Alternative Limbmaking

By: Bob Pluyter

Published by: Appropriate Health Resources and Technologies Action Group Ltd.
1 London Bridge Street
London SE1 9SG
U.K.

Available from: Appropriate Health Resources and Technologies Action Group Ltd.
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Alternative Limbmaking

The manufacture and fitting of low-cost below knee prostheses

AHRTAG
Appropriate Health Resources & Technologies Action Group Ltd

ALTERNATIVE LIMBMAKING

The manufacture and fitting of low cost below knee prostheses

Text and research: **Bob Pluyter**
Edited by: **Ann Darnbrough**
Deborah Birkett
Maggie Ware
Illustrations: **Shona Grant**

Published by the Appropriate Health Resources and Technologies Action Group Ltd.

ISBN (AHRTAG) 0 907320 15 5
Printed and bound in England
by Bourne Offset Ltd.,
2 The Ridgeway,
Iver, Bucks.

Contents

Community Based Rehabilitation — a World Health Organisation (WHO) definition

Community based rehabilitation (CBR) uses resources within the community to achieve social integration of people with disabilities. The resources include the disabled persons themselves, their families and members of the community.

A comprehensive CBR programme has rehabilitation workers at the community level, rehabilitation supervisors at provincial and district levels, and technical experts (prosthetists, physiotherapists, etc) at national, provincial and possibly district levels. Referrals and recommendations are made between the levels or services.

Individuals who are trained to make prostheses will receive referrals from many communities. If there is a CBR programme, the person who makes prostheses can teach community rehabilitation workers. These cooperators can then help amputees to learn how to use their prostheses in their homes and communities. They can also encourage after service care when the prosthesis does not fit well or some repair is needed.

Foreword

There is a critical need for orthopaedic appliances in the developing countries. WHO has estimated — and this is a cautious figure — that the annual production needs are 1·2 million prostheses, 1·2 million braces and 1·1 million pairs of correction shoes. Despite great efforts during the last 30 to 40 years, the needs of many countries have not been met. As little as one to two per cent of the appliances are available in some countries.

The following constraints contribute to this situation:

1. **Lack of materials for the manufacture of appliances**; this has led to a number of initiatives to use locally available materials such as rubber, wood, leather, metals, etc. But the use of such available materials — which avoids the need for costly and cumbersome imports — means that normal manufacturing processes sometimes have to be considerably changed.

2. **Dependence on complicated machinery**, imported from industrialised countries. Such machines have to be maintained, spare parts have to be imported (malfunctions are a regular problem), personnel have to be trained to use and service the machines, etc. As a logical consequence this has led to the development of more "manual" techniques, less dependent on machinery.

3. **Lack of properly trained technicians**, not only for the manufacture but also for the application of biomechanics in orthopaedic appliances when fitting a "customer". On this point there can be no shortcuts; biomechanics has to be taught well, understood and applied, even if the manufacturing process has been simplified. Some countries have three per cent of the trained technicians that are needed.

4. **Restricted delivery systems and high costs**. Because of the expense incurred in setting up and maintaining orthopaedic workshops, they have been started mainly in the capital cities of developing countries, far from most of the needy "customers". Another obvious obstacle has been the cost. In some countries, the full purchase price is paid by the "customers"; in others, these costs are subsidised. In an effort to decentralise the services, some countries have emphasized the training of local staff, under the supervision of technicians, and have tried to bring down production costs by combining the use of simplified manufacturing techniques with the use of local materials.

This publication, made possible through the efforts of AHRTAG and its partners, aims at overcoming some of the problems related to the production of prostheses. It describes in detail a number of innovative efforts which will help to bring a good product to these "customers", who today receive no services whatever. Not being able to walk means for a child that he or she will not be able to attend school, thus adding a lifelong handicap to the disability. For an adult it means having no job and consequently no income, and therefore being totally dependent on others. Without an orthopaedic appliance, many people will also be excluded from daily contacts with neighbours, friends and other community members.

We support the ideas described in this book to produce prostheses locally, at low cost, and to make them accessible to the customer. We hope that it may eventually contribute to a better life for a larger number of people with disabilities.

Einar Helander
WHO, Geneva

About the author

Bob Pluyter has been a consulting engineer for AHRTAG since 1983. Studying at the Enschede University of Technology, he specialised in biomechanical engineering and took part in many courses on appropriate technology and related issues.

After gaining experience at English and Dutch rehabilitation centres, Bob stayed at the Jaipur Rehabilitation Centre in India where he supported the further improvement of the rubber vulcanised foot and the limbs. He has also worked in Nigeria, Cameroon, and Kerala State, India.

Bob is now working at the National Hospital Institute in Utrecht in the Netherlands and is involved in medical technology assessment studies as well as management consultancy for hospitals in general.

Acknowledgements

We can never thank enough all those people and organisations who have provided us with information. It is impossible to mention all their names here, but particular thanks are due to Dr. Jan Ober of the Polish Academy of Science, Poznan, and to members of the Orthopaedic Workshop at the Roessingh Rehabilitation Centre, Enschede in the Netherlands for identifying ways in which the work of the manual could be structured and conveyed.

Much valuable material and advice was provided by : Dr. P.K. Sethi, former director of the Rehabilitation Research Centre, Jaipur, India; the Brothers Jaccard at the National Prosthesis Centre, Yaounde, Cameroon; Operation Handicap International in Lyon, France and Thailand; Dr. Roy Pfaltzgraff who was for many years Chief Consultant Leprologist at the State Leprosy Hospital, Garkida, Nigeria; Mr. Amit Mukherji, prosthetic engineer, Bombay; and Mr. S. Sankaranarayanan, mechanical engineer, Medical College, Trivandrum, India.

In addition, we are grateful to those who read and commented most constructively on the manuscript. In particular, we would like to thank Dr. Einar Helander and Dr. Ann Goerdt of the World Health Organisation, and Glen McGhee who has worked in Sudan and Bangladesh. We would also like to thank Mark Met for his contribution to the illustrations in the earlier stages of producing the manual.

The manual could not have been compiled without appropriate funding. We are most grateful for support received from the Allied Dunbar Charitable Trust, The Baring Foundation, The States of Jersey and HelpAge International.

To all the above and to unnamed friends we extend our thanks.

In addition to those named above, the preparation of this manual has been made possible in part by a grant provided through the Voluntary Fund for the United Nations Decade of Disabled Persons from the Arab Gulf Programme for United Nations Development Organisations.

Request to Readers

It would be very helpful to us, for future editions of this manual, if we could learn more about you and your work. We would be most grateful if you would spare a few moments to fill in the following questions.

This manual only has space to contain some of the ideas for alternative limbmaking that exist in developing countries. We would welcome any additional material and ideas you can provide. We will try to incorporate these suggestions in a later edition. Full credit would be given to readers supplying material. Please return the form and any additional comments, criticisms and material to:

Disability Unit
AHRTAG
1 London Bridge Street
London SE1 9SG
UK

1. Are you familiar with prosthetic technology and fitting aspects for below knee amputees?

   Yes ☐ A little ☐ No ☐

2. Are you working with an orthopaedic workshop or similar centre?

   Yes ☐ No ☐

3. If yes, how does your job relate to rehabilitation?

   a) auxiliary
   b) prosthetist
   c) orthotist
   d) nurse
   e) administrator
   f) engineer
   g) other (please describe)

4. Which particular information in the manual did you find most useful?

		essential	useful	not useful
1)	anatomy			
2)	basic fitting			
3)	plaster cast			
4)	leather socket			
5)	aluminium socket			
6)	wooden socket			
7)	resin socket			
8)	suspension			
9)	Rocker foot			
10)	SACH foot			
11)	walking comfort			

Please use a separate sheet for further comments.

5. If you are not yet involved in prosthetic services, but intend to become involved in the future, which section(s) of this manual would help you most to set up a service?

6. Which sections do you feel don't give enough information, or are not clear and easy to understand?

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7. Did you find the diagrams useful and clear? If not, why not. Please make any suggestions for their improvement. Use separate sheets if necessary.

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8. If you are not actively involved in prosthetic work, of what interest is the manual to you?

a) library or resource centre
b) course material
c) personal or other interest — please describe

9. Where did you hear about this manual?

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NAME . . . . . .

ADDRESS . . . . . .

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PLEASE CUT OUT THIS PAGE AND SEND IT TO AHRTAG. THANK YOU.

CHAPTER ONE : ABOUT THIS MANUAL

1. Purpose of the manual
2. Use of the manual
3. Artificial limb services

About this manual

1. Purpose of the manual

This manual provides technical information and advice on the manufacture and fitting of below knee prostheses.

Information has been collected from many rehabilitation centres in developing countries where the designs have proved both useful and practical in particular environmental conditions. The details have been set out for easy reference by the reader, so that the most appropriate type of limb can be chosen for local production, taking into account conditions and resources. Alternative components described in the manual may be adapted to suit existing designs. Costs for materials and tools as well as necessary labour time are indicated in the text as a guide. However, such economics vary from place to place, and should therefore be considered with care.

The manual aims to encourage the production of prostheses by alternative methods, using locally available resources, in those areas where more sophisticated techniques and limbs cannot be provided. The manual, therefore, will be of particular use to those who have gained a basic knowledge of anatomy and skin care, and who have experience of the specific needs of amputees.

In this manual we describe just some of a wide range of simple prostheses available in many centres in developing countries. We deliberately exclude from the body of the text those limbs which must be considered only appropriate where there is a limitation of even basic materials and other resources. Amongst these we might include the knee bent prosthesis, (briefly described in Appendix 1) in which the below the knee stump is severely flexed to rest on the prosthetic support. It is hoped that, at least by the year 2000, the year designated by the World Health Organisation as a goal for achieving appropriate "Health Care for All", that there will no longer be a need to provide this kind of prosthesis. A device of this kind is a poor replacement for the original limb in terms of comfort, appearance and, most important, as an aid to mobility.

Many amputees have few resources to pay for rehabilitation care, including the prostheses, they need. Are they to be denied help? Until the best possible care is available to all regardless of resources, it will be necessary to provide low-cost prostheses made to the highest possible standard. This manual aims to bridge the gap between the sophisticated artificial limbs available to amputees in areas where resources are relatively plentiful and those low-cost prostheses made available in mainly remote rural areas where both technical and material resources are severely limited.

About this manual

2. Use of the manual

Chapter 2
In this chapter we provide basic information on the anatomy of a leg. It is essential to have some knowledge of this subject to understand limb fitting techniques.

Chapter 3
This chapter provides an introduction to techniques for fitting a below the knee stump. Careful and sensitive fitting is the key to the successful provision of any kind of prosthesis. That is why this chapter is important for all limb makers whatever particular design of artificial limb they may choose to make.

Chapter 4
The part of the artificial limb actually in contact with the stump is the socket. Those sockets with the best fit are usually made from a plaster model of the stump. This chapter describes how to make a simple below knee prosthesis, using plaster of paris.

Chapter 5
In this chapter we describe how to make a simple below knee prosthesis when plaster of paris and plaster bandages are not available.

Chapter 6
This chapter provides basic information describing how to suspend a prosthesis on the thigh.

Chapter 7
Various types of artificial footpieces are described in this chapter. These may be used where a peg leg is not acceptable. Designs included range from modifications of the Rocker to more sophisticated footpieces, including the Jaipur foot.

Chapter 8
This chapter describes how to improve walking comfort for an amputee using a prosthesis. Information is included on bandaging the stump prior to limb fitting and on prevention of joint contracture. There is also a brief analysis of the reasons for poor fitting and poor alignment.

Appendices
These contain useful addresses, hints for using certain materials and other relevant information.

3. Artificial limb services

Artificial limb services vary widely in different parts of the world. Where rehabilitation workshops and skilled labour are scarce, limb makers have developed ingenious designs matching local needs to available materials and levels of technology.

In some parts of the world technology has developed dramatically allowing ever more sophisticated techniques to be used to provide upper and lower limbs for amputees. Those artificial limbs function well and look very like lost limbs. Great strides in technologies have also been made to accommodate children born with limb deficiencies.

However, in many developing countries rehabilitation services are limited and out of reach for many disabled people. There remains a need to provide limb fitting services for those amputees unable to take advantage of or to reach existing services.

Let us consider some aspects of providing a service where resources are limited.

1) **Availability of materials**
Where there are difficulties in obtaining certain materials such as plaster bandages, plastic resin, and microcellular rubber, it may be necessary to consider the use of alternative materials which are obtainable locally and may be less expensive. It may be necessary, where critical components cannot be locally produced, for these to be imported or to have them made in one central place in the country concerned.

2) **Shortage of skilled technicians**
Trained limb makers are in short supply, therefore, in some areas it may be useful to employ local artisans to undertake the production of component parts of a limb. Leather and metal workers can be quickly trained to use their experience in this way.

To employ highly skilled local people fits in very well with the World Health Organisation's strategy for community based rehabilitation programmes.

3) **Rehabilitation services away from main hospitals**
A limb fitting service can be run from existing clinics, health care centres and workshops. It is essential, when planning the service, to ensure an aftercare service at regular intervals. Any prosthesis is likely to need alterations and repairs. An efficient documentation system will be necessary to facilitate patient service and to ensure no amputee is left without follow-up.

4) **Cultural acceptance of limbs**
Other aspects to consider are cultural customs and environmental requirements. If people squat or sit cross legged in social gatherings or squat for urination and defaecation, or kneel for prayers, their artificial limbs must be appropriately designed to allow for these movements and postures. A limb should also be suitable to enable an individual, as far as possible, to carry on with their work whether this is in the paddy fields, cycling a rickshaw or working in an office.

The local environment needs to be taken into account in designing a limb and in choosing the materials to be used. It is important to remember that rubber deteriorates on exposure to air and sunlight, and that extreme temperature and rough and uneven ground affect materials - some more than others.

5) **Personal responsibility for repairs**
If amputees (or the local community) are able to take over responsibility for minor repairs, this will decrease reliance on the orthopaedic workshops and cut down on the problems of travelling. Local craftspeople will require only minimal training to understand how to repair an artificial limb when this is made from local materials.

CHAPTER TWO : ANATOMY OF A LOWER LIMB

Anatomy of a lower limb

An artificial limb is designed to act as a mechanical substitute for a human limb so that a person having had an amputation can continue life with as few psychological and social restrictions as possible. It is very important that the artificial limb fits the stump extremely well. It is necessary therefore, for those who are designing and fitting artificial limbs to have an understanding of the basic anatomy of the human limb as well as of the stump.

In simple terms, the lower human limb has three parts:

(1) above the knee: thigh

(2) below the knee and above the ankle: lower leg

(3) below the ankle: foot

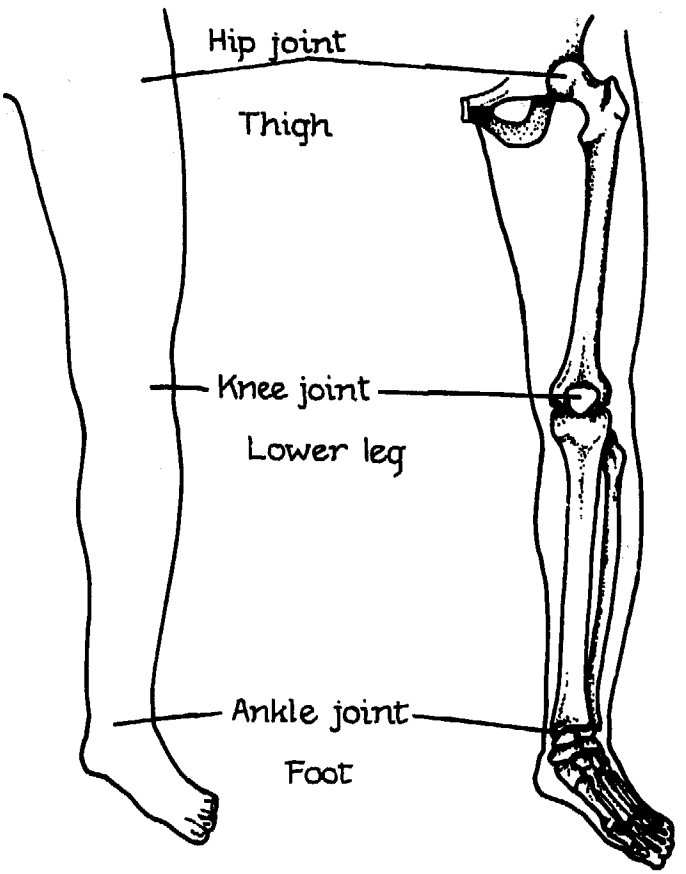
The figures below show these parts and how they are linked together.

Characteristic joints are:

(a) hip joint

(b) knee joint

(c) ankle joint



Anatomy of a lower limb

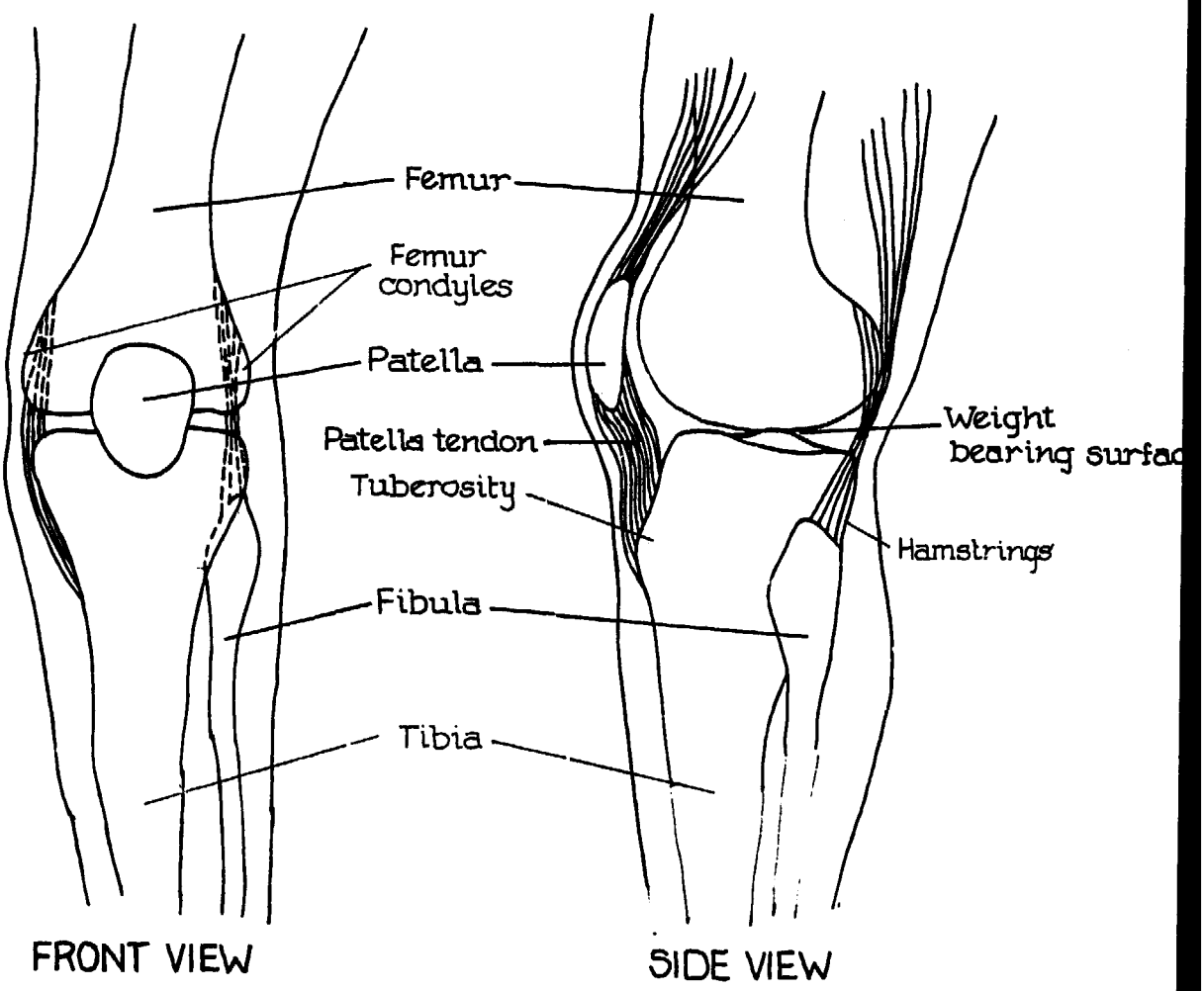
This manual only deals with below knee amputations. Amputations above the knee, through the knee joint and partially through the foot are not discussed in this manual, as the prosthetic techniques differ from those for below knee amputees.

Let us look at the anatomy of a knee joint in greater detail.

The knee joint consists of three bony parts:

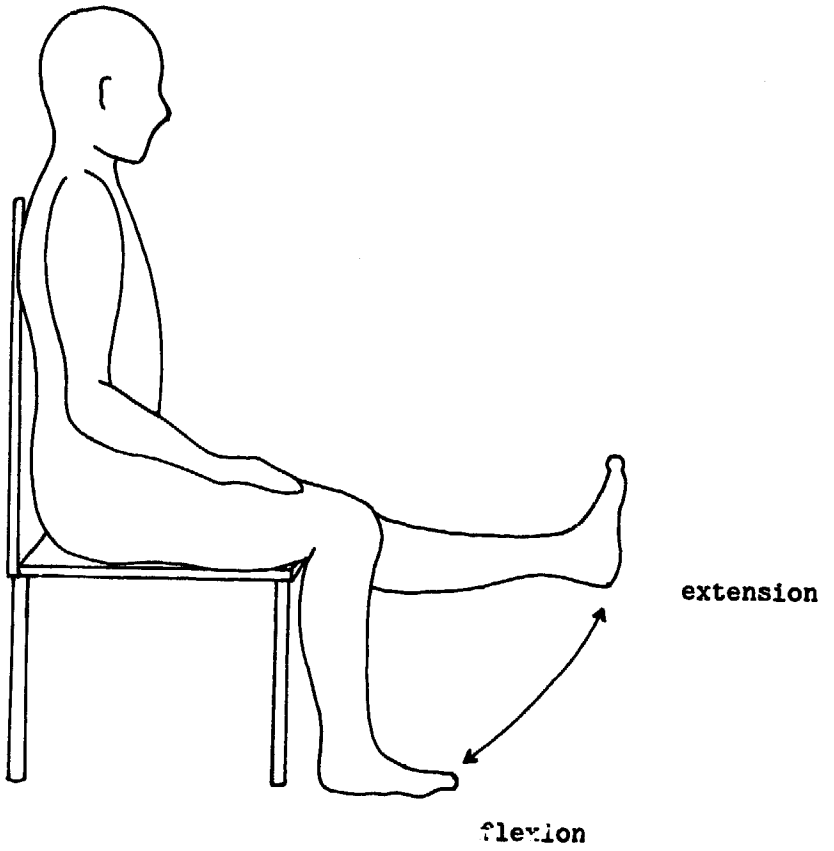
- end of tibia and its weight bearing surface
- end of femur and its weight bearing surface
- patella

The fibula is not a part of the knee joint. However, it is also an important bone for fitting the prosthesis.



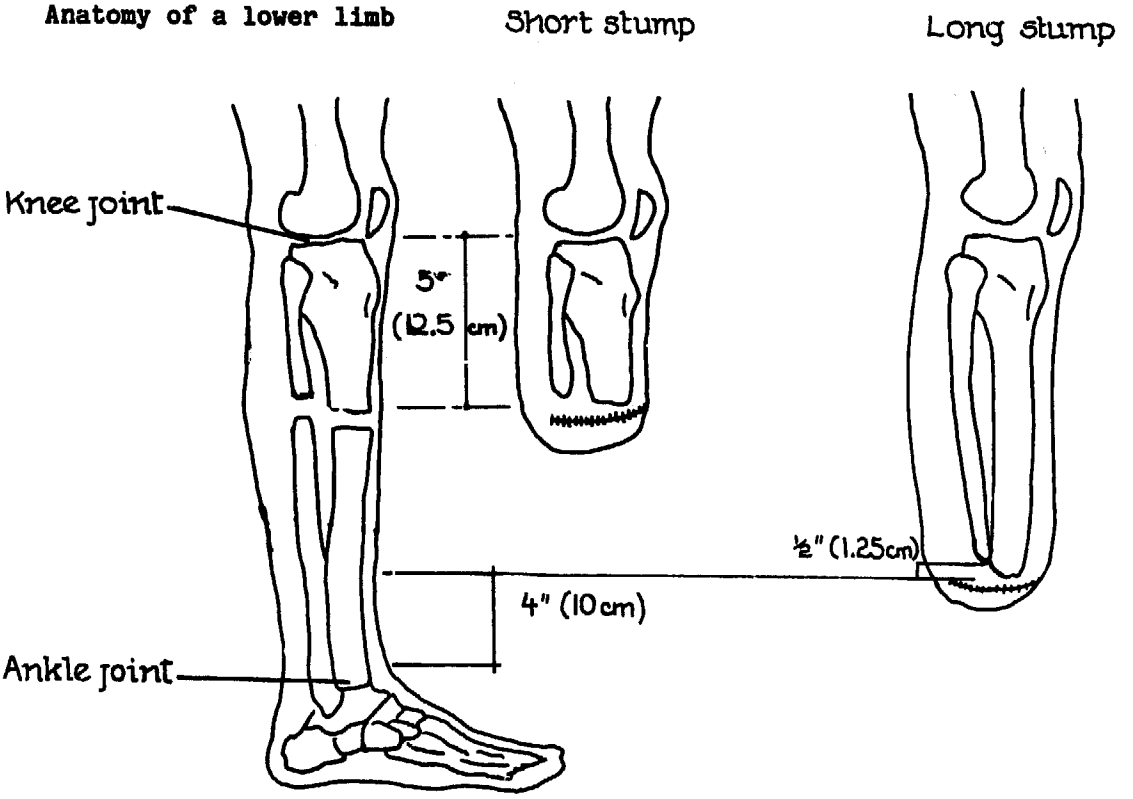
Anatomy of a lower limb

As shown below, the knee joint allows backward and forward movements. These are described as flexion and extension.



