopy, videofluoroscopy, or both. We generally support the approach that selection of the surgical procedure depends on the pattern of velopharyngeal closure, the degree of closure, and associated medical conditions.[92] A sample of common nasopharyngoscopic findings and selected surgical procedures is given for review (Fig. 69–7).

ACKNOWLEDGMENT

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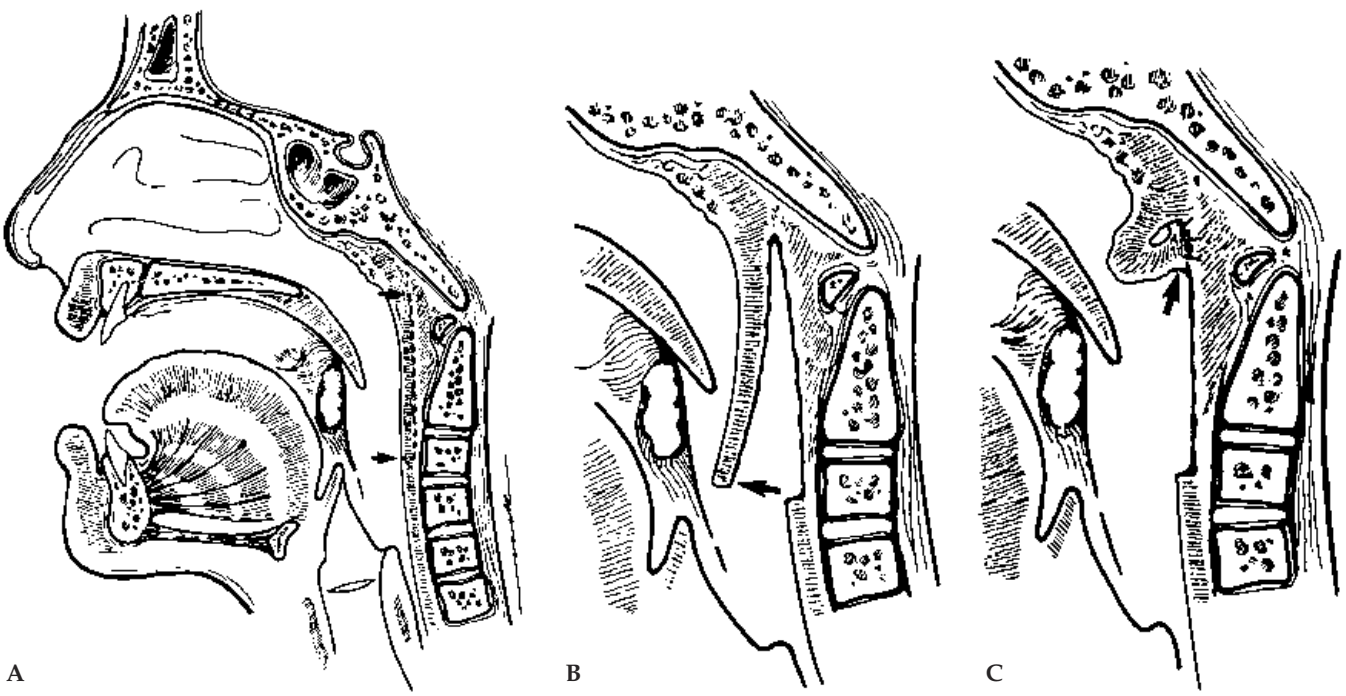

Figure 69–6 Augmentation of the posterior pharyngeal wall. **(A)** The section of the posterior pharyngeal wall to be elevated; the inferior level is at about the inferior pole of the tonsil. **(B)** The constrictor muscle is raised with the flap and elevated quite superiorly. **(C)** The flap has been folded and sutured in place. Even though the flap was elevated higher, the fold and maximum area of augmentation occur a little lower. Although not shown in **C**, sutures are often placed on the folded flap laterally to close some of the dead space; sometimes this seems to create a little more stability. (From Gray S, Pinborough-Zimmerman J. Diagnosis and treatment of velopharyngeal incompetence. *Fac Plast Surg Clin North Am* 1996;4(3):405–412. With permission.)