Flexion and extension of the knee joint

Anatomy of a lower limb

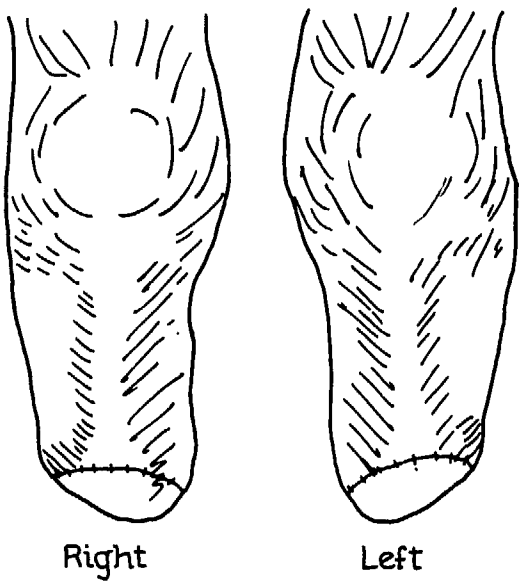


Amputation techniques are not described in this manual. It is enough to say that the following stump lengths are appropriate for an adult:

- **length of tibia from the knee joint is at least 5" (12.5cm)**
- **length of tibia above the ankle joint is at least 4" (10cm)**

The fibula length remains 1/2" (1.25cm) shorter than the length of the tibia.

During surgery, skin flaps are carefully cut and stitched around the front of the remaining stump. A left and right stump are shown in the figures.



CHAPTER THREE : FITTING OF A BELOW KNEE PROSTHESIS

1. Introduction
2. Length of below knee stump
3. Skin observation
4. Usual bony bumps

4.1 End of the tibia

4.2 Fibular head and fibular end

4.3 Crest of the tibia

4.4 Tibial tuberosity

4.5 Patella

4.6 Hamstrings

4.7 Hollow of the knee

5. Usual pressure tolerating areas

5.1 Patella tendon

5.2 Medial and lateral flares

5.3 Calf

6. Summary

Fitting of a below knee prosthesis

1. Introduction

Having studied the basic anatomy of a lower limb we will now consider basic details concerning below knee amputations: how to fit a prosthesis onto a stump.

The importance of proper fitting cannot be overemphasised. A prosthesis is unlikely to be used by an amputee unless proper fitting and comfort has been assured. Care of the stump, which is so important, is described in Chapter 8.

An amputation below the knee has various causes:

- trauma
- vascular disease (difficulties of blood circulation including diabetes)
- burns
- infection
- leprosy
- congenital (from birth) malformation
- cancer

Some countries show a high incidence of traumatic amputations, in other countries the incidence of leprosy leading to amputations is higher. In any case, each stump is likely to be different. Therefore, each stump should be closely examined by the limb maker to ensure maximum fitting comfort.

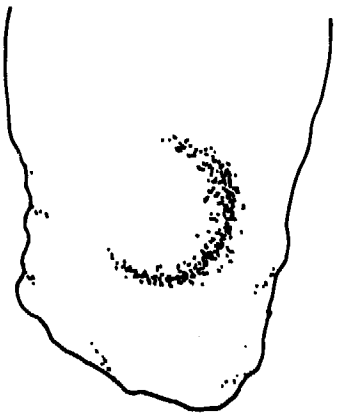
Fitting of a below knee prosthesis

General assessment of the stump should include:

- length of the stump
- blood circulation (through skin temperature and skin colour). There should be as little swelling as possible.
- strength of muscles, especially of the flexor and extensor muscles at the thigh
- knee joint mobility/range of motion (possibly to be improved with physiotherapy or surgery)
- whether the amputee has worn an artificial limb - details including period of use, negative reactions, etc.
- shape of the other limb

Regarding fitting comfort, the examination should also include:

- skin condition
- painful bony parts
- place and quality of surgical scar



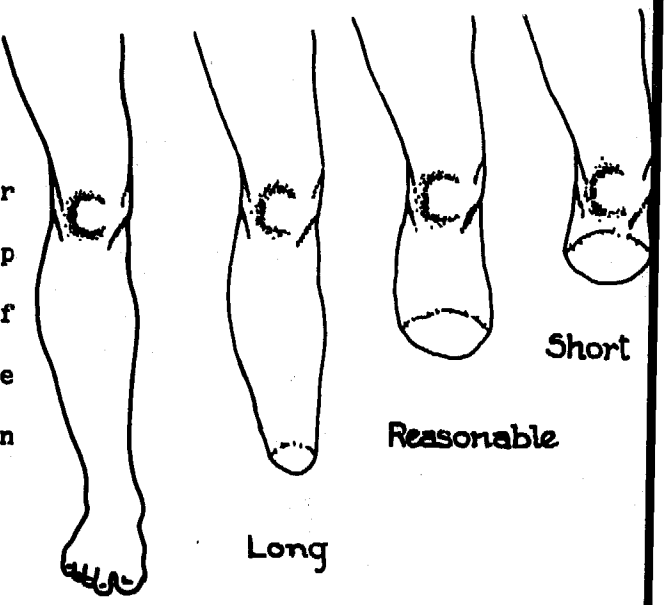
bad stump

Why is this a bad stump?

notice

- the shortness below the knee
- amount of weak and flabby tissue
- rippled skin

Fitting of a below knee prosthesis

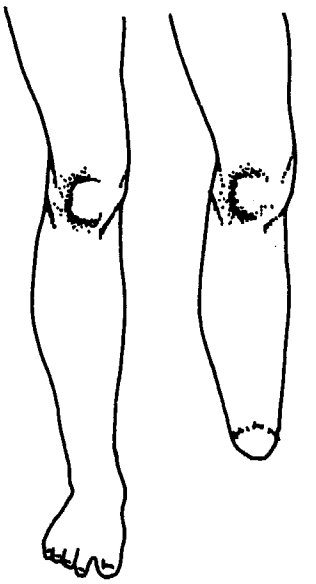


2. Length of a below knee stump

A stump is called 'long' if 2/3 or more of the tibia is left. A stump is called 'short' if 1/3 or less of the tibia remains. A reasonable length of stump is somewhere between the two.

long stump

A long stump has a relatively large vertical bearing surface. Hence, pressure of a prosthesis on the skin is relatively low. Also, the larger bearing surface allows such an amputee greater stability in walking.



There are some difficulties arising from long stumps. Blood circulation is not always sufficient at the end of the stump. This may lead to death of bone tissue. For this reason the end of a long stump should preferably not be exposed to pressure by the prosthesis. Also, it can be difficult to attach artificial feet when there is little space to make the attachment.

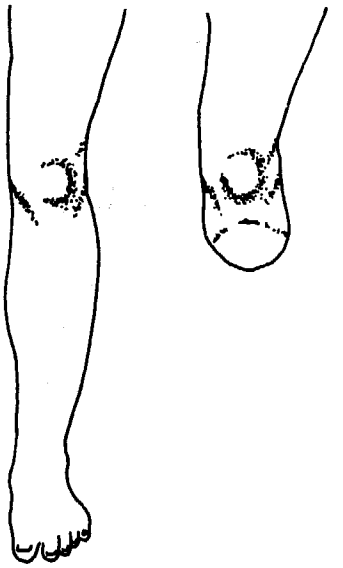
Points to bear in mind when fitting long below knee stumps:

- large bearing surface
- stable walk
- poor blood circulation at end of stump
- difficult attachment of foot piece

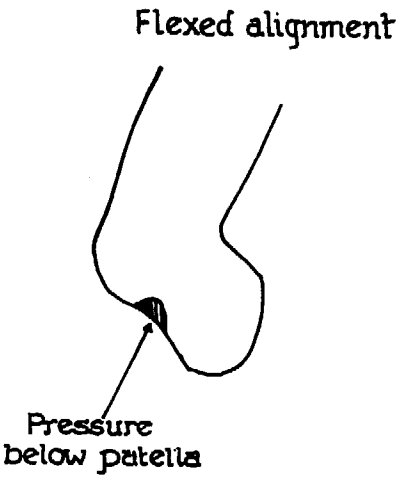
Fitt[illegible] a below knee prosthesis

[illegible]rt stump

A short stump has a relatively small bearing surface. This is why pressure of a prosthesis on the tibial skin is relatively greater than is the case for long stumps. Walking stability is also less. In some cases, it may be preferable to enlarge the bearing surface with a thigh suspension (see chapter 6).



The tissue below the patella can tolerate higher pressure than the tibial skin. In the case of short stumps, where skin pressure is already high, it is recommended to put relatively more pressure on the tissue below the patella than on the tibial skin. This is done by positioning the prosthesis-socket in a slightly flexed alignment.



In some of the short below knee cases, a knee joint may be set in a fixed position, a so-called flexion contracture. This is further assessed in chapter 8 on improving walking comfort.

Points to bear in mind for the fitting of short below knee stumps:

- small bearing surface
- reduced walking stability
- in order to prevent extreme pressure on the remaining stump, consider positioning the socket in flexion
- possibly a flexion contracture

Fitting of a below knee prosthesis

3. Skin observation

Careful observation of the skin of a stump is essential before proceeding further. Note carefully any painful bony bumps. These bumps will normally not tolerate pressure from the prosthesis. Should an amputee return to the rehabilitation centre with a painful stump as the result of an ill fitting prosthesis, it is essential to examine the skin carefully to ensure the problem is not repeated in the next socket.

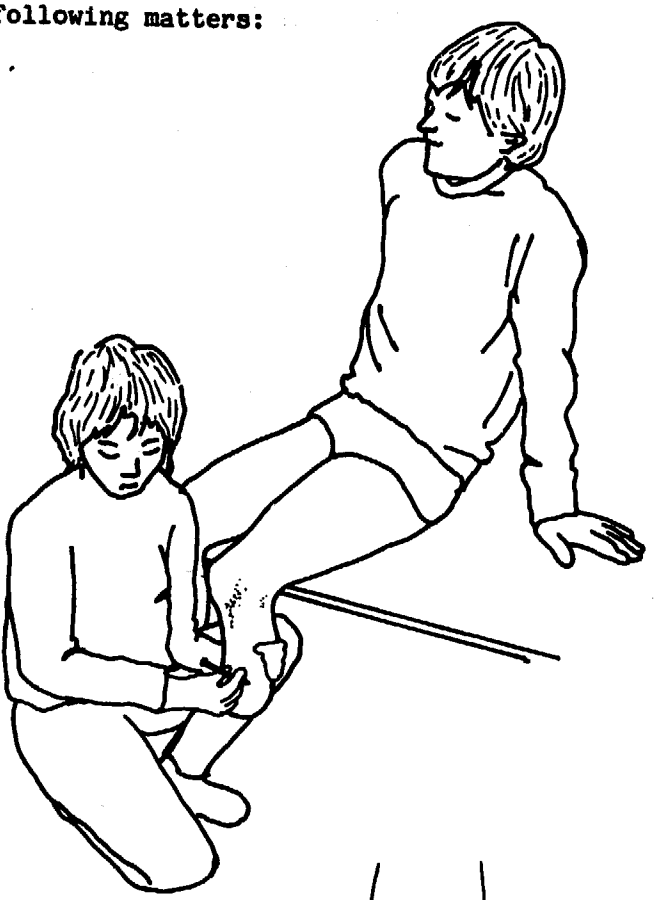
A stump often decreases in size (atrophy) during the first year after amputation. This may also occur after some years if the amputee is not so active and is not walking on the artificial limb often. This could be as a result of discomfort caused by ill fitting. Considerable care should be taken to ensure that if the stump sinks in the socket, no pressure is borne on the end of the stump and on the fibula head. If aftercare cannot be guaranteed, it is important to keep the socket open at its end, possibly only filled with soft foam.

Fitting of a below knee prosthesis

Finally, when a patient's amputation is caused by leprosy or diabetes, extra care should be given to the following matters:

1) **Absence of sensitivity**

Check sensitivity of the skin by touching the stump with a finger nail or feather. Preferably, the skin should not be pressed by the socket on this area. If the stump is really short and a small insensitive area has to bear the weight, teach the amputee to check regularly and especially carefully that no sores are developing.



2) **Cracks**

In the case of leprosy where the nerve supply is lost, the skin may become dry, scaly and cracked. All such cracks tend to admit infection and may be the cause of serious troubles for the stump.

Cracks

Preparation of skin:

You can use oil or lotion to keep the skin from getting too dry. Use as little as possible. Too much oil or lotion may irritate the skin when it is inside the socket. This treatment is important for those who have insensitive areas on their stump, and it must be done every day. Preferably, do not allow pressure to occur on the cracked areas of the stump when fitting with a prosthesis.

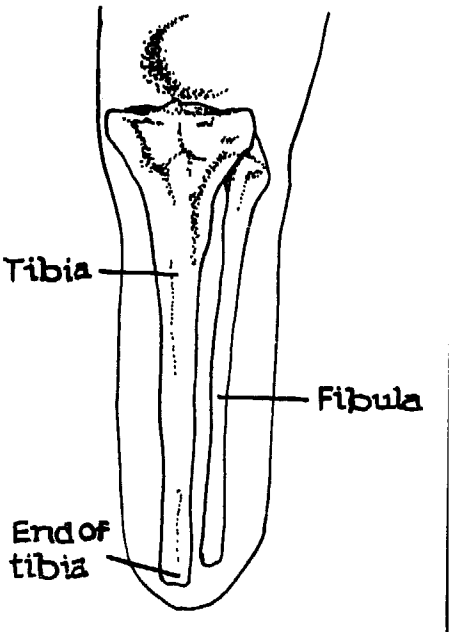
Fitting of a below knee prosthesis

4. Usual bony bumps of below knee stumps

We describe below some usual bony bumps which need special attention for proper fitting.

4.1 End of the tibia

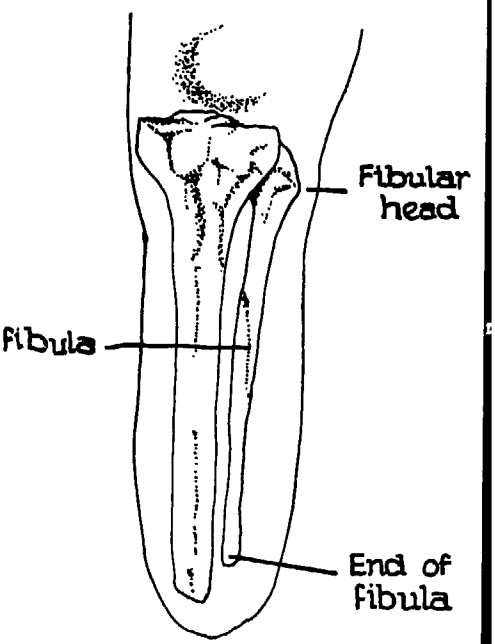
Usually, the end of the tibia cannot bear any pressure. To encourage blood circulation, light massage of the tibial end of the stump is recommended. This also helps to diminish the stump pumping inside the socket, causing local friction and sometimes a tremendous temperature increase. The massage may be achieved by placing the stump in contact with soft foam which is inserted in the end of the socket, under the stump.



4.2 Fibular head and fibular end

The fibular head does not tolerate pressure because nerves are present near the skin surface (nerve peroneus).

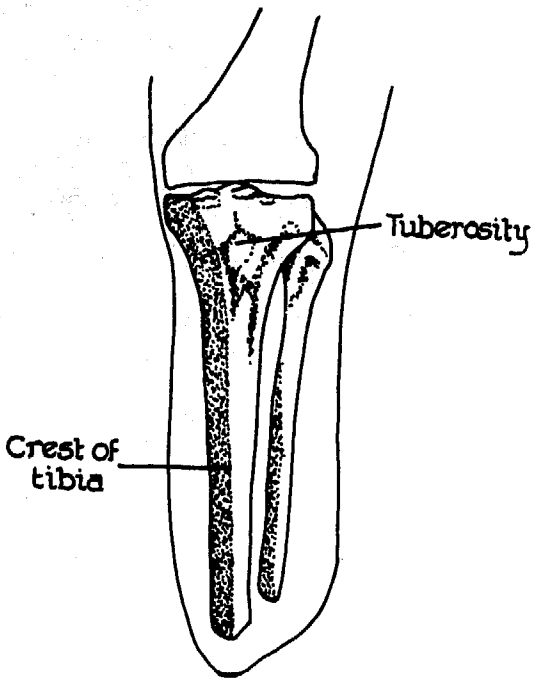
The fibular end also does not tolerate pressure owing to its relatively sharp surface. Sometimes the fibular end is connected under surgery with the tibial end by a bone bridge.



FRONT VIEW

4.3 Crest of the tibia

The tibia has a triangular shape, and one of its brims is called the tibial crest. It is found in front of the stump. Due to its relatively sharp shape, it does not tolerate pressure.

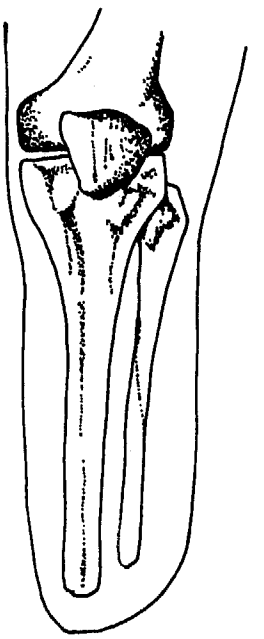


4.4 Tibial tuberosity

The tibial tuberosity is a bony bump positioned just above the crest of the tibia. It does not tolerate pressure. It is here that the extensor muscles are attached to the tibia.

4.5 Patella

The patella does not tolerate any significant pressure. The prostheses presented in this manual allow pressure only on the tibia and soft tissues of the stump.



FRONT VIEW

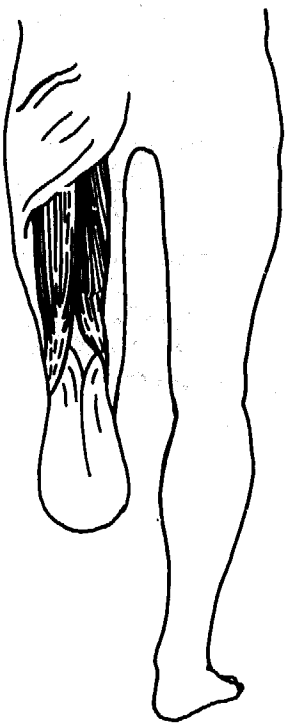
Fitting of a below knee prosthesis

4.6 Hamstrings

If comfort is to be ensured, movement of the flexor muscles and tendons (hamstrings) must not be restricted by a socket fitting too closely.

Medial hamstrings require even more space than lateral hamstrings. This can be seen when the amputee is sitting with knees flexed.

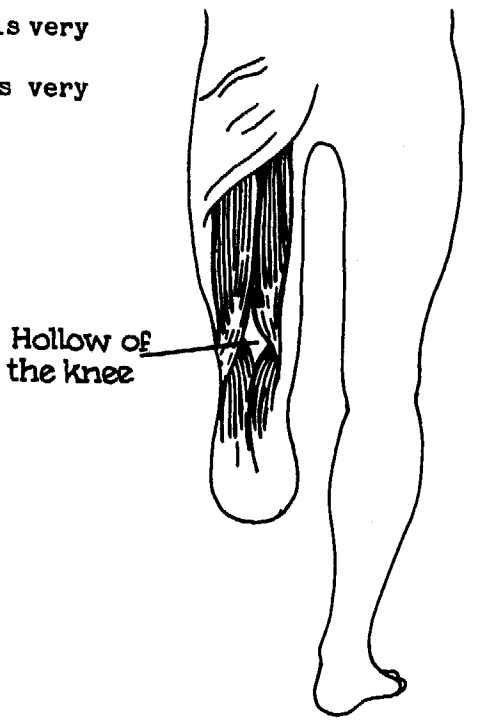
While trying out the prosthesis, the amputee should check for any discomfort by walking and sitting.



BACK VIEW

4.7 Hollow of the knee

In the hollow of the knee the skin is very sensitive. Therefore pressure is very uncomfortable and often painful.



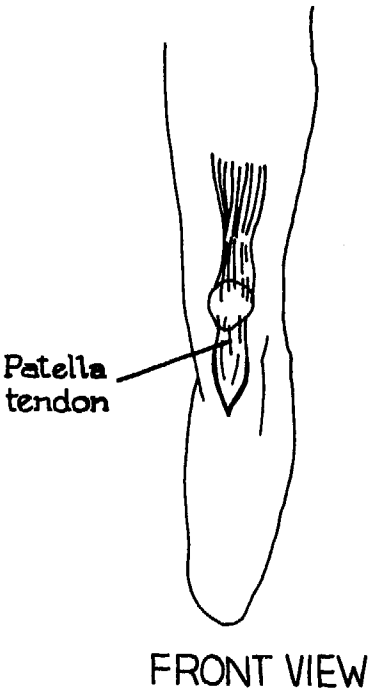
Fitting of a below knee prosthesis

5. Characteristic pressure-tolerating areas

We have indicated the delicate areas on a stump which occur below the knee. We now describe areas which normally are able to tolerate varying degrees of pressure.

5.1 Patella tendon

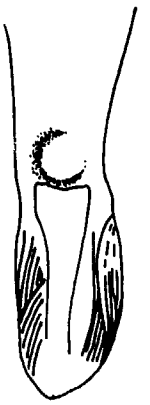
The tissue below the patella is called the patella tendon. It is able to tolerate a lot of pressure. (For more detail see pages 15, 33 and 152).



As we have seen, the bearing surface of a short stump is relatively small. Therefore, the ability to bear on the patella tendon area becomes very important. This is made easier if the stump and prosthesis are positioned in a slightly flexed position.

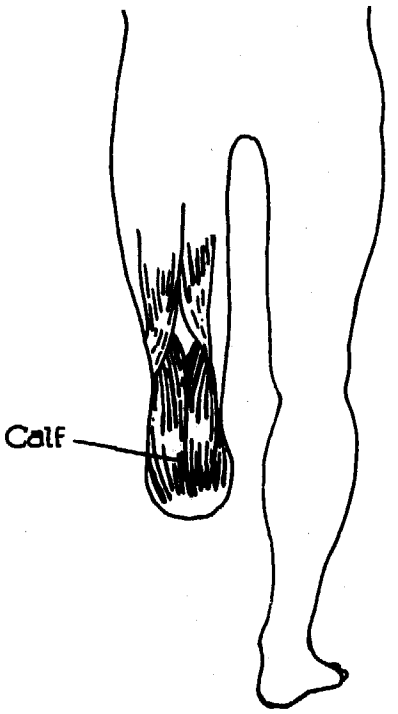
5.2 Medial and lateral flares

Medial and lateral flares can also take a lot of pressure.



5.3 Calf

The calf of a limb below the hollow of the knee is able to take a little pressure, as a counterbalance to the pressure of the medial and lateral flares. However, too much pressure will often cause irritation.

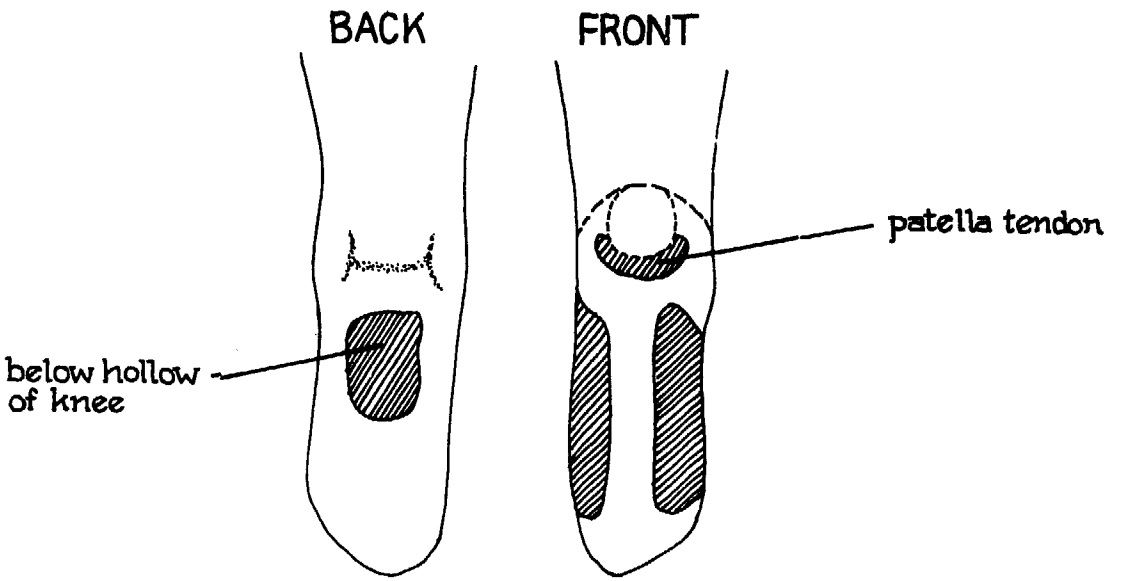


BACK VIEW

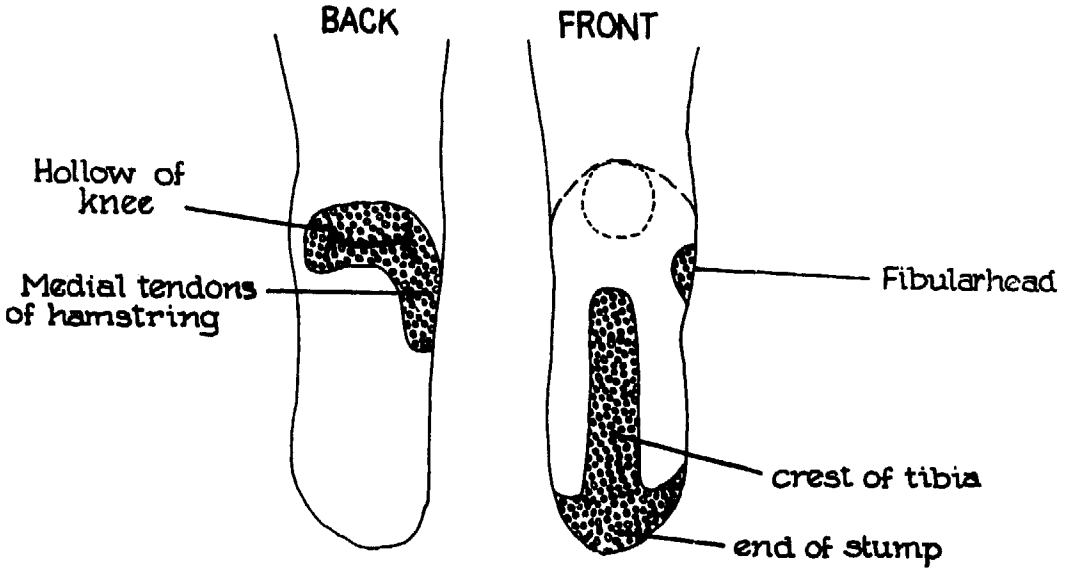
Fitting of a below knee prosthesis

Summary

areas tolerating pressure



areas not tolerating pressure



CHAPTER FOUR : PROSTHESIS MADE FROM A STUMP CAST

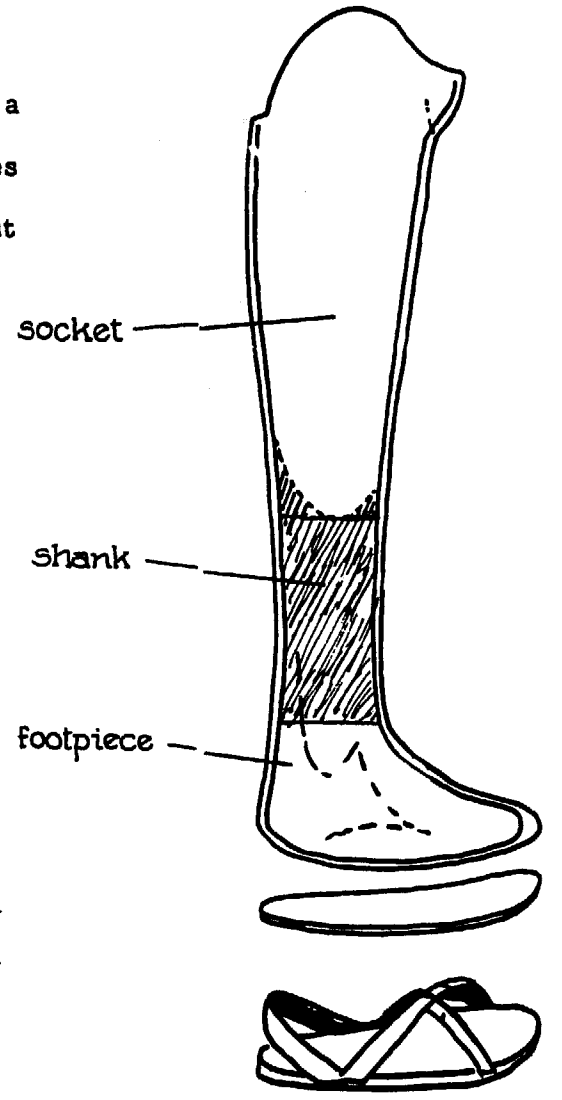
1. Introduction
2. Making a copy of a stump out of plaster
3. Modifying the plaster cast
4. Preparing a leather socket from the plaster cast
5. Building a prosthesis with a leather socket
6. Alternative prosthesis with a leather socket

Prosthesis made from a stump cast

1. **Introduction**

The basic fitting requirements are now understood, and it is time to start making a prosthesis for a below knee amputee patient.

The most important component of a prosthesis is the socket, which provides the actual contact between the patient and the walking aid.



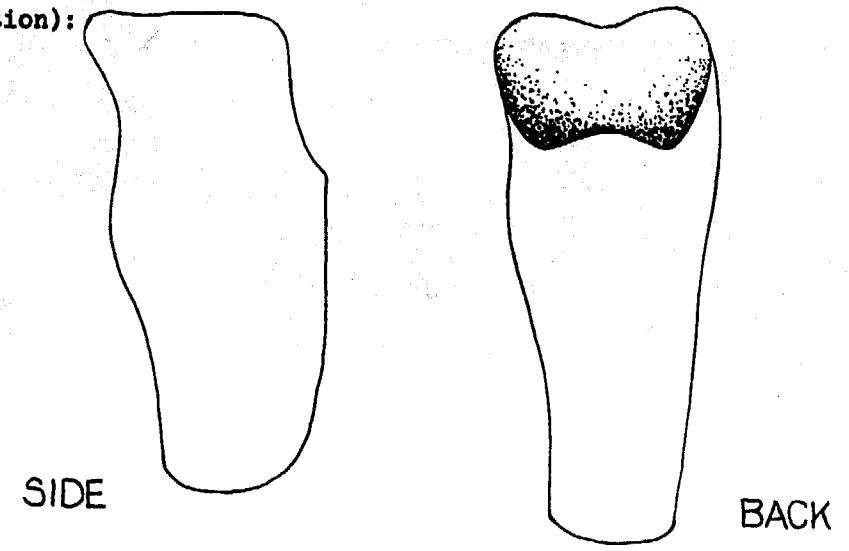
Whatever materials are used for making a footpiece, if the socket is not correctly made the prosthesis will be useless.

In practical terms, a socket for a below knee stump will fit properly if it allows pressure only on those places able to tolerate pressure. There should be no pressure on the socket where this cannot be tolerated.

The socket must also be durable, maintaining its shape for a long time and during wet seasons.

Prosthesis made from a stump cast

A socket may have the following shape (drawn for left below knee amputation):



The most popular way of making a socket for below knee prostheses is to use plaster of paris and plaster bandage. This is likely to give the best results. The use of plaster should result in a precise fit of the prosthesis onto the stump. A precise fit is very important if the socket is rigid because it cannot adapt to the shape of the stump. Rigid sockets may be made from resin, aluminium, wood, etc.

When preparing a leather socket, however, complete accuracy is not so important as leather adapts more readily to the shape required. In this case, instead of plaster you can make a positive stump model from materials like wood, beeswax or clay. Operation Handicap International has gained experience with a wooden model and leather sockets.

This chapter describes the making of a positive cast of a stump using plaster, and describes how to make a socket from the positive cast. It also describes how to build a prosthesis around the socket.

Prosthesis made from a stump cast

2. **Making a copy of the stump out of plaster - materials needed**

- plaster bandage (3" (7.5cm) or 4" (10cm) rolls)
- plaster of paris powder
- stockinette (3" (7.5cm) or 4" (10cm) rolls), or a plastic sack
- vaseline or other greasy substance, for instance palm oil
- steel pipe (½" (1.25cm) or wooden stick
- scissors
- marking pen
- soapy water
- basin of clean water

Method

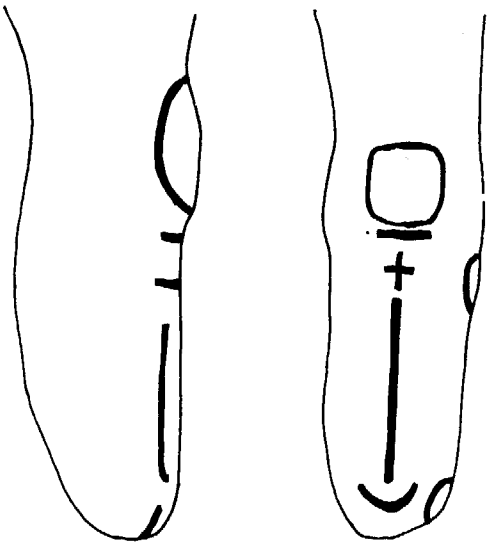
1) Clean the stump, removing hair on the stump if possible, and wet with soapy water. If available, coat the stump with vaseline or use another greasy substance.

2) If the skin is sensitive and where there may be open ulcers or sores, fit a plastic sack or stockinette sock around the stump to avoid plaster sticking to the skin.

3) Check the stump carefully to discover the areas which will tolerate pressure and those which will not tolerate pressure. Mark with a pen on the stump or on the stockinette sock the following:

- patella outline
- tibial tuberosity
- head of fibula
- end of fibula
- crest of the tibia
- end of the tibia
- any other sensitive areas or insensitive areas

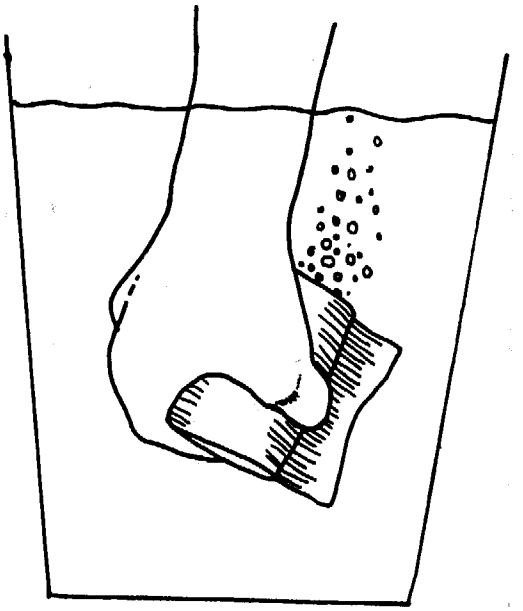
MARKINGS ON THE STUMP



You can locate these areas by studying the previous chapter.

Prosthesis made from a stump cast

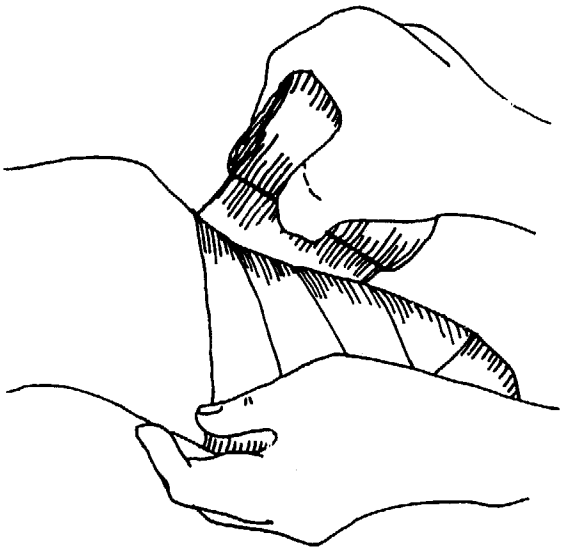
4) Plunge the plaster bandage in a water basin for about 1/2 minute (until no air bubbles appear anymore).

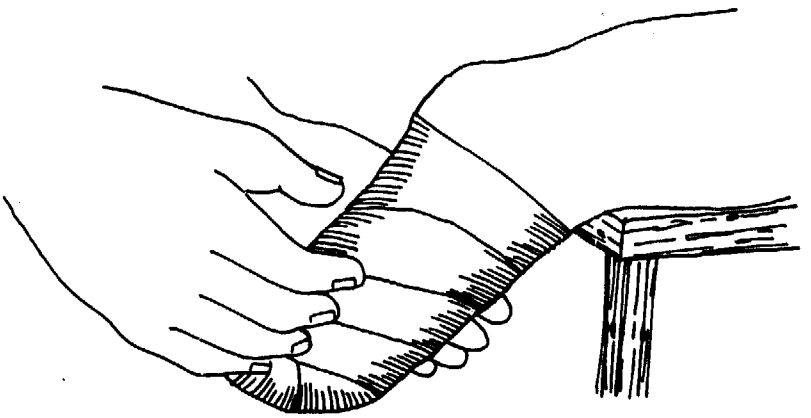


Squeeze out excess water.

Note: If you are going to use the plaster cast as a temporary socket for the prosthesis with, for example, a bamboo pylon, plunge the plaster bandage in a water-based glue. This makes the cast stronger and more durable.

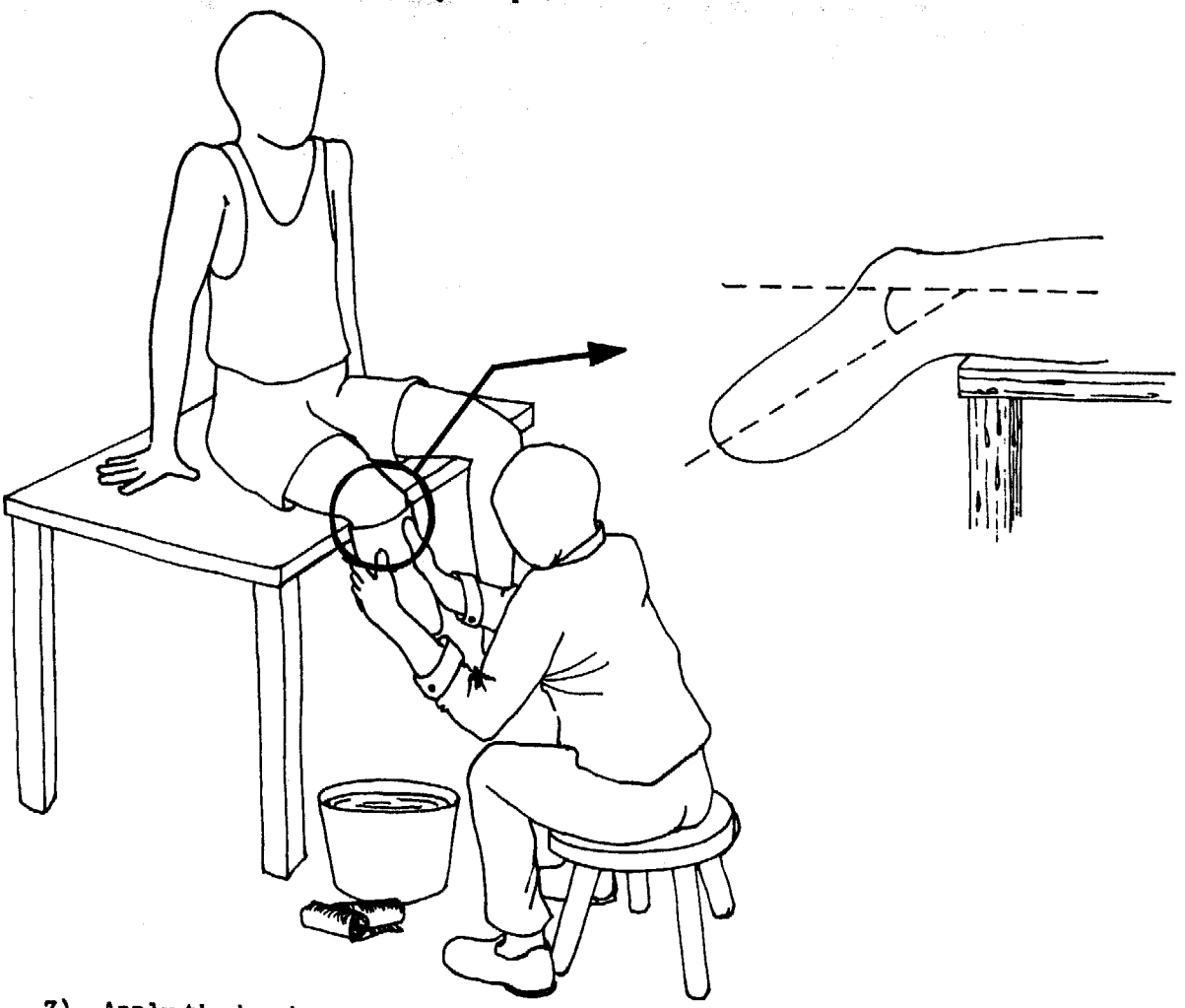
5) Wrap the bandage around the stump. Start near the patella, spiralling down to the end of the stump. Overlap one half the width of the plaster layer with the next, do not enclose the patella. Do not apply much pressure while wrapping the stump.





6) Smooth the layers while they are being applied.

Wrapping should be done with the amputee sitting on the edge of the table, and the stump held a little in flexion. This is necessary to emphasise certain bony bumps.

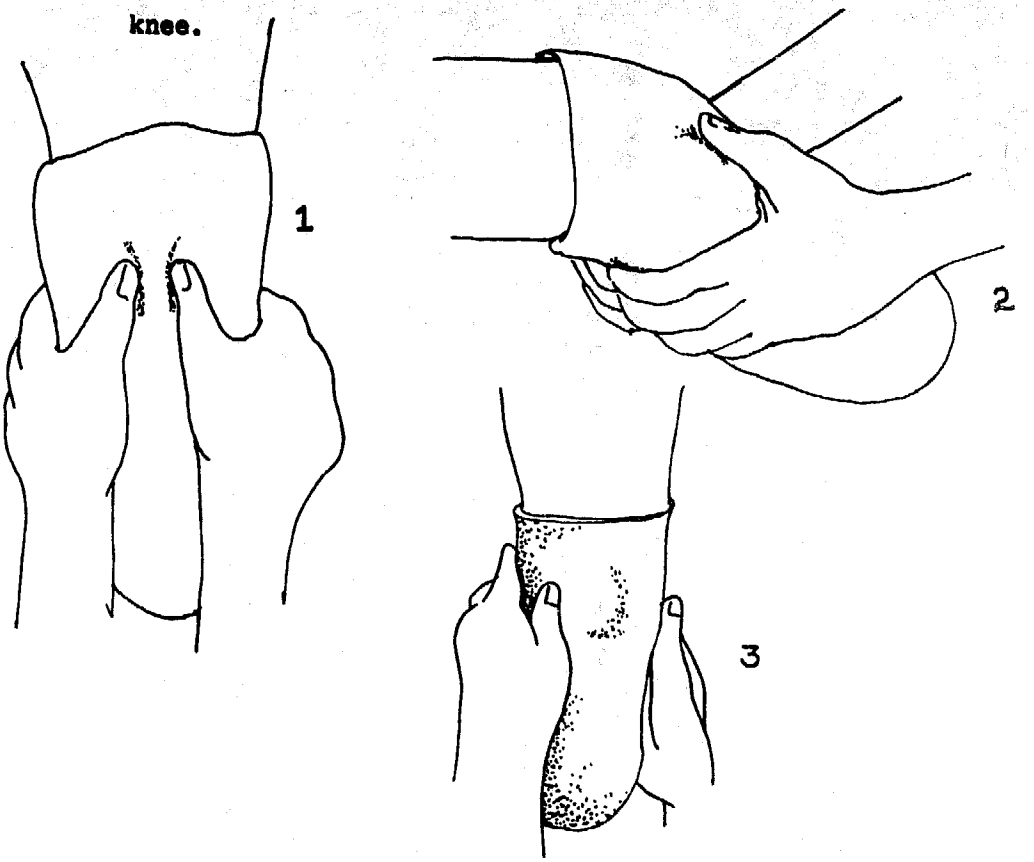


7) Apply the bandage until the shell has a thickness of about 4 layers or more. Do not enclose the entire patella, otherwise it will be difficult to remove the cast. (The wrapping of the plaster bandage should only be extended if you wish to place pressure above and at the side of the femoral joint, and above the patella. This is a more sophisticated fitting technique not described in the manual.)

Prosthesis made from a stump cast

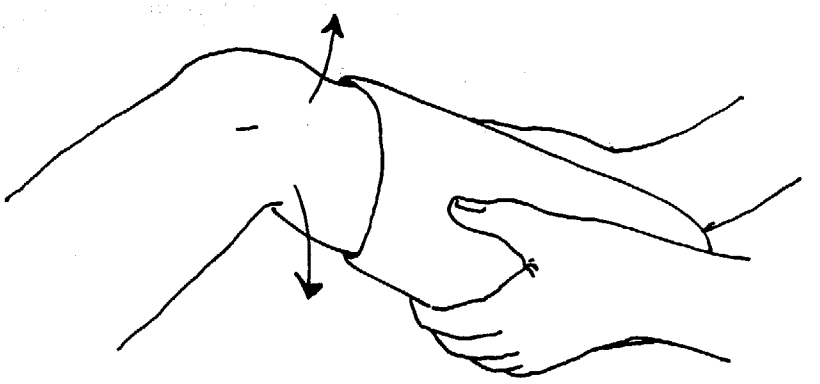
8) As the plaster begins to harden, take the stump in your hands following the shaping grip shown below.

The thumbs outline the patella tendon, the fingers outline the popliteal tissue. The palms of the hands press the tibial flares. The fingers provide gentle counter pressure below the hollow of the knee.



Hold the stump in like this until the plaster has hardened enough to keep its shape.

9) When the plaster has hardened, ask the amputee to push his/her stump against your hands. Carefully remove the cast from the stump.



Prosthesis made from a stump cast

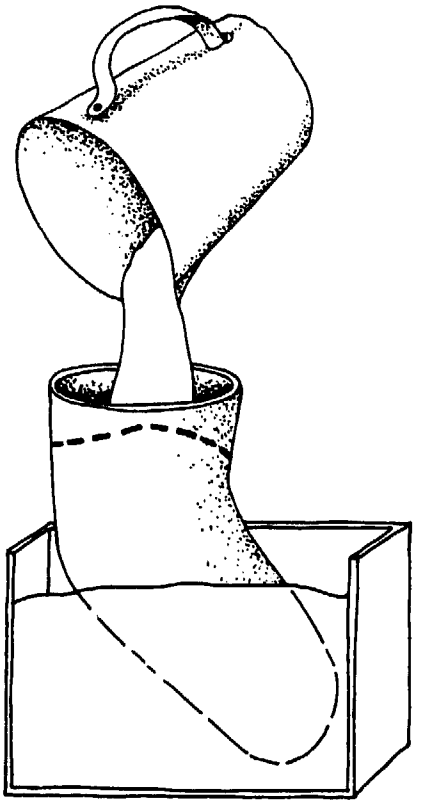
A negative model of the stump is now ready. Let the model dry overnight. This cast may possibly be used as a temporary socket for the prosthesis with, for instance, bamboo or PVC. If you do this, you should use a water-based glue instead of water alone when you wet the plaster bandage. (See page 51 and following pages).

Assuming we are continuing to work with plaster of paris: mark with a pencil the areas in stage 3 on the negative cast.

10) Trim the edges then add a piece of plaster bandage around them. This is done to heighten the wrap cast. The cast must be larger to facilitate the making of the socket. If the cast is too short it will be impossible to mould the full length of the socket accurately.

11) Wet the surface of the wrap cast with soapy water. This stops the plaster bonding to the cast. Place the negative cast in a sand box, making sure that the cast is stable.

12) Fill the wrap cast with plaster of paris. The cast should be higher than will be needed in order to fill it properly with plaster of paris. (See appendix 2 for recycling of plaster).

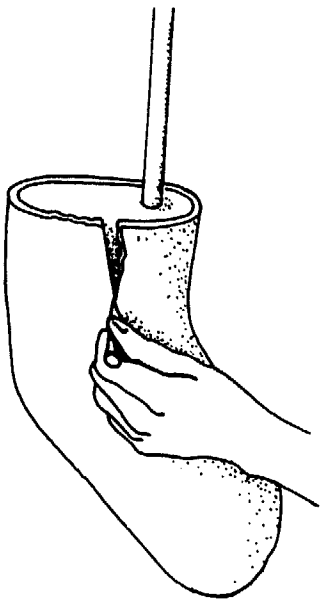


FRONT VIEW

Prosthesis made from a stump cast

13) Position a steel pipe or a wooden stick in the cast. Take care not to damage the negative cast while doing this, and make sure the stick does not touch the bottom or the sides of the cast.

14) After the plaster has set for 20-30 minutes, take off the wrap cast carefully.



15) Clean away the soap, fat, etc. from the model.