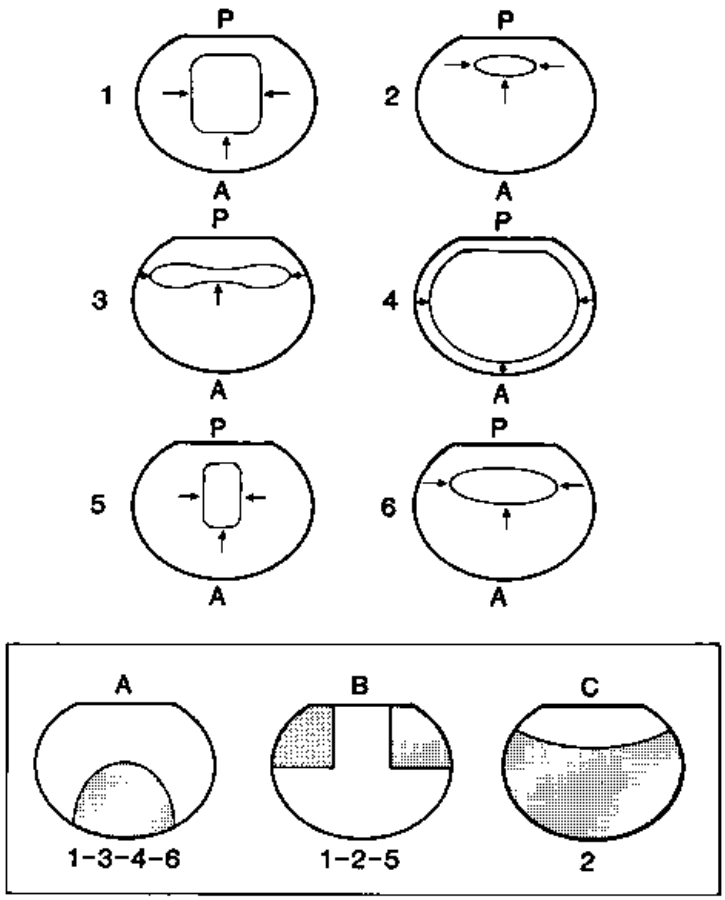

Figure 69–7 The types of obturation that can be expected with these surgical methods described. *Shaded areas* represent parts of the velopharyngeal area left open following the surgery; *white areas* show what is obturated with tissue during the surgery. Remember that in all of these examples there are variations; with surgery more or less can be obturated than is demonstrated. **(A)** The type of obturation obtained with a sphincter pharyngoplasty. Significant augmentation and closure of the posterior and lateral pharyngeal walls occurs. The area left open is midline and located just behind the uvula. This helps demonstrate why someone with good soft palatal motion will generally do well with a sphincter pharyngoplasty. A sphincter pharyngoplasty would work well in treating the patients in *1* (this sphincter would need to be a little bit snug), *3, 4* (black-hole patterns are usually best treated with a very snug or tight sphincter or with an prosthetic obturator), and *6*. **(B)** Obturation following a pharyngeal flap attachment to the soft palate. Because the lateral areas (ports) are left open, it is apparent why this surgery works best in people with good lateral wall motion. Matching the obturated pattern over *1* to *6*, it can be seen that a good match could be made in patients in *1* (wider pharyngeal flap would be needed), *2*, and *5*. **(C)** The folded or rolled pharyngeal flap mildly augments the posterior wall. The best match for this procedure is the patient in 2. Although this patient could be treated by any of the surgical methods, the described augmentation of the posterior wall is the least aggressive approach and leaves the most unobturated area. Therefore, it is less likely to cause airway obstruction. (From Gray S, Pinborough-Zimmerman J. Diagnosis and treatment of velopharyngeal incompetence. *Fac Plast Surg Clin North Am* 1996;4(3):405–412. With permission.)

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