Prosthesis made from a stump cast

3. Modifying the plaster cast

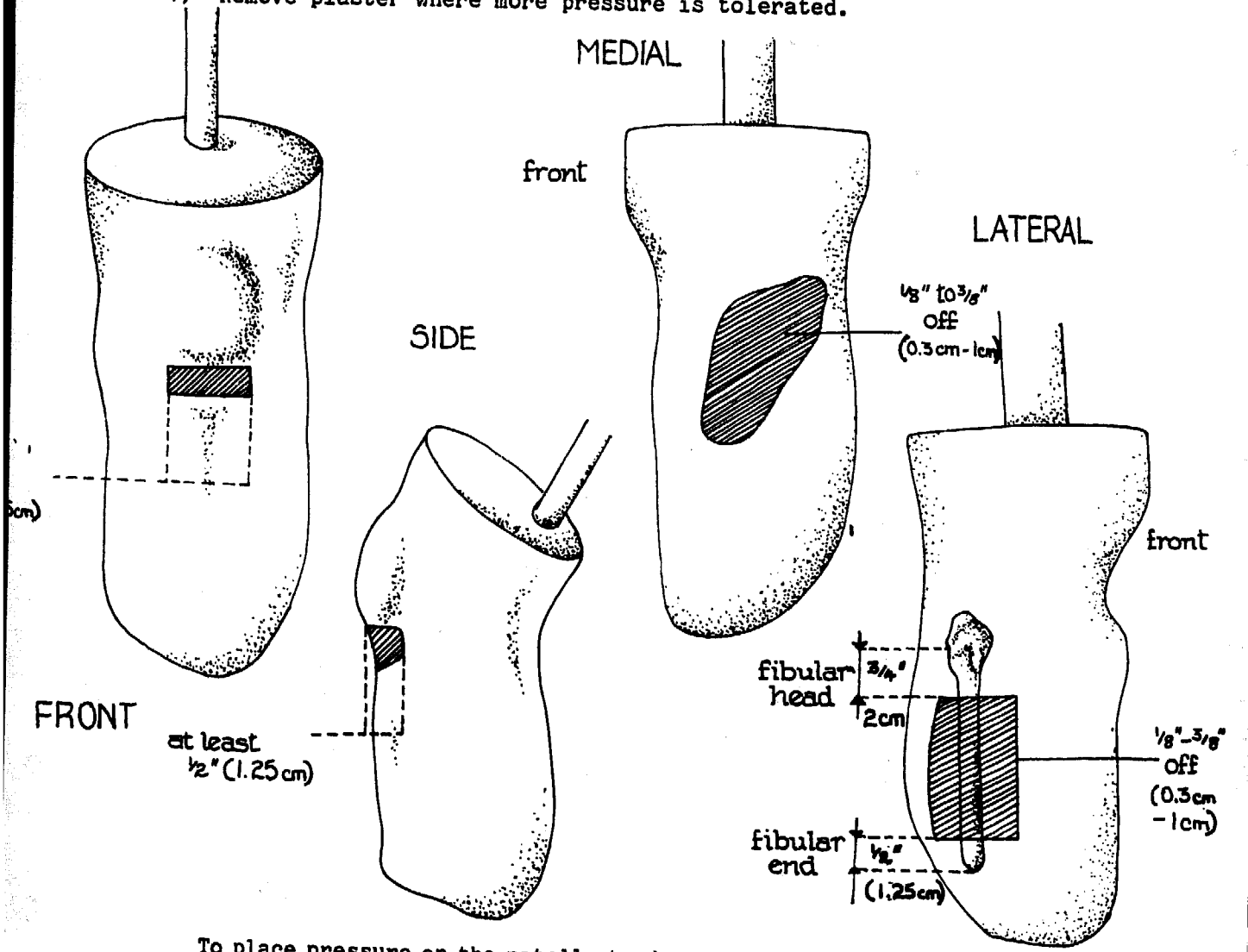
The model is now ready to be modified.

This means:

a) Plaster should be removed from those areas on the model where pressure can be tolerated.

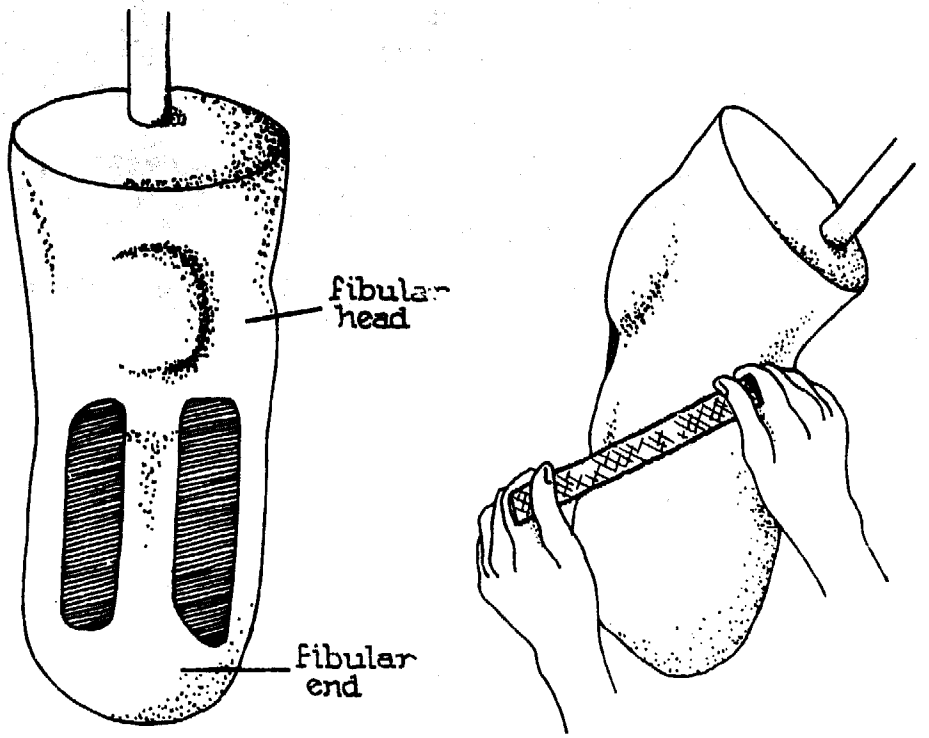
b) Plaster (or patches of leather) should be added on those areas where low or no pressure is tolerated.

1) Remove plaster where more pressure is tolerated.

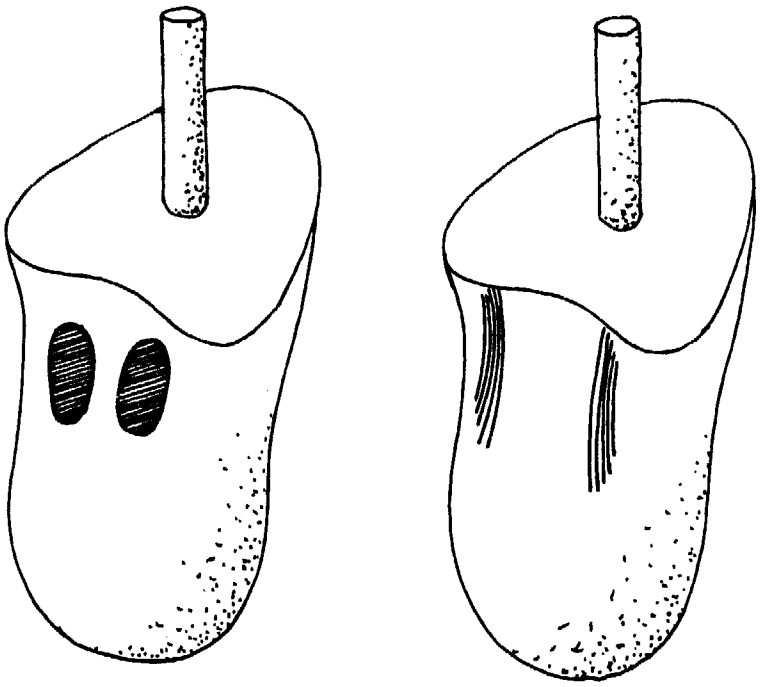


To place pressure on the patella tendon, remove at least depth 1/2" (1.25cm) plaster below the patella as indicated.

Prosthesis made from a stump cast



To place pressure on medial and lateral flares, remove 1/3" (1cm) plaster from either side of the tibial crest.



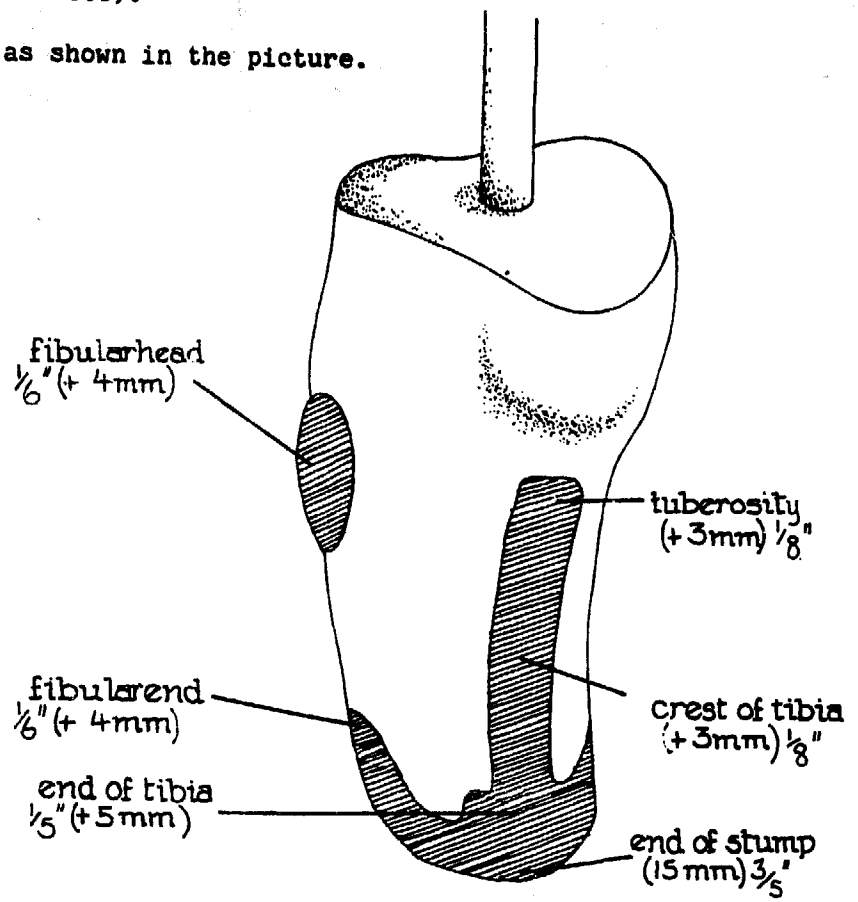
Remove plaster from the rear side, and smooth the calf area (see finger print marks). Be careful not to shave material from the hamstring tendons.

Prosthesis made from a stump cast

2) Add plaster or other material (leather, foam) to ensure less pressure on bony bumps.

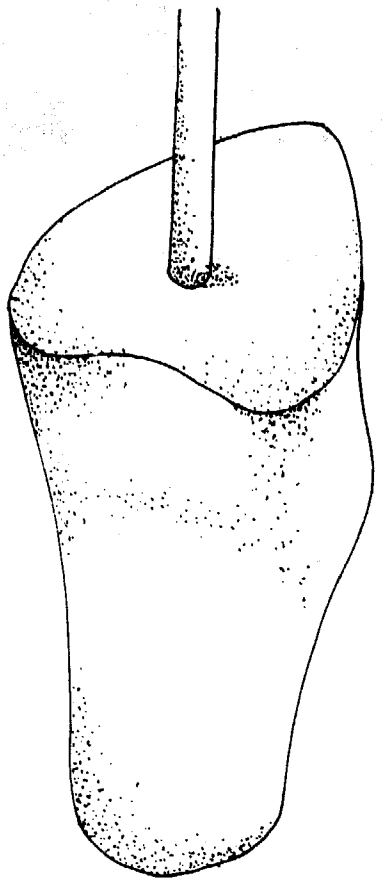
Prior to adding any plaster to the cast, make sure all the soap has gone. Pencil marks show relevant places where there is no pressure (crest, fibular head etc).

Add the material as shown in the picture.



NOTES:

1. Using small nails is helpful in achieving the precise amount of plaster needed. (These nails also reinforce the extra plaster's bonding to the cast).
2. After a time, the stump sometimes sinks lower into the socket than it should and a somewhat larger socket is required at the fibula head area. Therefore, add extra plaster in an oval shape below the head of the fibula to prevent pressure in the future.



BACK VIEW OF POSITIVE STUMP MODEL

Smooth the surface carefully while, at the same time, taking care not to remove too much material.

The model is now ready and can be used to shape the final socket. Remember that, if the socket is going to be made of a flexible material like leather, the stump model shown above could also be made out of wood, beeswax, or clay.

Prosthesis made from a stump cast

4. Preparing a leather socket from the plaster cast

The socket may be made from a variety of materials depending on what is available and on climate as well as on available skills.
Each of the materials has its own advantages and disadvantages, depending on the local skills and environment.
Materials may include:

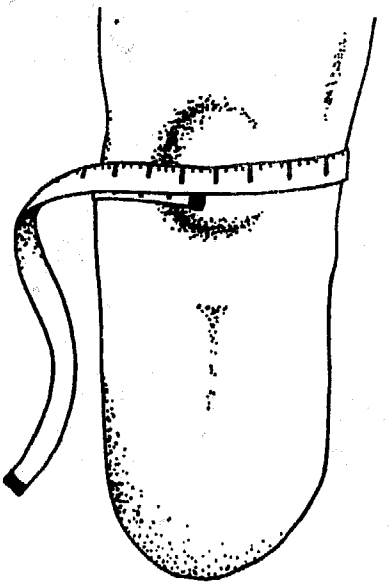
- leather
- rubber, with reinforcement of jute, bamboo, or rattan cane
- wood
- plastic resins

Leather is a very useful material from which to make a socket, since it has the capacity to adapt to the shape of a stump. This means that pressure sores are not so likely to develop as quickly as they might with rigid sockets. This is a particular advantage where regular check ups cannot be organised.

Leather is available in most areas and leather handling is easier than rubber handling, it needs no vulcanizing phase. This is why this manual describes a leather rather than a rubber socket.

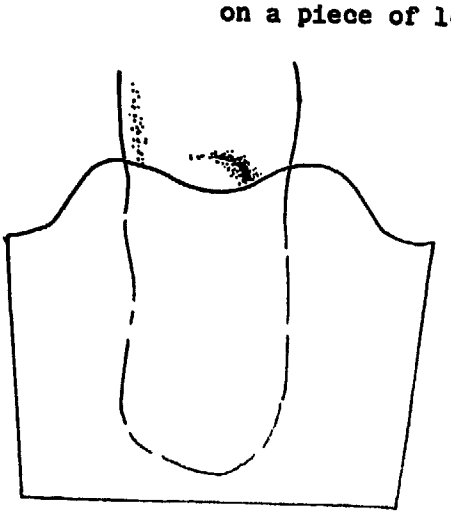
The work shown on the following pages has been developed in the Centre Jamot, Yaoundé, Cameroon. Further modifications made by Operation Handicap International are partially included.

Prosthesis made from a stump cast

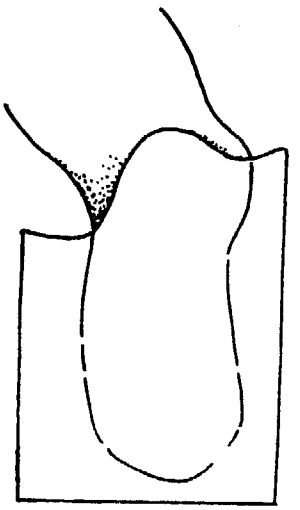


1) Measure the circumference of the knee joint just under patella, using the centre of the patella cap as a landmark. Measure the length of the stump from under the patella.

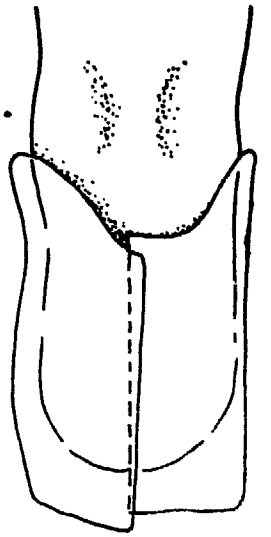
2) Take an appropriate sized piece of paper, and cover around the stump as shown in the picture. The paper should cover at least 1/3 of the patella. Shape the paper so that it covers the stump precisely, with an extra 1/2" (1.25cm) at the back. Then copy the shape of the paper on a piece of leather.



FRONT VIEW

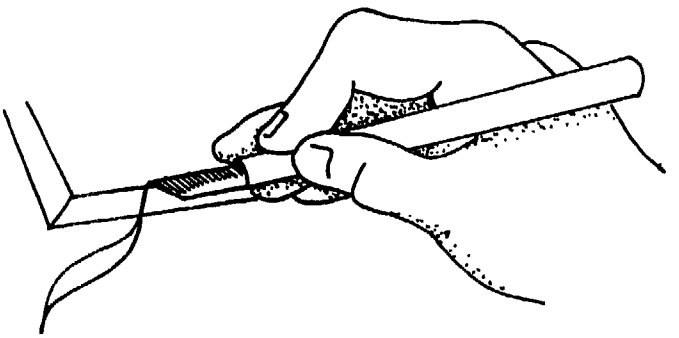


SIDE VIEW



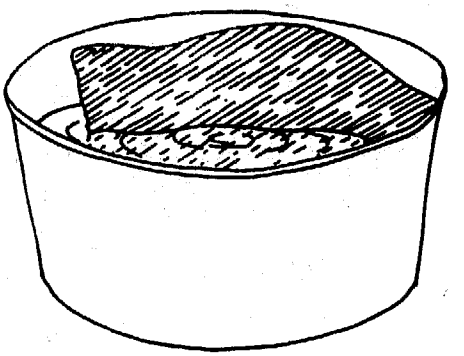
BACK VIEW

3) With a sharp knife, bevel the lower edge and one other edge of the leather on the rough side.

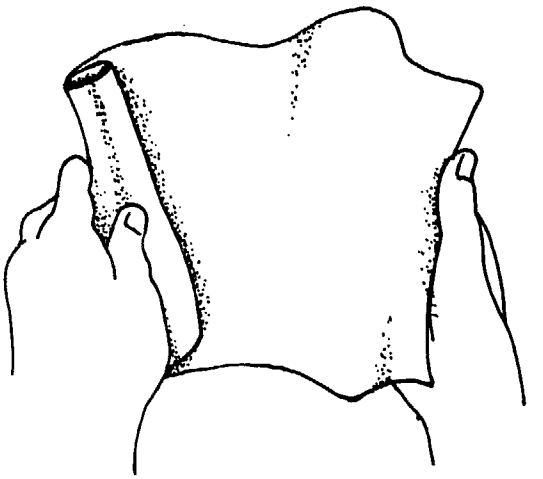


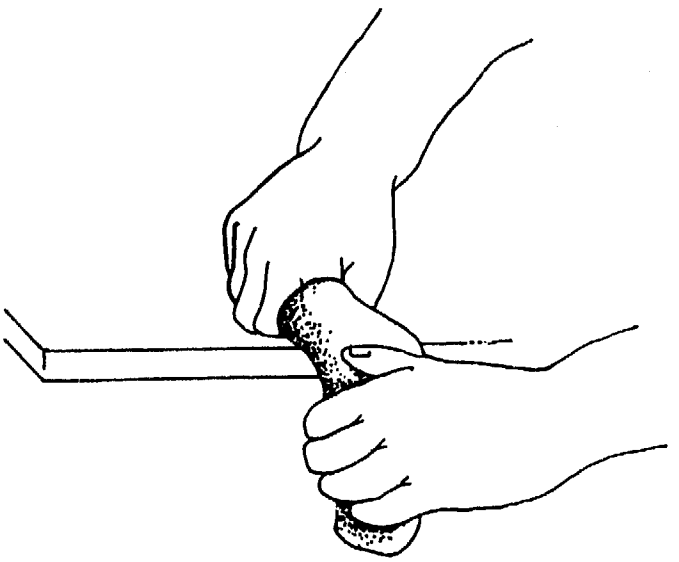
Prosthesis made from a stump cast

4) The leather must be made very pliable by handling it in water until it is supple. Thick leather may sometimes need immersing in water for several hours!

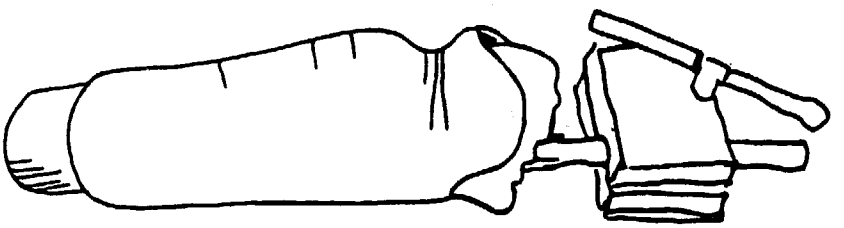


5) Leather must be supple before it can be used. Roll and unroll the wet leather throughout its length and width. Always roll it with the smooth side of the leather inside. Then roll it backwards and forwards along the side of a sink or a table.



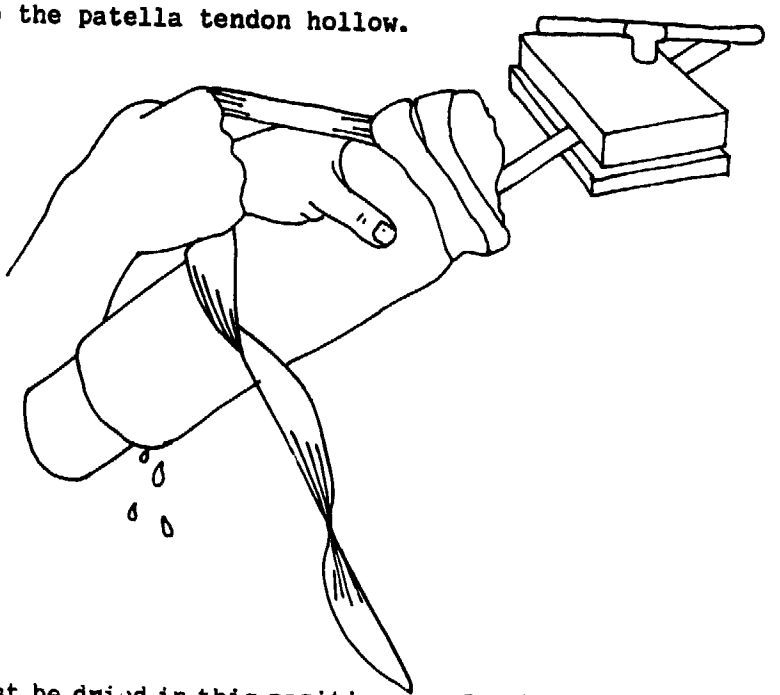


6) When the leather has become suitably pliable, wrap it closely around the model of the stump. As with the paper pattern, the leather must cover at least 1/3 of the patella.



7) Tighten the leather very firmly by using a piece of cloth or rubber from a tyre inner tube. As you wrap, stretch the cloth or rubber as much as possible, so that the leather fits very snugly around the mould.

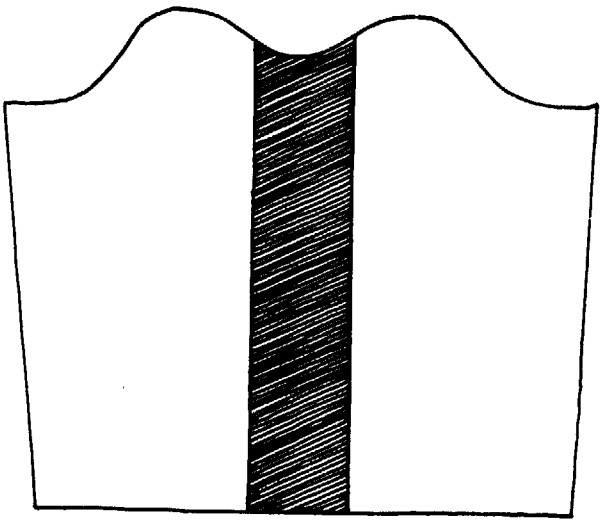
You may like to use a screw driver to force the leather as deeply as possible into the patella tendon hollow.



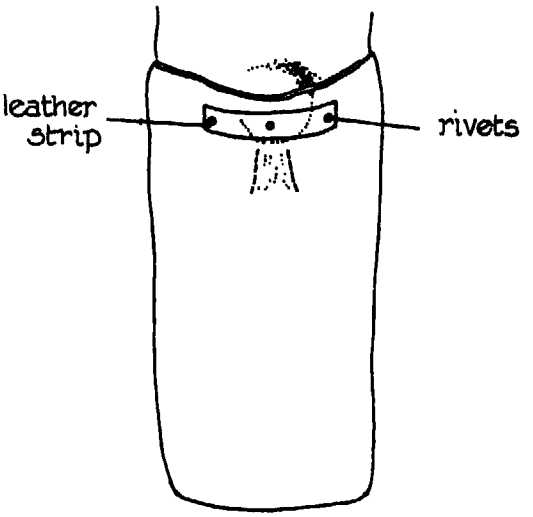
8) The leather must be dried in this position, preferably in open shade outdoors. This will take many hours! It should not be dried in direct sunlight, as it could dry too fast and crack the leather.

Prosthesis made from a stump cast

9) You may find it helpful to glue some thin foam or soft cloth inside the socket, corresponding to the tibial crest areas, tuberosity and the bony head of the fibula. Such foam or cloth could then, in its turn, be covered with soft leather. Take care that the inside of the socket remains smooth.

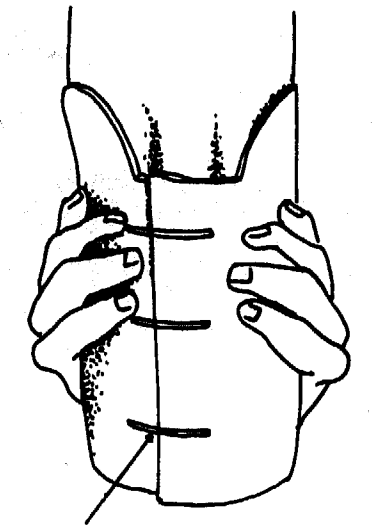


10) The socket should be reinforced with a leather strip on the area above the patella tendon bearing surface. Place a rivet in the middle of the strip first, then one on each end. Position the strip horizontally as later the pylon structure will need to rest on this. Any rivets should be covered with pieces of cloth to prevent skin damage.



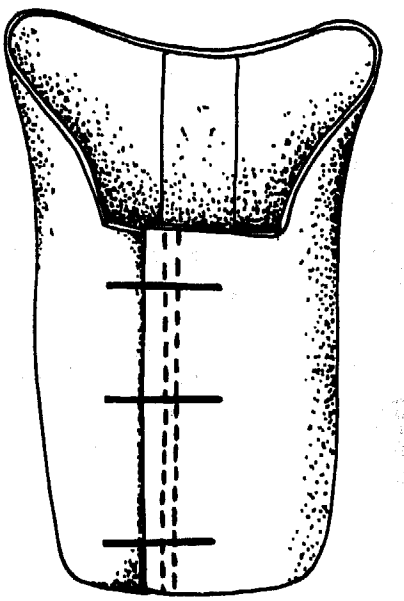
Prosthesis made from a stump cast

11) Wrap the socket around the stump and check any pain or skin irritation. Tighten the socket to fit snugly while you are doing this. Make sure that the overlap of the leather parts, where they meet, is sufficient for any further alterations. Then make some horizontal marks on the cross section, so that positioning remains precise.



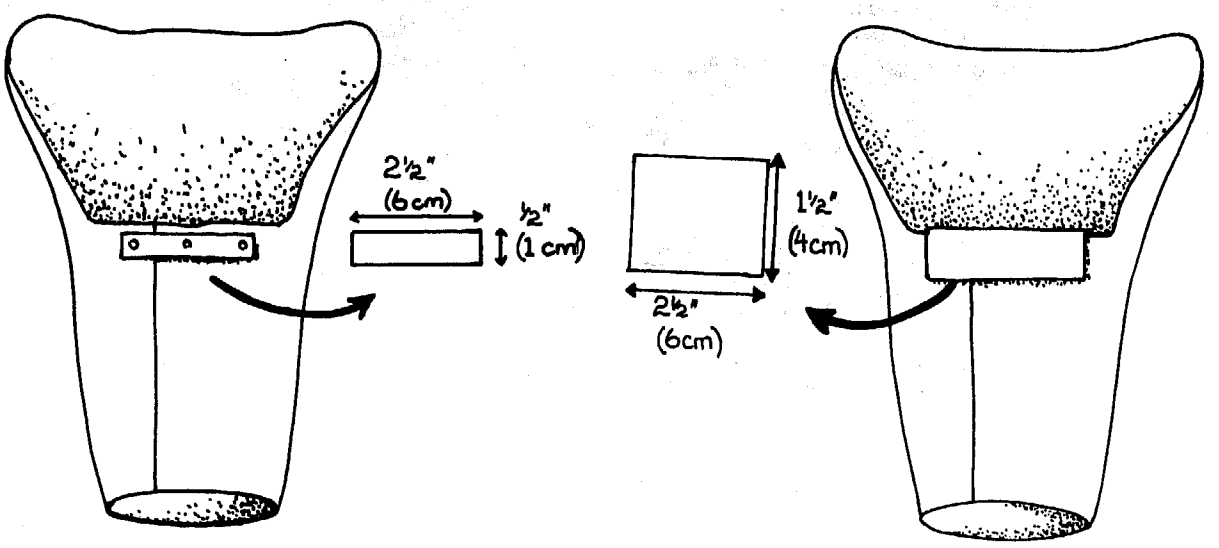
12) Finally, sew or glue the leather parts together. Avoid any rough surfaces inside the socket which may cause the skin to break.

If you use rivets for closing the socket, the first rivet should be set in the leather. Then check the position of the socket on the stump, before aiming the next rivet. Three or four rivets are enough to keep the leather parts together.



Prosthesis made from a stump cast

13) Fix a leather strip at the back of the socket. Cover inside and outside with a piece of soft leather to prevent skin irritation.



The strip at the back should be placed horizontally, in the same way as the strips in the patella area.

The socket is now ready. It will provide appropriate pressure on those stump areas where this can be tolerated, while leaving other areas pressure free.

For the process so far - Material costs: $20-$35

Labour time : 4-6 hours

To make the rest of the prosthesis we will again follow the procedure originally developed by the Centre Jamot, Yaoundé, Cameroon, and later modified by Operation Handicap International.

Prosthesis made from a stump cast

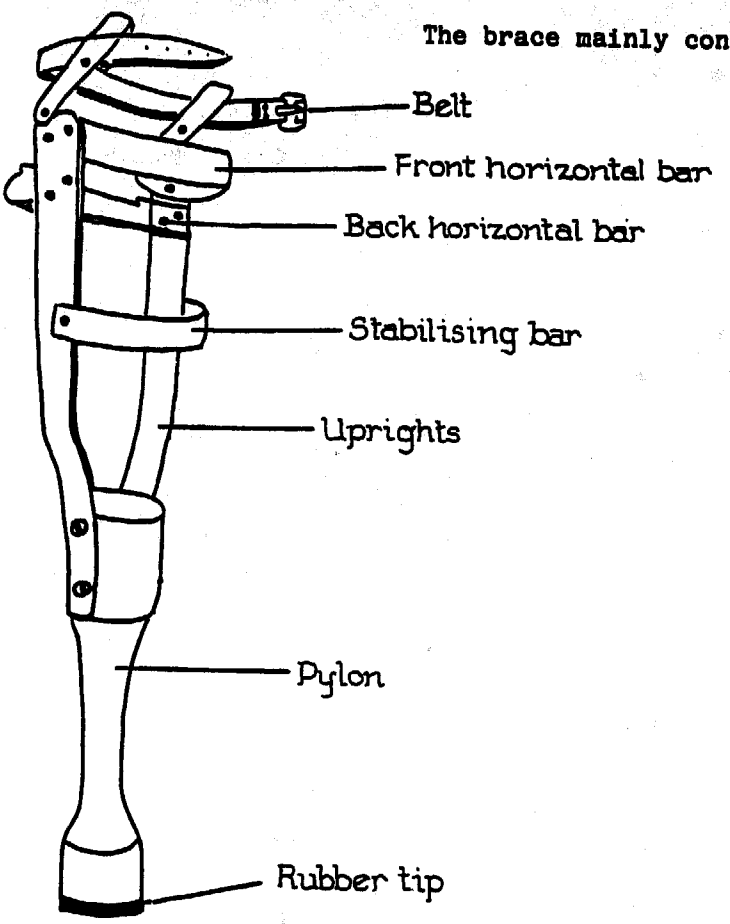
5. Building a prosthesis with a leather socket.

Material costs: $15-$25

Cost of tools : $40-$60

Labour time : 4-5 hours

The brace mainly consists of:



This section deals with the assembly of the various parts. It includes:

5.1 preparation of pylon

5.2 front horizontal bar

5.3 back horizontal bar

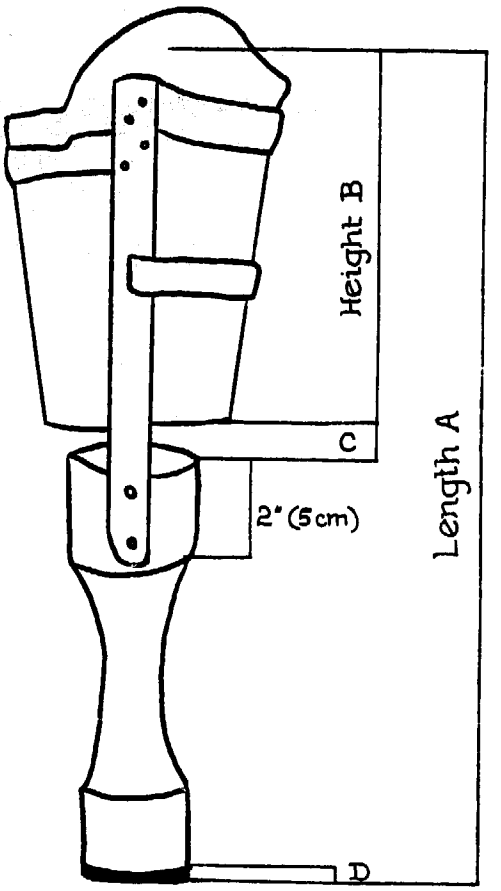
5.4 first assembly

5.5 stabilising bar

5.6 finishing

Prosthesis made from a stump cast

5.1 Preparation of the pylon



Measure:

* the total length of the natural limb - A
* the height of the socket - B
* the space between the socket and pylon - C
* the height of the shoe or rubber tip - D

Add together:

B (height of socket) + C (space between socket and pylon) + D (height of shoe or rubber tip)

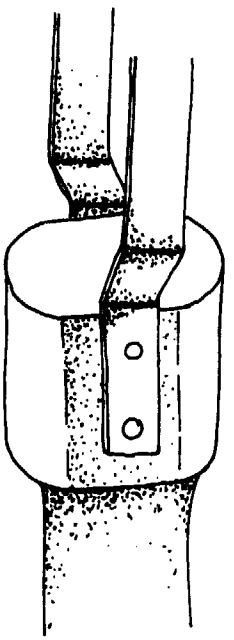
Subtract this figure from A (total length).

This gives the length of the pylon.

To calculate the length of the upright add together:

B (height of socket) + C (space between socket and pylon) + 2" (5cm)

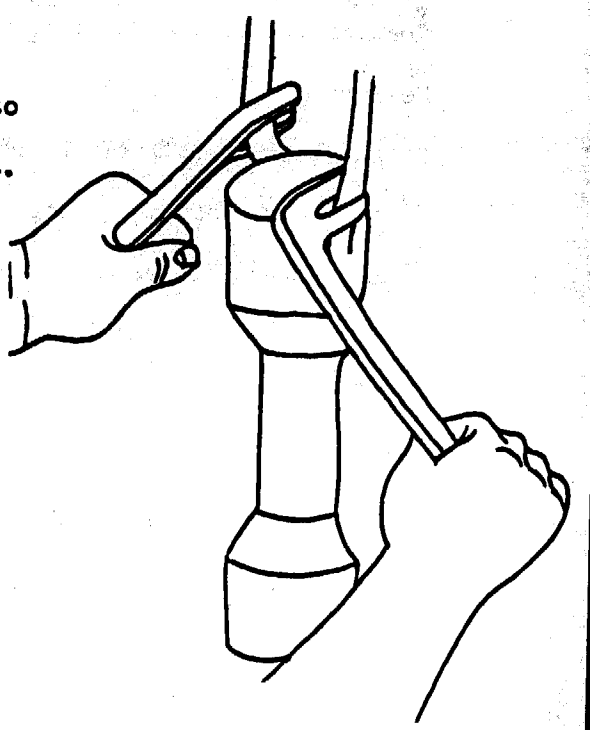
This gives you the length of the upright.



Prepare the pylon from a tough and light wood. Uprights are made from steel bars or aluminium alloy. The latter is preferable because it is lightweight, but it is expensive and not easy to weld. Fix the uprights on the pylon using two bolts and nuts. Pay attention to proper alignment; the uprights must be positioned vertically on the pylon. It is also important to take care that the pylon is not split when fixing the bolts through the upper part of the pylon.

Prosthesis made from a stump cast

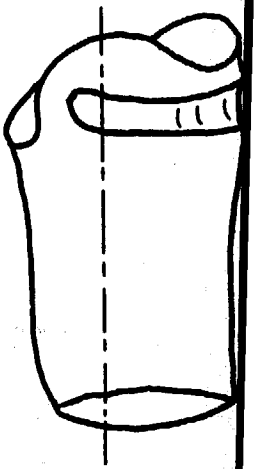
Bend the uprights to allow the socket to be fitted in between the two uprights.



5.2 Front horizontal bar

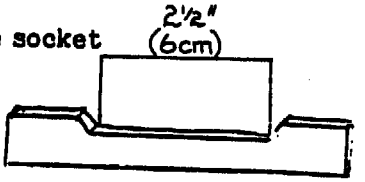
Make a front horizontal bar from a strip of aluminium or steel about 1/2" (1.2cm) wide and as long as necessary to ensure easy fixing to the uprights at a later stage. This bar must be rounded to support the patella tendon. It must be semi-circular and its edges rounded.

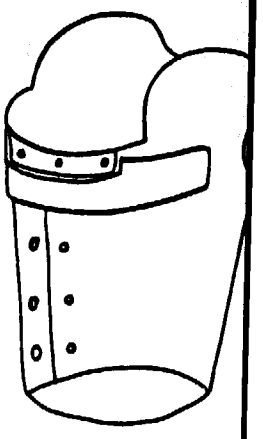
Strip of aluminium ½" (1.2cm)



5.3 Back horizontal bar

Also prepare an aluminium or steel strip to cover the back of the socket. The shape of this bar should be similar to the leather strip at the back and should follow the rounded contour of the socket itself.



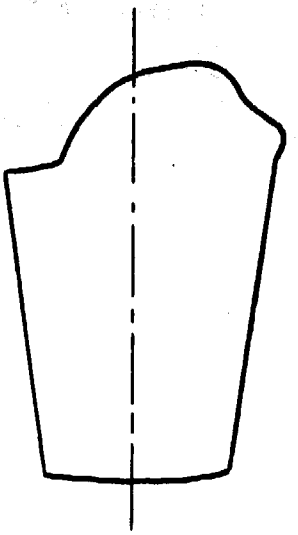


Prosthesis made from a stump cast

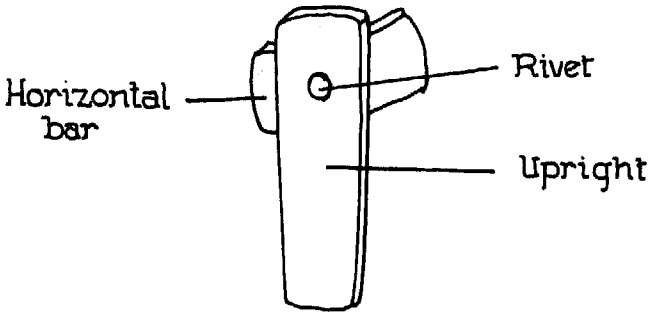
5.4 First assembly

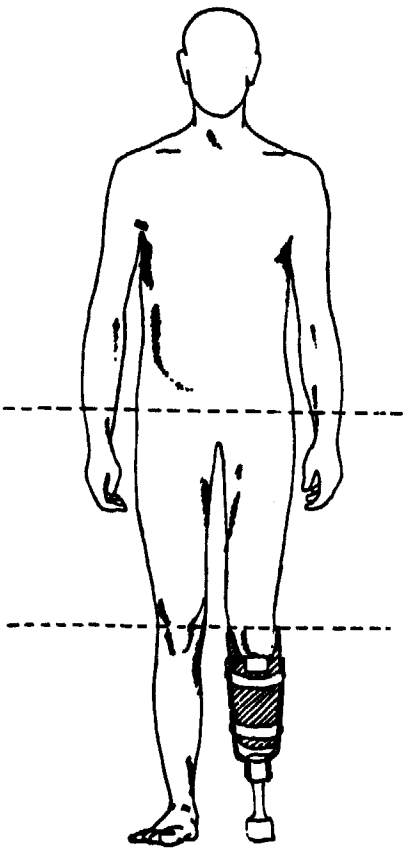
Place the stump in the leather socket and position the front horizontal bar on the socket as required. Ask the amputee to stand and completely stretch the stump.

Mark the middle of the socket with a pencil.

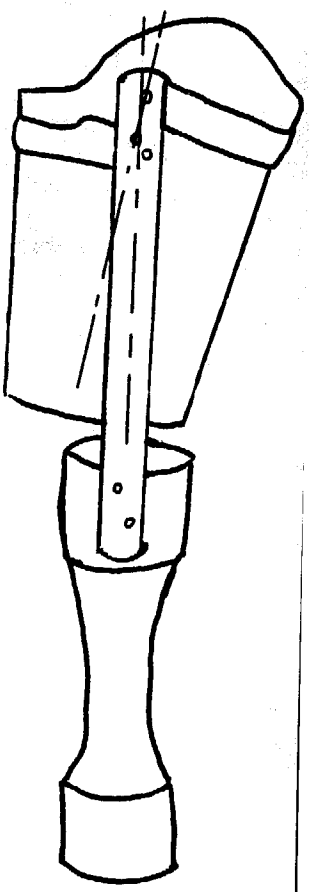


The amputee now holds the stump and socket in between the uprights. Check level of both the knee joints for proper height. Mark the connection between front horizontal bar and uprights with a pencil. Then fit the bar to the uprights with a single rivet at each side.





This is an important phase of the assembly as it determines the overall alignment and length of the prosthesis. To execute the work accurately, you will need two people for holding the horizontal bar, checking the length and marking the correct connection.



Prosthesis made from a stump cast

Check proper orientation of the stump and socket in between the uprights. That is, that the knee is flexed in the correct position. Then fit the horizontal back bar to the uprights.

Rivetting the horizontal back bar must be done very precisely, providing stability and proper fitting of the prosthesis.

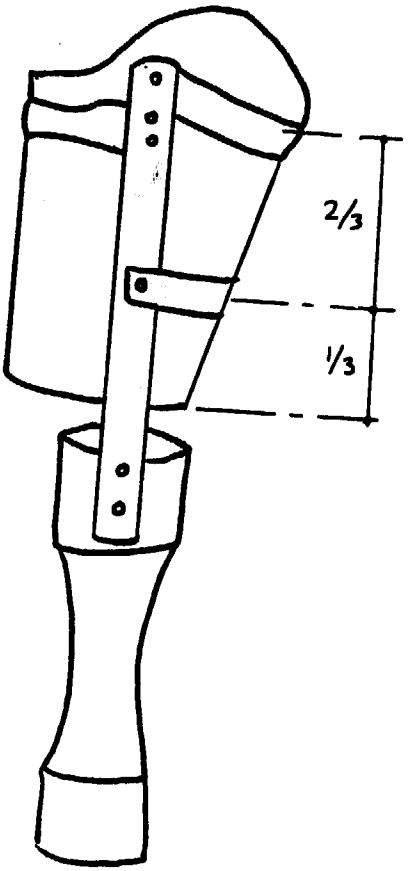
A rubber tip can be added to aid stability, but remember this will add to the length.

The prosthesis is now ready for the amputee to try out. First check the following:

* any pain in the stump due to ill fitting
* length of the prosthesis. (Make sure the patient is standing straight, and include any rubber tip which has been added)
* middle of prosthesis (average bearing point) above pylon.

Now rivet each of the bars with two rivets onto the uprights.

Prosthesis made from a stump cast



5.5 Stabilising bar

Make and fix the stabilising bar. This will usually be made of soft aluminium or leather.

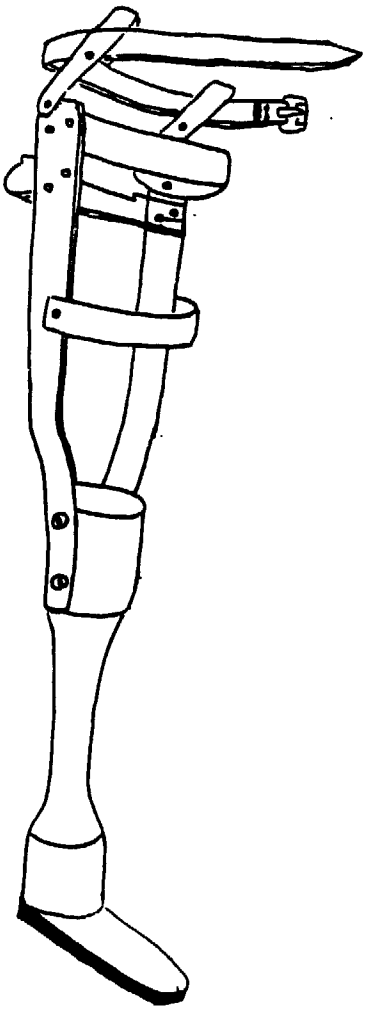
This bar will restrain the stump from going too far forward as the amputee walks.

The bar is placed above the end of the stump, usually 2/3rds down the length of the socket.

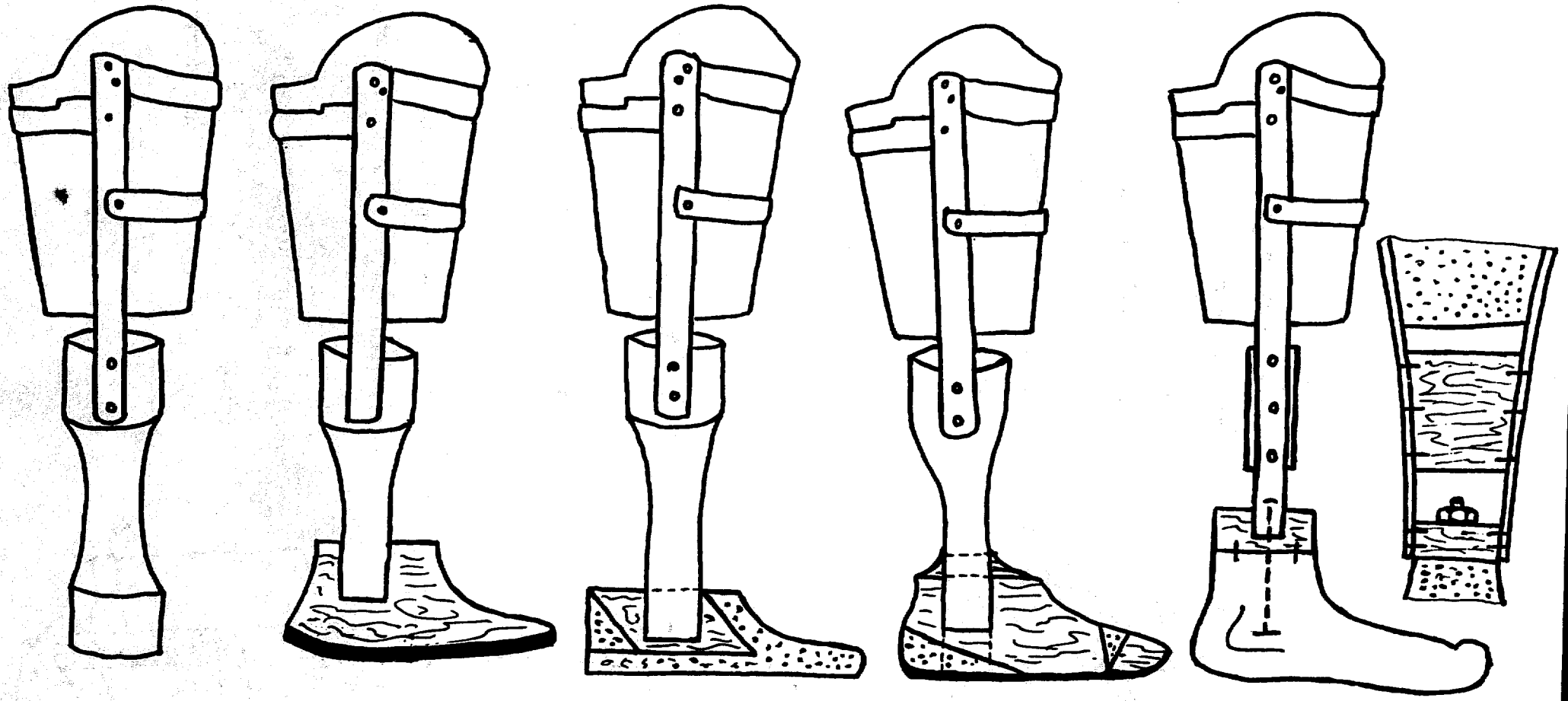
5.6 Finishing

The finishing phase includes the following steps:

* painting the pylon and metal frame
* attaching a suspension strap of about 12" (30cm) (see chapter 6)
* adding a rubber tip or some kind of artificial foot
* always remember that the metal frame must be smoothly finished on all edges to prevent damage to the skin and leather distortion.



LEATHER SOCKET WITH VARIOUS FOOTPIECES



Pylon

Rocker

Sach Type 1

Sach Type 2
with toe break

Jaipur

Prosthesis made from a stump cast

6. Alternative prosthesis with leather socket

Material costs: $2-$5

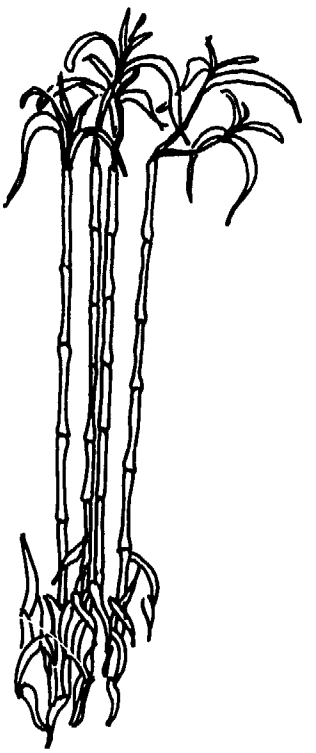
Cost of tools : $15-$20

Labour time : 3-5 hours

The technology already described may not always be possible due to the absence of certain materials including aluminium or steel bars, rivets, etc.

There may also be other reasons why it is necessary to look for alternatives. Below we show how the "Yaoundé concept" is imaginatively transmitted into other materials.

Bamboo is strong and light in weight, and when it has just been cut it can be bent considerably. If a freshly cut piece of green bamboo is held in a certain shape until it is dry, the shape can be maintained for a long time.



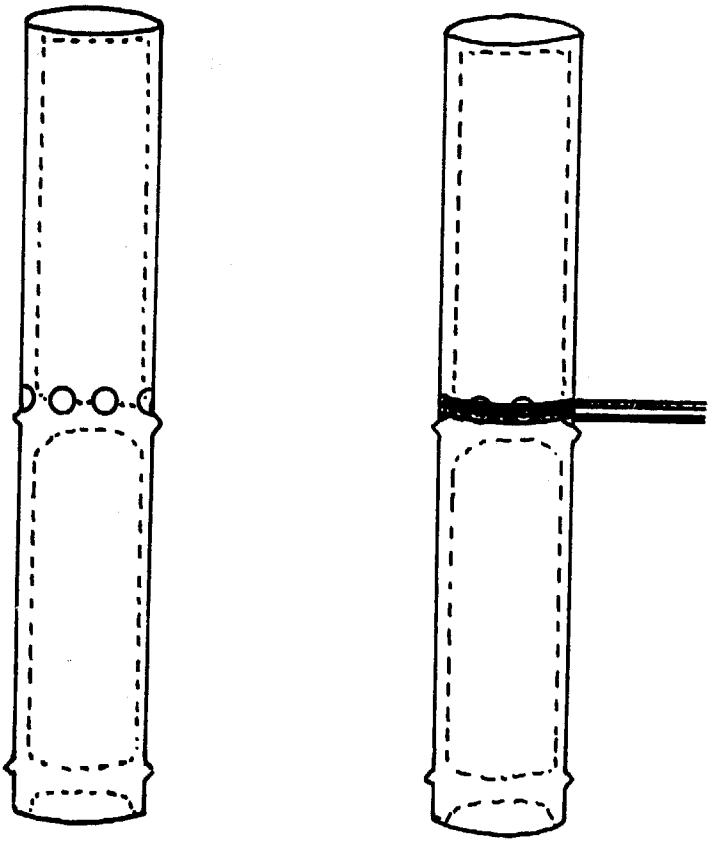
Prosthesis made from a stump cast

Phase 1

Cut a piece of bamboo, diameter about 4" (10cm) and length 23" (57cm).

Just above a joint, drill about 10 holes with diameters of 1/4" (6mm).

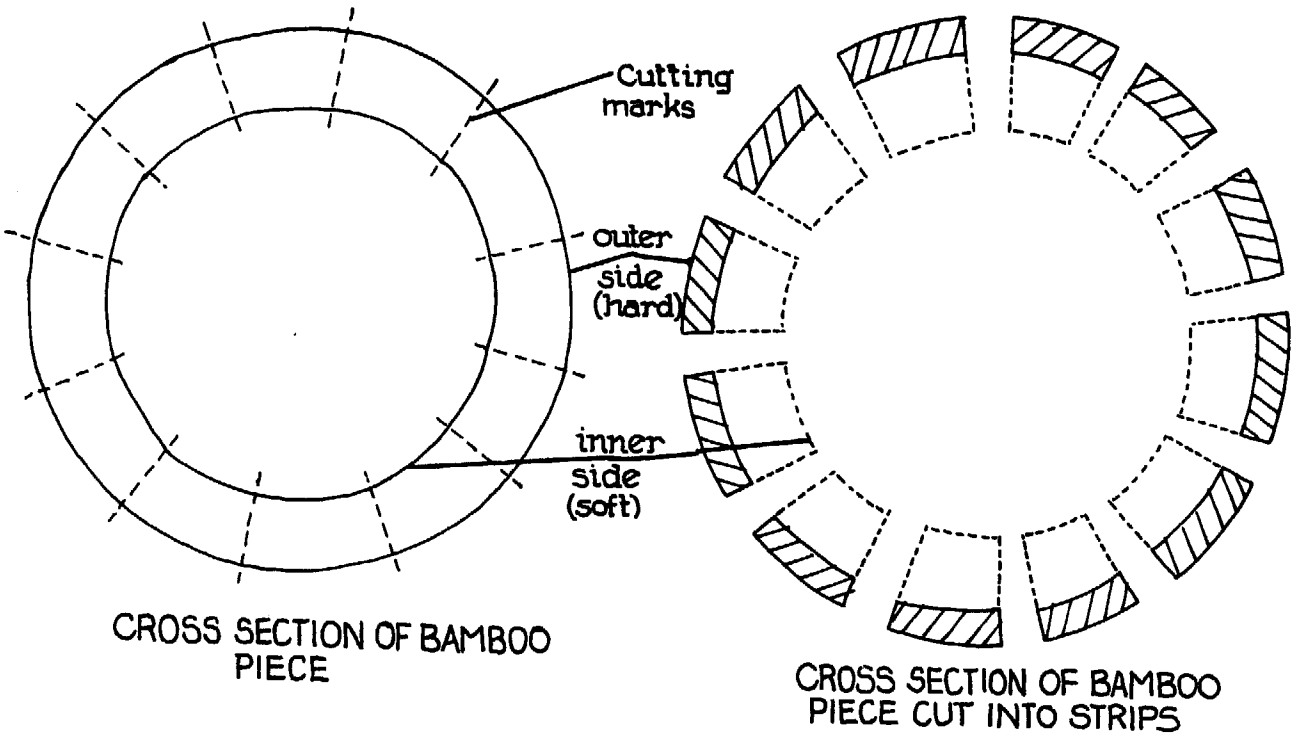
Where the holes have been drilled, place a piece of rope or wire and secure tightly.



Prosthesis made from a stump cast

Phase 2

Carefully split the bamboo from top to joint. Although the small holes and the rope or wire will prevent further splitting of the bamboo, it is still necessary to be careful when doing this.

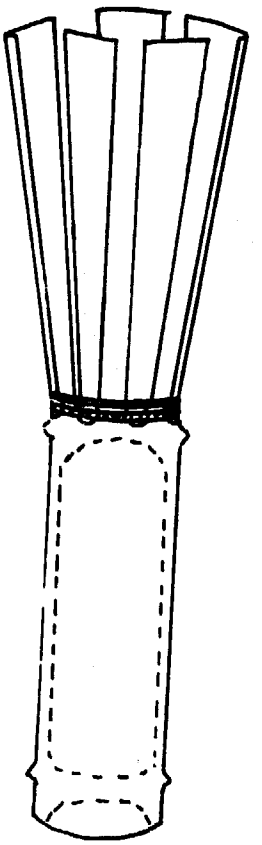


If the bamboo is only cut length wise, the strips may be too thick for easy bending. You could make each strip thinner very easily (up to say 5-6mm) using a knife. The softer inner part is cut away, and the hard outer part remains as a socket holder.

Prosthesis made from a stump cast

Phase 3

Now take a socket of leather, rubber, microcellular rubber, plaster of paris or other material - whichever you find the best and most suitable for your work and purposes. Check that the socket will fit into the bamboo frame. If it does not, adjust the frame accordingly. If it is necessary to make the split ends of the bamboo more flexible, thin each strip on the inside by scraping with a knife.



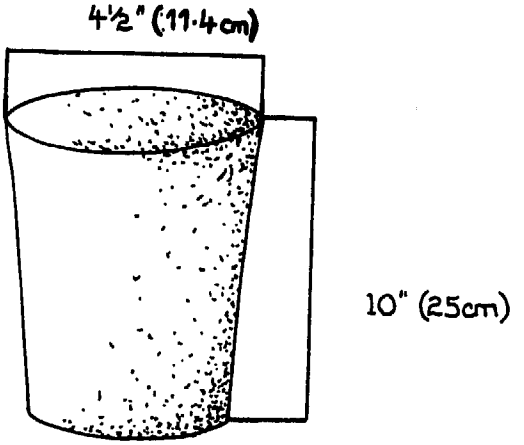
Phase 4

When the bamboo is young it may be rather weak. In this case, prepare a wooden die of similar size to the socket. The measurements should be approximately:

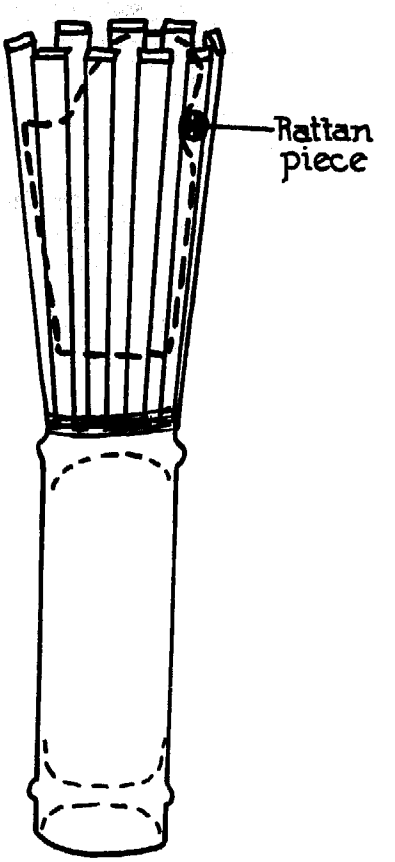
length - 10" (25cm)

diameter at the top end - 4 1/2" (11.4cm)

Put the die into the bamboo frame and leave it there for a few weeks until the bamboo is dry and stiff.



Prosthesis made from a stump cast

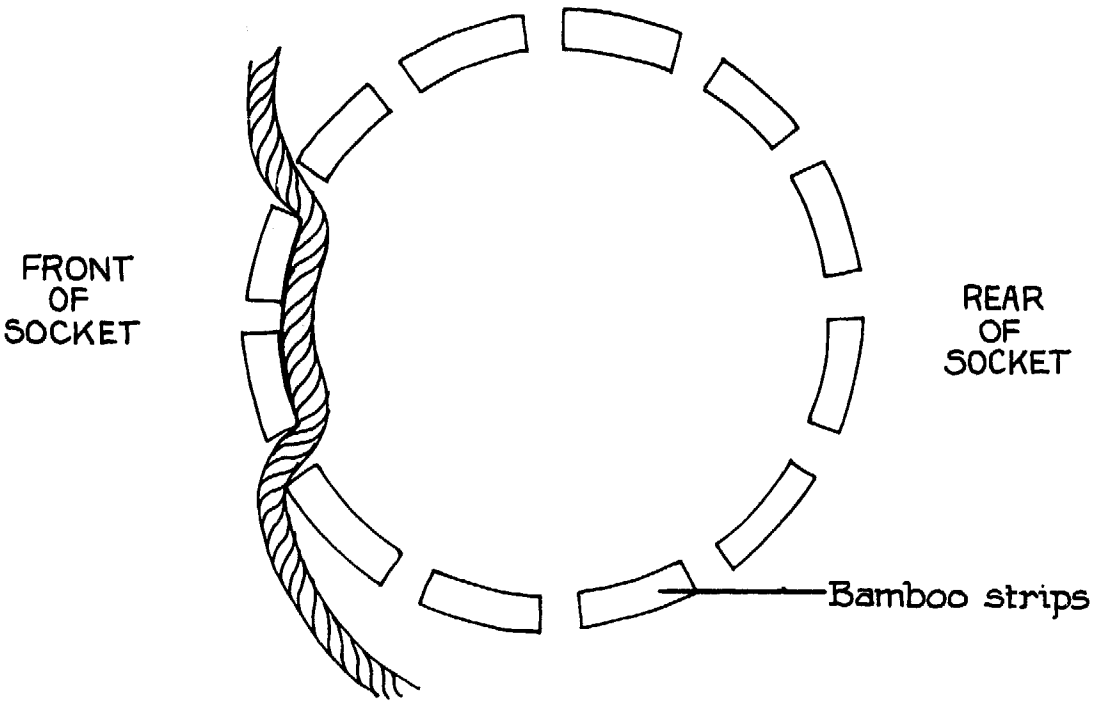


Phase 5

Place the socket in the bamboo frame. A thick piece of rattan helps to achieve and maintain patella tendon bearing. The rattan piece should be firmly attached to the frame, using thread or thin rope. Check it does not slip.

Phase 6

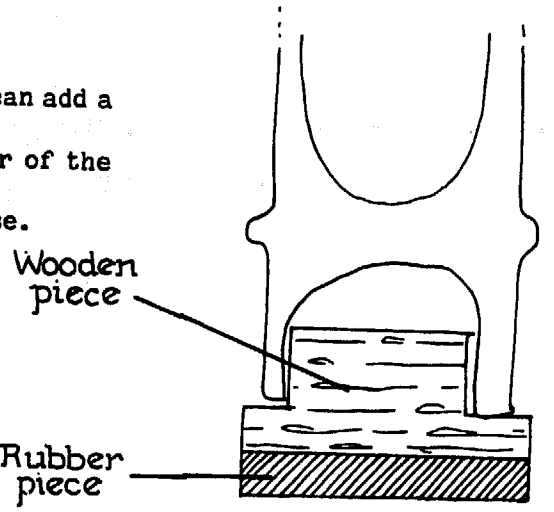
The frame and socket should now be made stable. Cotton cord, coconut fibre or strips of rattan are woven between the bamboo strips to make the frame firm. Plaster bandage can also be used. A mixture of sawdust and glue or plaster of paris should be added to secure the position of the socket onto the bamboo frame.



Prosthesis made from a stump cast

Phase 7

At the lower end of the prosthesis you can add a piece of wood and rubber to prevent wear of the bamboo and to avoid slipping and noise.



Plastic pipes

A similar technique may be used with plastic pipes.

To make the frame with 5 uprights it is necessary to drill 5 holes. To make the plastic pliable so that the uprights can be bent, heat the pipe in boiling water or an oven.

The socket is fixed securely in the pylon as outlined in Phase 6.

CHAPTER FIVE : PROSTHESIS WITH DIRECT FITTING

1. Introduction
2. Prosthesis with aluminium socket
3. Prosthesis with resin socket
4. Prosthesis with wooden socket

Prosthesis with direct fitting

1. Introduction

The last chapter described how to make a socket for a prosthesis, using a positive model of the stump. Ways of modifying the model were described to allow some parts of the stump to bear more pressure than other parts. The mould could be made from plaster of paris, wood, beeswax, clay or other suitable materials. If you are not able or prefer not to make use of this particular manufacturing technique, an alternative method may be used that is called the direct fitting technique. In this method the socket is made directly on the amputee's stump.

It is difficult however, to achieve a proper fitting of the prosthesis onto the stump using the direct fitting method. This is especially true if the socket is made of a rigid material. You will, for instance, need a certain amount of experience and a good deal of skill to hammer an aluminium limb! On the other hand, when once the necessary precautions with the technique have been learnt, the direct fitting technique is quicker and cheaper.

The following techniques are practised:

- aluminium socket, hammered out sheet (Jaipur, Rajasthan State, India)
- wooden socket (Nigeria, Thailand, etc.)
- plastic resins (Nigeria)

The techniques for direct fitting are described in the following pages.

Prosthesis with direct fitting

2. Prosthesis with aluminium socket

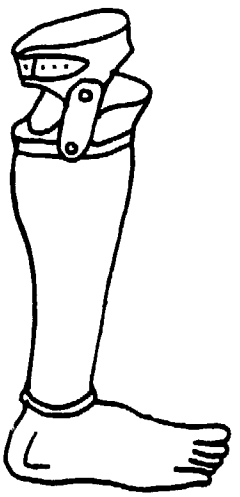
A prosthesis with an aluminium socket has been made for many years in a rehabilitation workshop in Jaipur, Northern India.

The technique requires considerable expertise in handling aluminium, as well as understanding the welding of aluminium sheeting. Alternatively, you could use steel plate, which is heavier, but easier to weld!

Stages of manufacture:

1. Measurements of the stump and of the natural limb
2. Preparation of the socket
3. Attachment of the walking device
4. Re-alignment, if needed.

In Jaipur, an experienced prosthetic technician needs about 30 minutes to one hour to make an aluminium socket out of aluminium sheeting!



Jaipur limb

Prosthesis with direct fitting

Minimum Materials and Tools

aluminium sheet, thickness about 1/25" (1mm)

measuring tape

pen for marking aluminium sheeting

anvil with rods extending

welding equipment for aluminium (conventional: acetylene and oxygen)

soldering metal for welding

mallet

shears

file for working aluminium

cloth and glue

steel rod, diameter about 1/8" (3mm), length 32" (80cm)

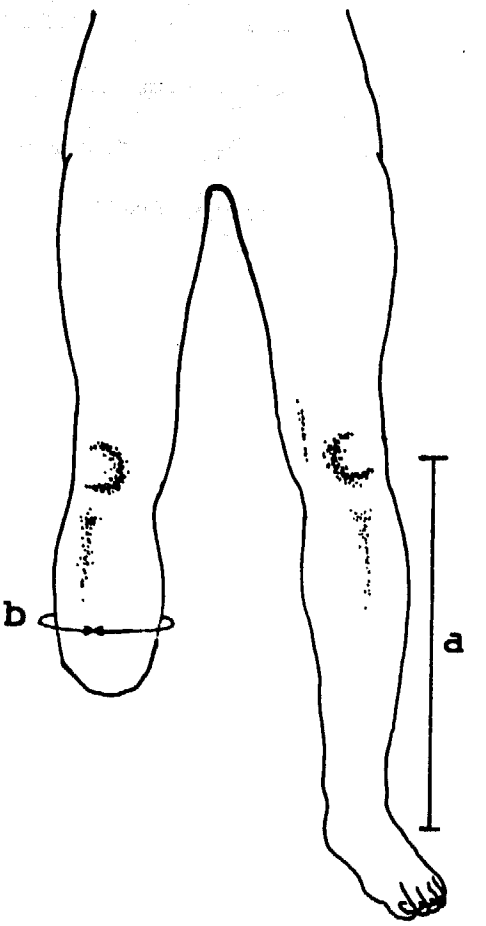
walking device (footpiece or other)

Material costs	:	$5-$10 (not including foot)
Cost of tools	:	$80-$150
Making and fitting:		one day for trial
		one day for finishing
Labour time	:	2-4 hours

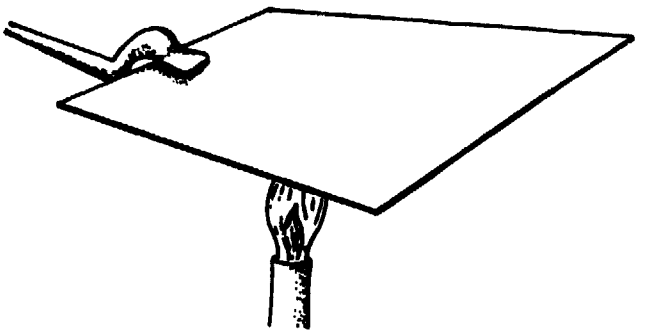
Prosthesis with direct fitting

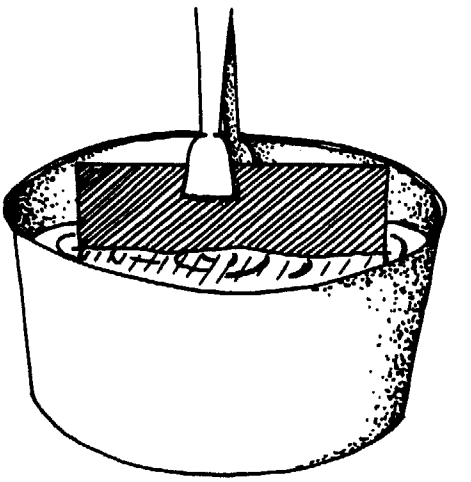
Measure the length (a) of the normal limb, from knee joint to floor. This measurement will be the length of the aluminium sheet required.

Measure the circumference (b) of the remaining part of the amputated limb. This measurement will be the width of the aluminium sheet required.



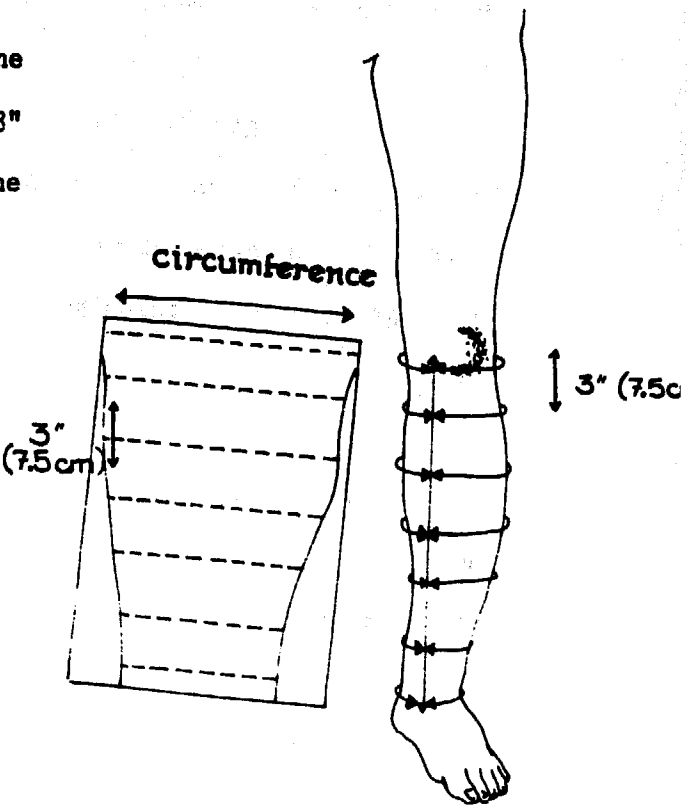
Cut the aluminium sheet (thickness about 1mm) to an appropriate size, heat it over a fire and then plunge it in water. This makes the aluminium sheet softer and easier to work with.



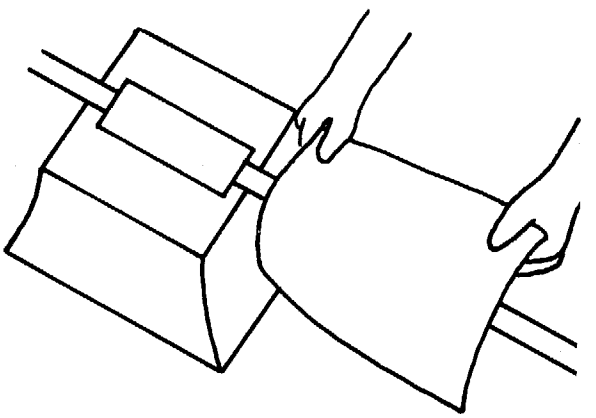


Prosthesis with direct fitting

Measure the circumferences of the natural limb in intervals of 3" (7.5cm), and draw a pattern on the aluminium sheet.



Shape the sheet into a tube, using an anvil. Weld the seam using oxygen and acetylene gas. The weld area must be properly cleaned, and welding should start immediately after cleaning. A good aluminium flux should be used, while a filler rod containing five to ten per cent of silicon may be an advantage.

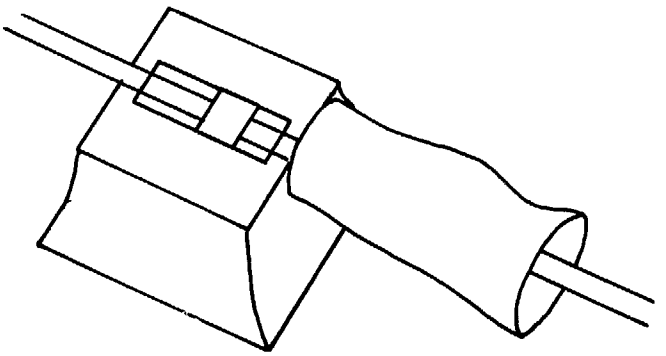


A soft flame is necessary due to the low melting point of aluminium. As no colour change takes place during heating, it is not possible to easily assess the temperature. Therefore, it is necessary to take extra care to prevent overheating. Under no circumstances must the flame flare up through oxidising. An alternative to welding is to rivet the sheet.

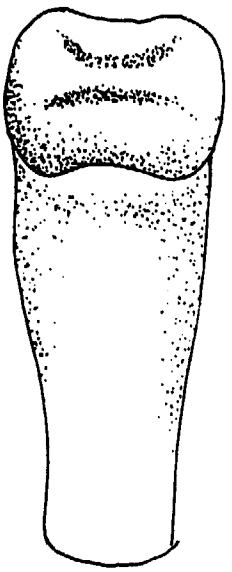
Prosthesis with direct fitting

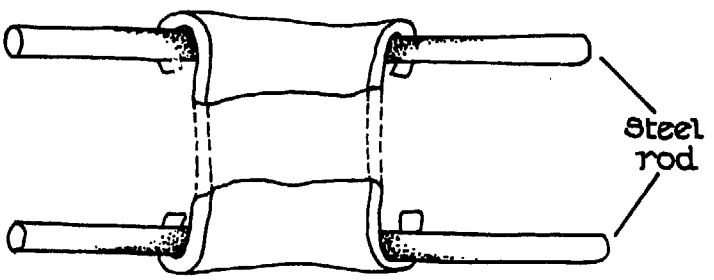
Shape the tube into a replica of the natural limb by using a mallet.

The technician/artisan makes the appropriate shape which will only cause pressure on the patella tendon and other pressure tolerating areas (see previous chapter). At the same time, space is allowed for bony prominences such as the tuberosity and tibial end. This shaping is an art rather than a skill, to be learnt from a craftsperson.
The aluminium hardens itself and becomes strong during this process.



Make sure an area is provided for the hamstrings. This can be done with a pair of shears. Smooth both ends of the socket by rounding their ends. A steel rod is inserted to prevent cracking which may be caused in the rounding process.





Prosthesis with direct fitting

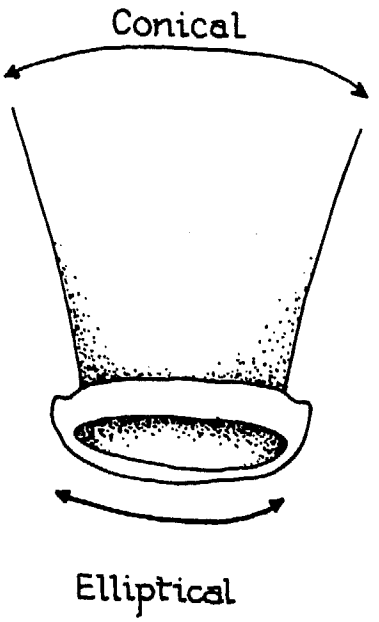
Help the patient to try the limb out by walking a little, having attached a footpiece or wooden block (see chapter 7). Once you are satisfied the patient is comfortable with the limb, it should be finished as follows.

Roughen the aluminium surface with a file and glue a layer of stockinette or cloth on the aluminium. Then paint the entire surface with skin coloured plastic emulsion paint.

Pad the inside with a thick cloth. This cloth will absorb sweat and will not crack when it dries, in the way that leather does.

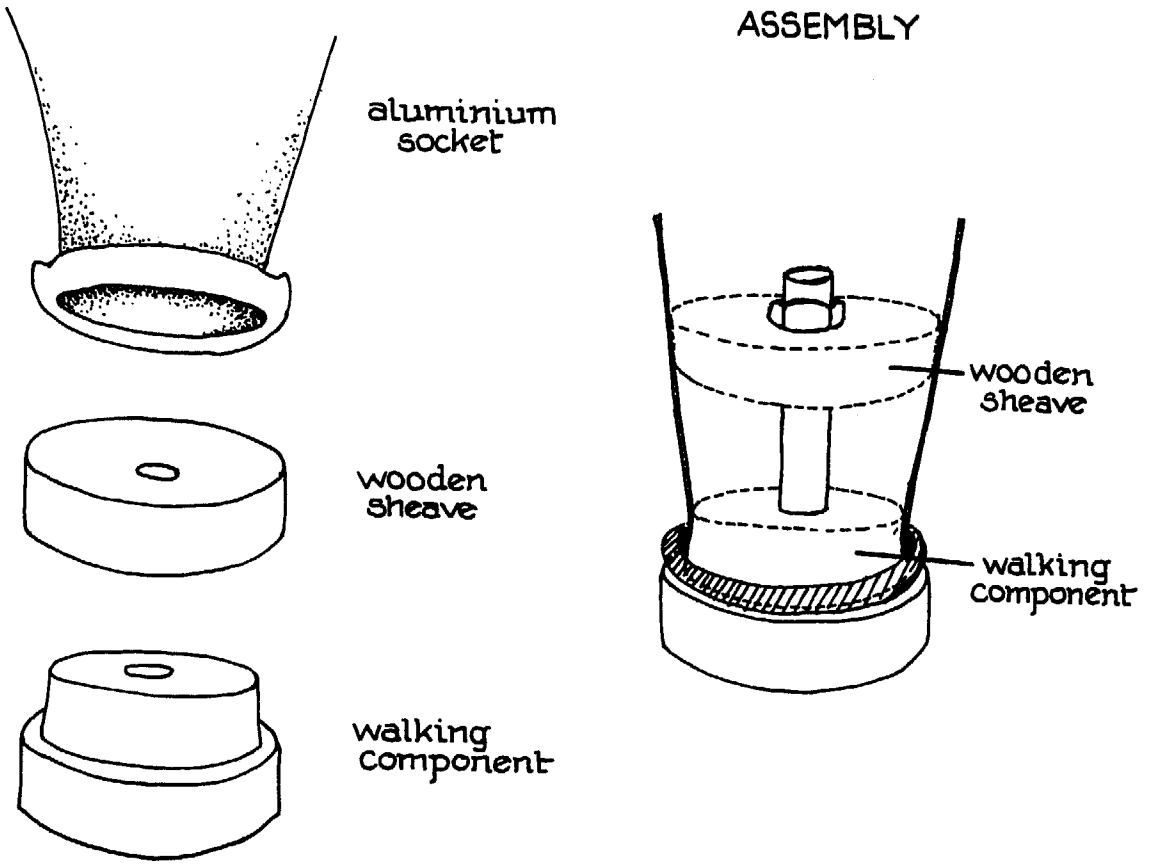
2.2 How to attach a walking device on an aluminium socket

The end of the socket must be both conical and elliptical to ensure a good fitting of the footpiece to the shank.



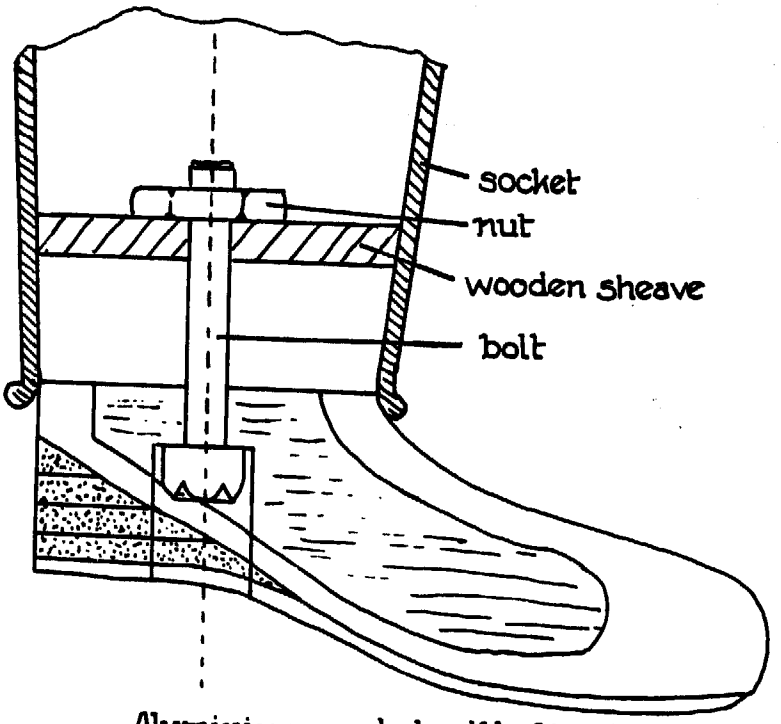
Prosthesis with direct fitting

Make a wooden sheave, thickness about 1/2" (1.25cm), which fits precisely in the socket. Drill a hole in the sheave to allow a bolt to go through. The pictures below illustrate the procedure.

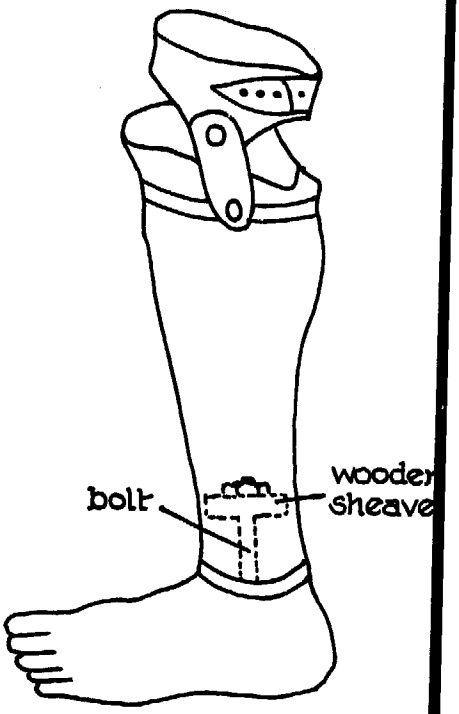


The aluminium socket and wooden walking component may be more closely fastened together by further tightening the nut. Alternatively to the peg leg type, a footpiece may be added to an aluminium socket in a similar way.

Prosthesis with direct fitting



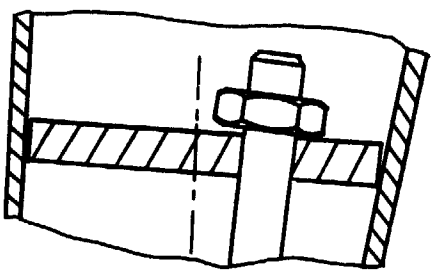
Aluminium socket with SACH footpiece



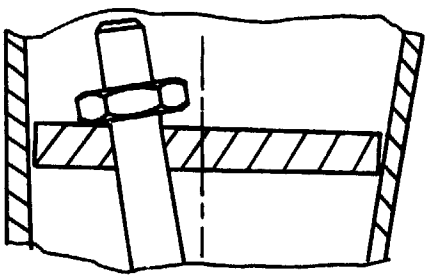
Aluminium socket with Jaipur foot

When a footpiece is attached to the socket, it is important to pay close attention to the alignment of the footpiece. Some adjustment may be obtained by drilling a hole out of centre in the wooden sheave. The more the hole is drilled in the front part of the sheave, the more a foot should be attached in dorsiflexion . The more the hole is drilled in the back part of the sheave, the more the foot will be attached in plantar flexion . This procedure is further described in chapter 8.

Adjustment in wooden sheave



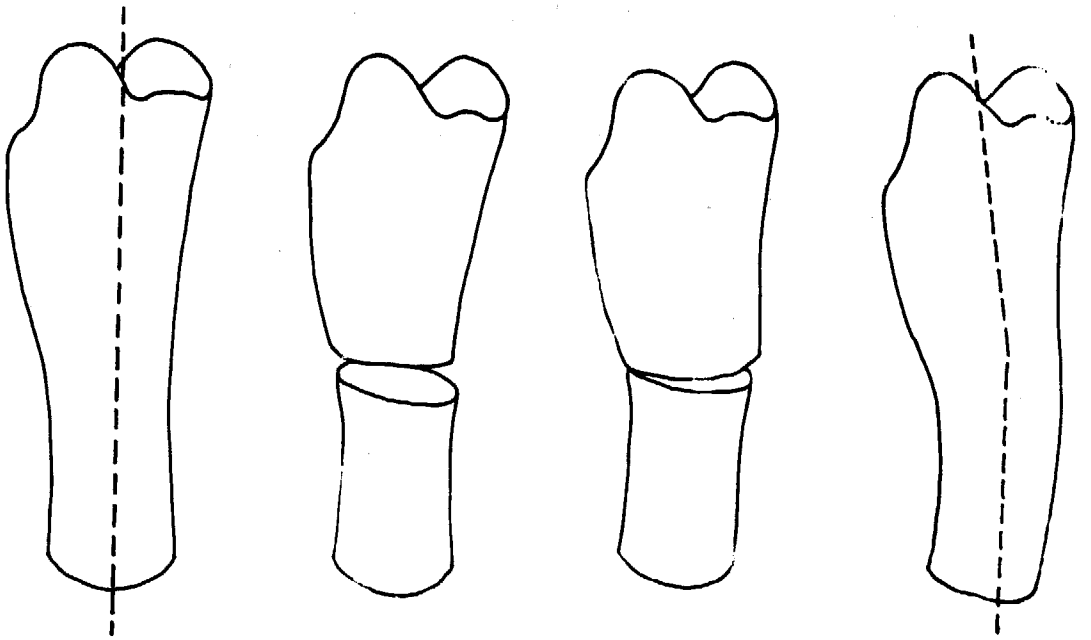
Dorsi flexion



Plantar flexion

Prosthesis with direct fitting

Finally, the entire alignment of a prosthesis with an aluminium socket can be adjusted simply by cutting and re-welding the tube.



Prosthesis with direct fitting

3. Prosthesis made with resin socket

The prosthesis described below has been widely used by leprosy patients for many years. It was developed 20 years ago and has been modified since then by staff of the Gongola State Leprosy hospital in Garkida via Yola, Northern Nigeria. The technique does not require a fully qualified prosthetist using expensive tools. Essential to success is proper preparation of the stump. It should have reached the stage of being well shrunk to a stable size, and the skin should have been toughened by daily massage and use of bandages (preferably elastic). (See also chapter 8). Make sure the knee joint is mobile. It is easier to learn to walk if there is no contracture of the knee.

Stages of manufacture:

1. Fabrication of soft insert
2. Fabrication of hard socket
3. Alignment with wooden block
4. Reinforcement
5. Finishing

Material costs : $20-$40

Cost of tools : $40-$200

- gas oven $20
- electric oven $160

Making and fitting: minimum 4 days

Labour time : 5-7 hours

Prosthesis with direct fitting

3.1. **Fabrication of soft insert**

Materials

Plastazote 1/4" (6mm) and 1/2" (12mm)

glue for Plastazote (this is a rubber cement)

large paper

stump socket

Equipment

pen, scissors, knife

gloves

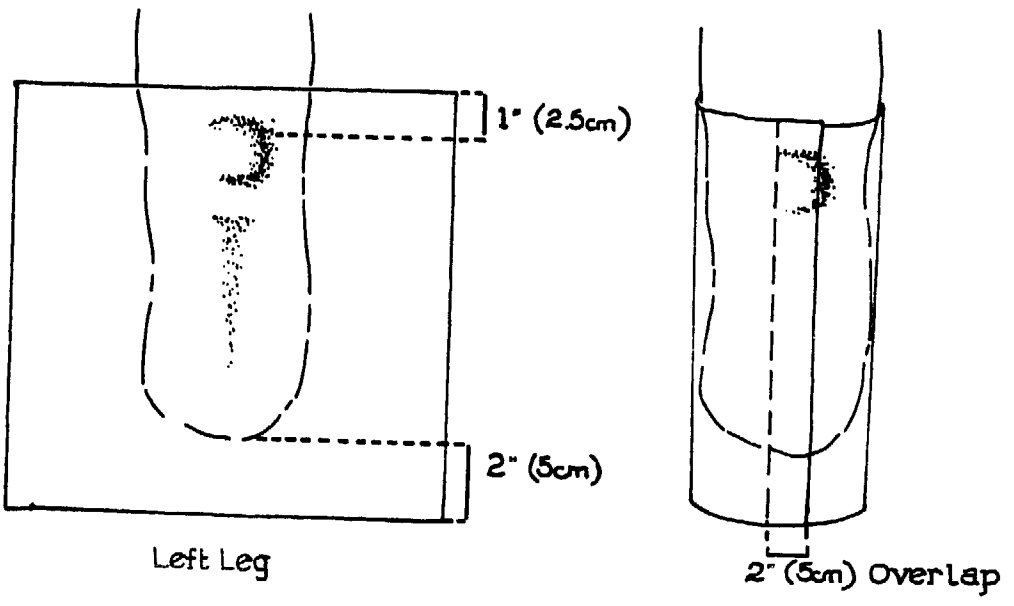
elastic bandage (or rubber tyre from bicycle)

oven with thermometer

watch or clock

1) Take a piece of paper, and wrap it around the stump. Shape the paper so that it covers the stump precisely. The paper should extend 1" (2.5cm) above the patella and 2" (5cm) below the end of the stump.

2" (5cm) overlap is allowed at the tibial crest.



Prosthesis with direct fitting

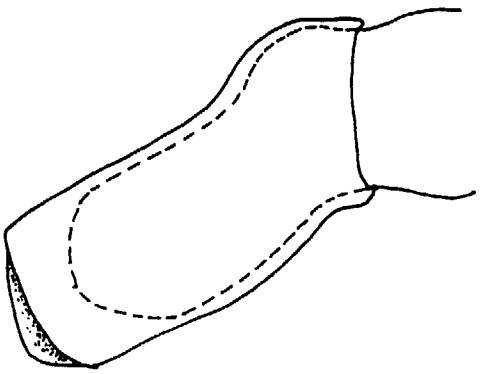
2) Copy the shape of the paper on a piece of 1/4" (6mm) Plastazote. Bevel those sides which will overlap each other and which will be stuck together.

3) Stick together with rubber glue those edges that will later overlap.

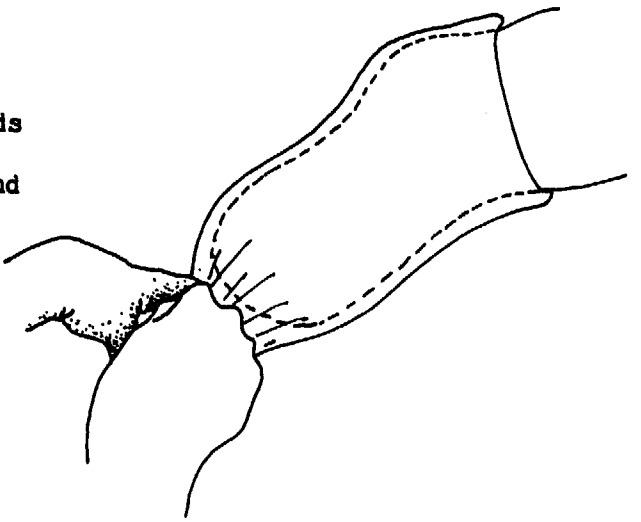
4) Heat the Plastazote in the oven, according to instructions from the manufacturer. (This takes usually 5 minutes, at 140°C [350°F].)

5) Sit the patient on a table, with his/her stump flexed about 10° from full extension.

6) Quickly mould the softened Plastazote on the stump. Fit the glued edges snugly together. Be sure it is tight. You will need two people for this.

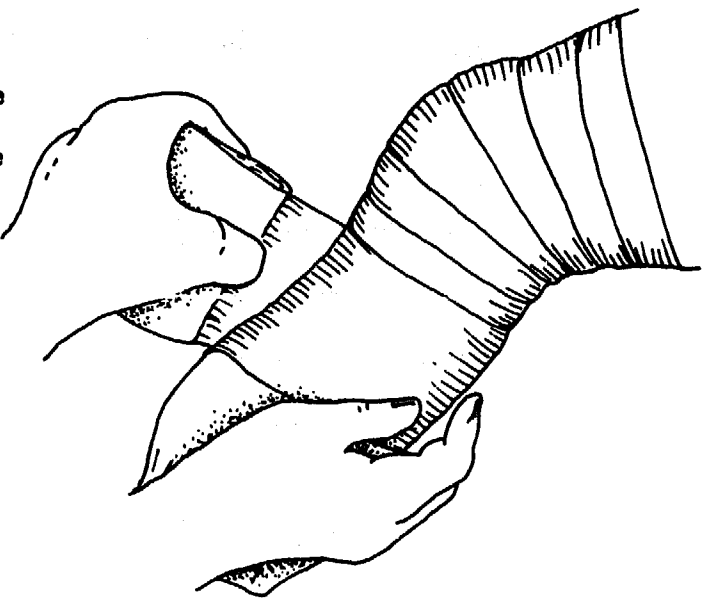


7) Quickly squeeze the ends together with the fist and hold till cool.



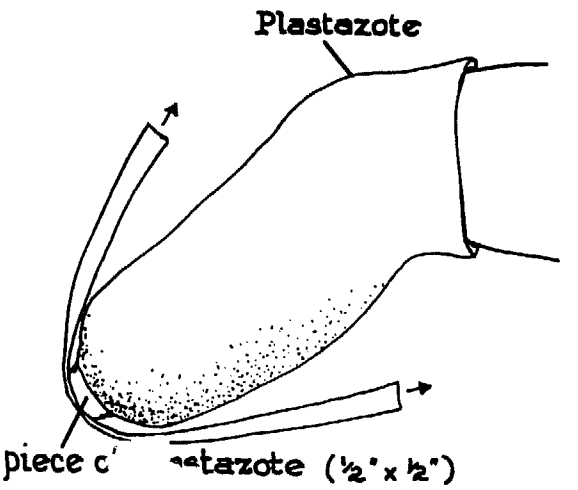
Prosthesis with direct fitting

8) At the same time wrap the bandage tightly over the Plastazote until it is cool.

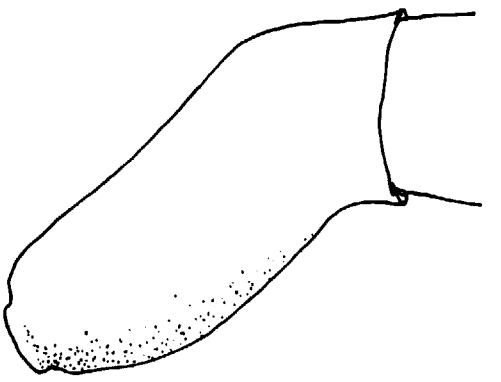


9) Trim the lower end, and bevel a 1/2" (1.25cm) piece of Plastazote.

10) This piece is heated, as before, for around 5 minutes and then glued over at the lower end using the rubber cement. Hold it in place with firm pressure using a bandage held over the end.



11) Finally, bevel off any edges with a knife to get a smooth contour.



Comments

You will have noticed that the soft insert touches the entire surface of the stump, including its end. This is called a total contact socket. In Garkida, where the limb was developed, the total contact socket proved successful. However, if the end of the stump is in a really bad condition, or you do not like total contact for other reasons, a semi-open socket could be made.

A semi-open socket is prepared by putting a sock filled with cotton wool on the stump. The Plastazote is then moulded over stump and sock.

Prosthesis with direct fitting

3.2 Fabrication of a hard socket

Materials and Equipment

epoxy resin and hardener (for a discussion on resins, see appendix 3)

piece of micro cellular rubber

cotton bandage

3" (7.5cm) stockinette

polyethylene plastic sheeting (ordinary plastic bag)

sellotape/adhesive tape

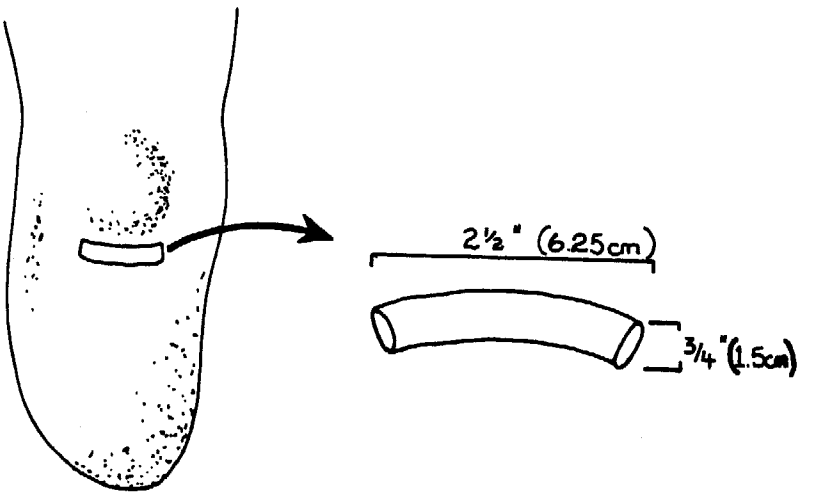
mixing cup, stirring stick, etc.

spoon

gloves

cleansing soap and hand brush

1) As with other below knee prostheses, this socket is made so that the patella tendon area takes most of the pressure.



Shape a piece of micro cellular rubber as shown above.

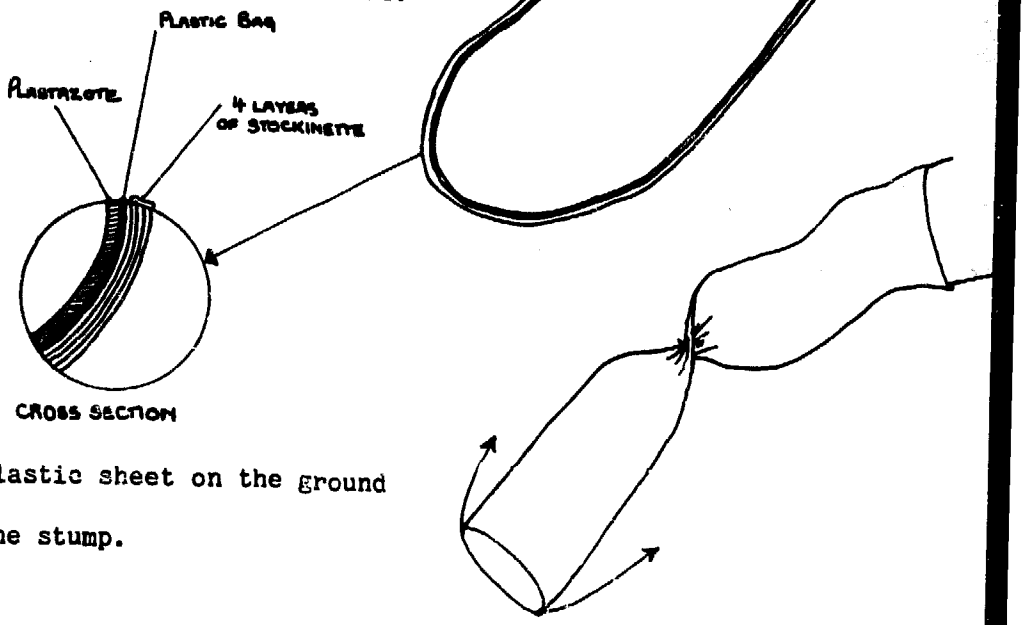
2) Press the piece firmly on the stump, and check that the shape does not cause pain.

Prosthesis with direct fitting

3) Put the Plastazote socket on the stump. (Use talcum powder if necessary).

4) Put a plastic bag over the Plastazote socket, and secure it with sellotape. This will prevent the hard socket from adhering to the Plastazote socket.

5) Put two layers of doubled stockinette over the plastic, as shown in the illustration. This makes 4 layers of stockinette in all.



6) Put a plastic sheet on the ground under the stump.

7) Measure epoxy resin and hardener. (Ratios are given as examples.)

	epoxy resin	hardener
For a small stump:	200gm (7oz)	13gm (1/2oz)
For a large stump:	300gm (10 1/2oz)	20gm (7/10oz)

Prosthesis with direct fitting

Instead of epoxy, polyester resin may be used. (See appendix 3 for a comparison between epoxy and polyester.) If you use polyester resin the following ratios are recommended:

polyester: 50gm (1.75oz)

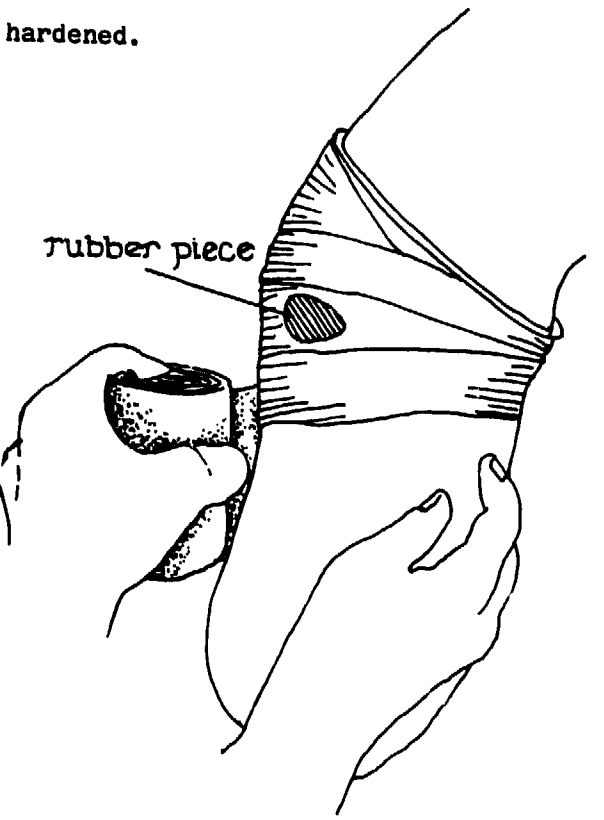
accelerator: 25 drops

catalyst: 4 drops (1 gram equals roughly 20 drops)

8) Impregnate the stockinette thoroughly with the resin, using the back of a tablespoon or other suitable instrument, to rub the resin into the stockinette. If your skin is sensitive to the resin, use gloves. Wash any part of the body which is exposed to the resin, with a cleansing powder such as Vim, Comet or Lava soap using a hand brush. If it is difficult to wash off add a bit of alcohol to the cleanser. Acetone would be very helpful, though difficult to obtain. Do not use a sink where the drains may become blocked.

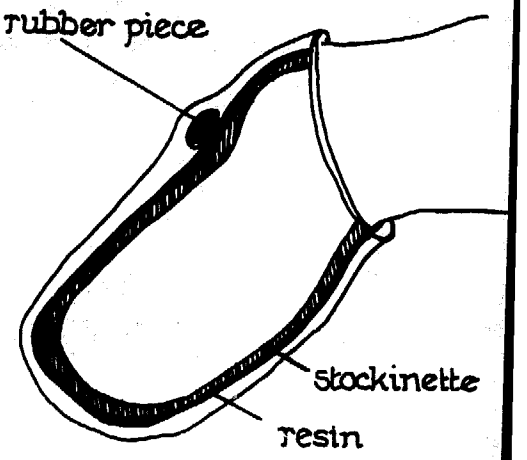
9) Position the prepared micro cellular rubber piece over the patella tendon area, before the resin has hardened.

10) Take care the piece is placed horizontally. Wrap a cotton bandage firmly around the entire socket. Wrap evenly and firmly in the same way as a stump is bandaged after an operation. Begin at knee level and work up the stump incorporating the rubber piece. To allow the socket to be taken on and off easily, it should not extend more than 1/2" (1.25cm) above the patella area.



Prosthesis with direct fitting

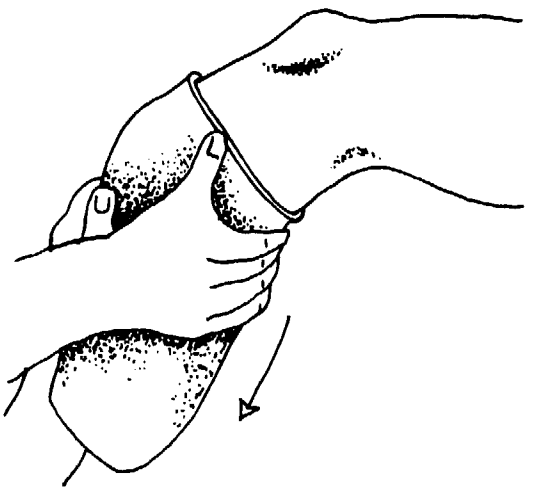
11) The cotton bandage used in this way becomes impregnated with resin, soaking it up during the wrapping process. A cross section would look like the next illustration. It is important to remember that resin sets hot. Therefore it is necessary to continuously ensure that the patient is not burned by the resin. If you find it is becoming too warm pour cold water over the bandage to cool it down.



CROSS SECTION

12) While the resin sets, the patient must not move his/her limb. Rest the stump in slight flexion over the edge of a folded blanket covered with plastic. The shorter the stump, the more flexion is recommended.

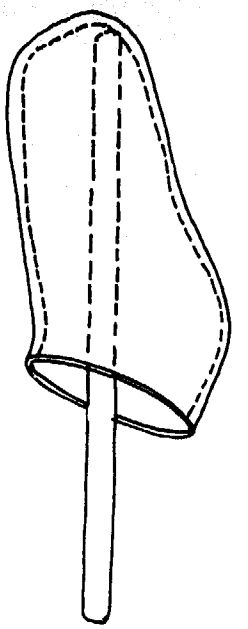
13) When the socket is hard, remove it from the patient.



Prosthesis with direct fitting

14) Remove the soft socket from the hard one, and remove the plastic bag or sheeting.

Let the hard socket set overnight.



15) Wrap the patient's stump and ask him/her to return tomorrow.

3.3 Alignment with wooden block

Materials

3" (7.5cm) stockinette

resin and hardener

corrugated cardboard or old x-ray film

wooden block (see following page)

talcum powder

thumb tacks

sellotape

corrugated cardboard

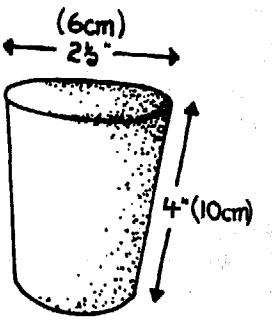
Equipment

sander or rasp

plastic sheet on floor

tools for handling resin

Prosthesis with direct fitting



1) Prepare a wooden block, about 4" (10cm) high and 2 1/2" (6cm) in diameter. Preferably, the block should be tapered a little.

2) Trim the rough sides of the hard socket with a knife and rasp, smoothing irregular areas.

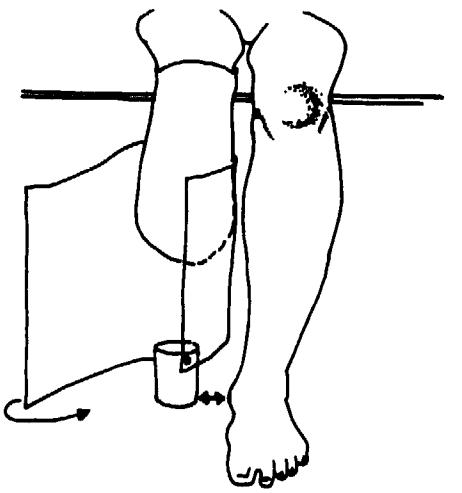
3) Put on the soft socket in exactly the same position as before. (Use talcum powder if necessary).

4) Let the patient sit, with the normal limb vertically positioned.

5) Place the wooden piece in a spot precisely equivalent to the heel of the foot.

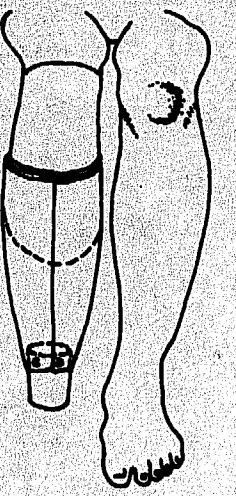
Thumb tack the lower corner of the x-ray film to the wood. Then roll the paper around the socket and wooden block.

Be sure the legs are in a similar position to each other, at this stage. If it is now possible for the patient to stand using crutches, you should take the opportunity to check alignment from different angles.



Prosthesis with direct fitting

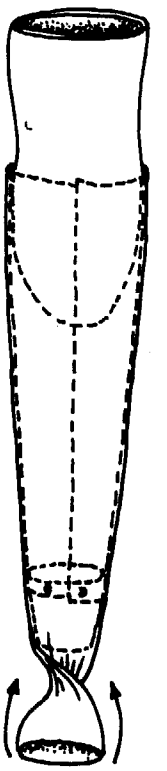
6) Trim the cardboard or x-ray film as necessary to ensure a smooth and snug fit.



7) Fit the cardboard or x-ray to the wood using another thumb tack. Fasten the socket with adhesive tape.

8) Now carefully remove the prosthesis from the patient. He/she may leave.

9) Remove the soft Plastazote socket, and cover the prosthesis area with only one double layer of stockinette. It is not wise to use any more layers as this will cause too much pressure on the cardboard.



10) Fix the prosthesis on a stick.

11) Impregnate with resin mixture as before, protecting the area with a plastic sheet. You will probably need about 8oz (100gm) of resin and a relative amount of hardener.

12) Let it set overnight.

Prosthesis with direct fitting

3.4. Reinforcement

Materials

1" (2.5cm) nails

stockinette

resin and hardener

colour powder

Tools

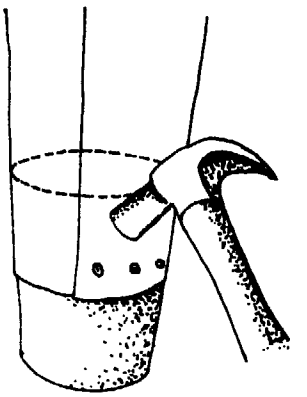
grinder or rasp

tools for handling resin

1) Put the prosthesis on the patient and check alignment. Do not allow more than partial weight bearing at this stage. Continue with step 2 if alignment is alright. If not, the alignment must be corrected before continuing.

2) Remove the prosthesis from the patient. Hammer 4-8 nails into the block.

3) Add 2 layers of stockinette to the prosthesis, and impregnate with resin as before. You will need roughly 150gm (4 1/4oz) of resin and an appropriate amount of hardener.



4) Allow to set overnight.

5) Apply a final layer of resin, this time mixed with colour powder. Usually, a dessertspoon of brown and about 1/8 as much of black powder will be the right quantity to mix in a suitable container. Apply liberally so as to obtain a smooth finish, or sand and make a second application. (A polyvinyl alcohol (PVA) cone is the best way to finish this stage if the technician knows how to use PVA. It adds to the cosmetic appearance.)

Prosthesis with direct fitting

3.5 Finishing

Materials

rubber tip (preferably the tread of a car tyre)

thin leather

Tools

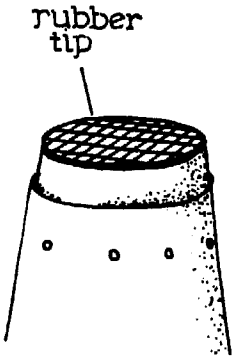
pen

coping saw, grinder or rasp

nails and hammer

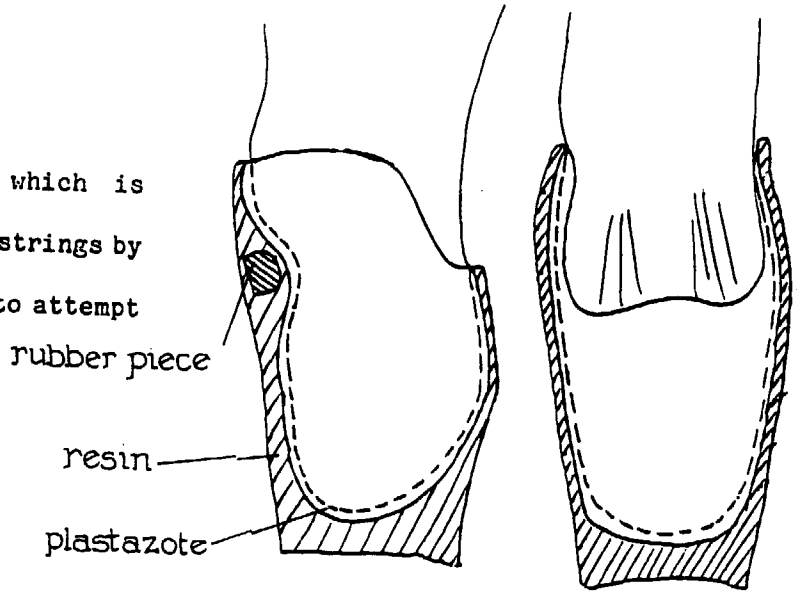
scissors or knife

1) Cut the lower end off, but make sure it is still longer than necessary. Fix a temporary rubber tip with rubber glue. Wait to finally trim the end until after the patient has walked awhile. In this way, the stump will have settled and it will be possible to get the exact length.



2) Put the prosthesis on the patient and mark with a pencil the part of the top to be trimmed. The illustration below indicates the final shape required.

Locate the space which is required for the hamstrings by asking the patient to attempt knee flexion.



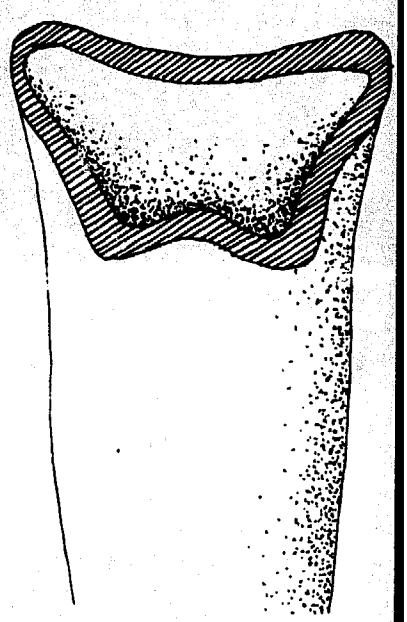
3) Remove the soft Plastazote socket, and trim the prosthesis along the line you have marked. A coping saw, rasp or grinder will help you do this.

Prosthesis with direct fitting

4) Re-insert the soft socket. You will then see what needs to be trimmed.

5) Encourage the patient to walk with the prosthesis at this stage over a period of several days.

6) Cut a piece of soft leather into a 2" (5cm) wide strip and glue it on the top of the prosthesis to hold the soft and hard sockets together.



7) As in other below knee prostheses, it is advisable to have a suspension strap to improve walking comfort. In the next chapter, some ways of suspension are assessed.

4. Prosthesis with wooden socket

In many areas, aluminium sheeting and plastic resins, such as epoxy and/or polyester are not available or they are very expensive. In this situation it is necessary to search for other materials which may be used instead.

If there is a craft such as woodcarving in the area, you can develop and use this skill to provide prostheses with wooden sockets.

Originally, sockets throughout the world were made of wood. The wood was hollowed, sometimes conically shaped, with the intention of putting pressure only on areas able to tolerate pressure. Unfortunately, pressure would sometimes also occur on places where this was not tolerated, causing discomfort and pain. As a result, a thigh corset was often provided (see chapter 6). This section describes a modified method of making a wooden socket which allows some kind of weight bearing on the necessary areas, especially on the patella tendon. Obviously, the manufacture can be adjusted to suit your own ideas.

Material costs : $20-$50

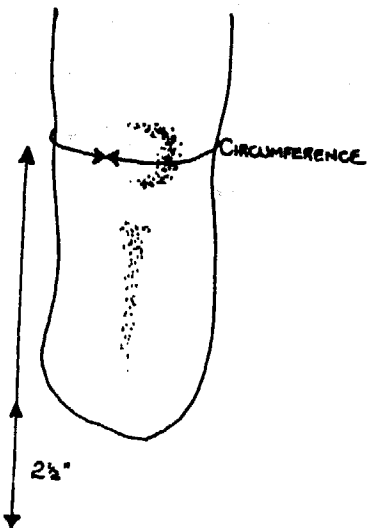
Cost of tools : $80-$100

Making and fitting : direct fitting; 2 days
fitting with plaster model; 3-4 days

Labour time : 6-8 hours

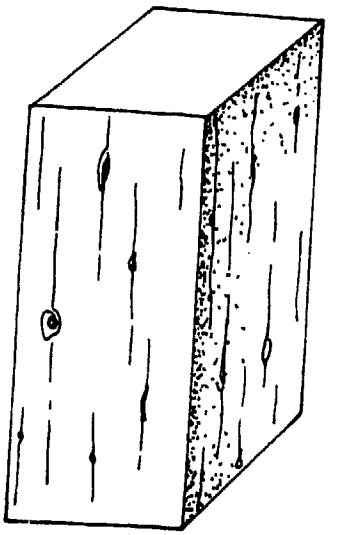
Prosthesis with direct fitting

1) Measure the length of the stump down from the knee. Add an extra 2 1/2" (6cm) to measure the external length of the wooden piece required.



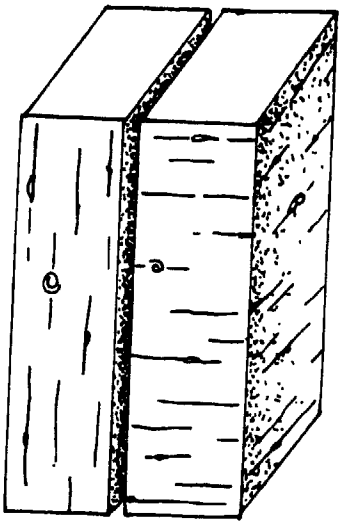
2) Measure the circumference of the stump at knee level.

3) Take a strong and light weight piece of wood of the appropriate size, preferably with no knots or cracks in it.



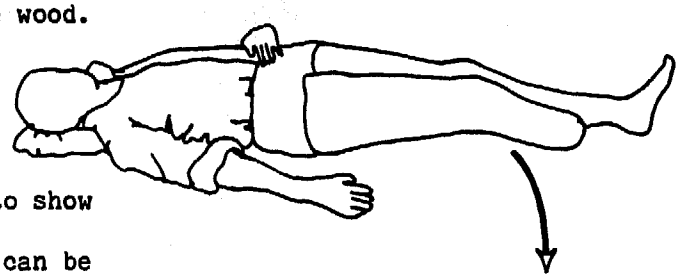
4) This piece is sectioned from top to bottom.

You may prefer to use two separate pieces of wood, with their grains running different ways (vertical/horizontal). This helps to make the socket stronger.

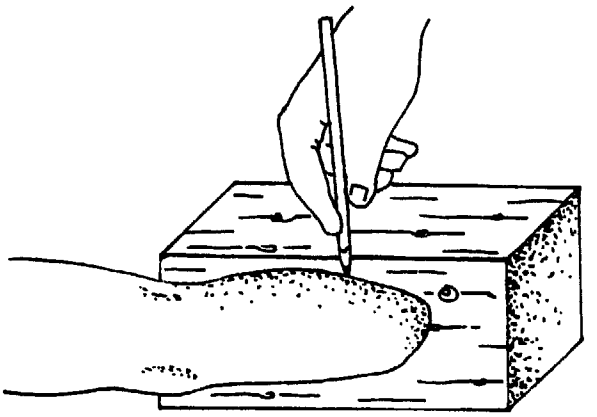


Prosthesis with direct fitting

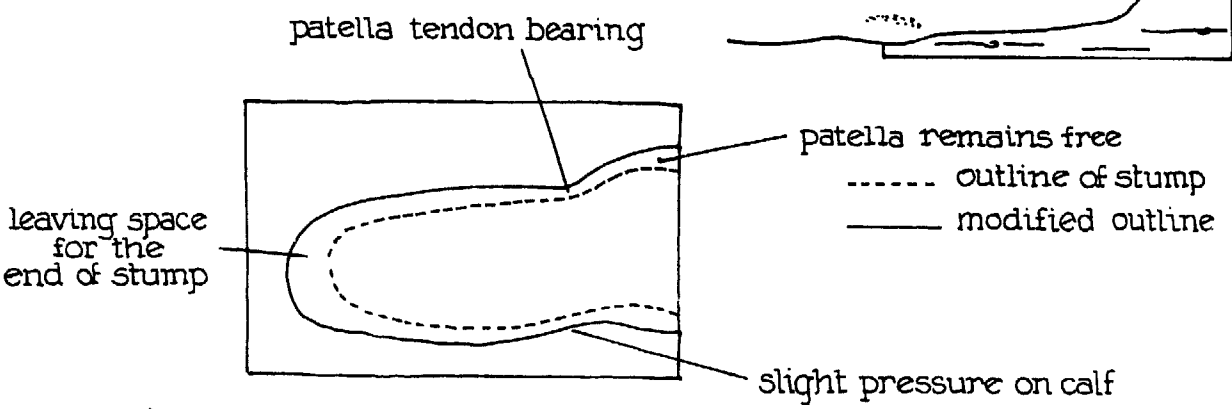
5) With the patient lying on a table or on the floor, mark around the outline of the stump on the wood.



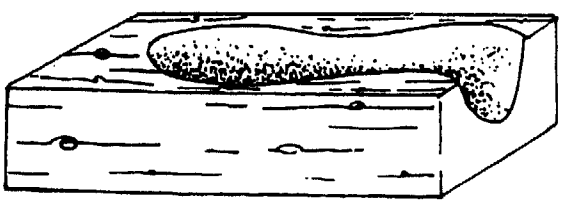
6) This mark is then modified to show where appropriate pressure can be tolerated.



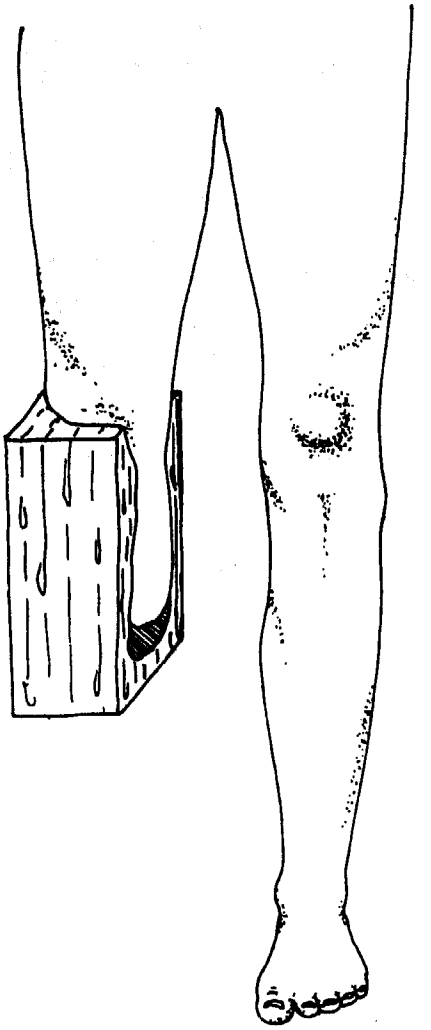
Follow guidelines from chapter 3 while doing this.



7) Carve the first block carefully with a chisel so that half of the stump fits in precisely.

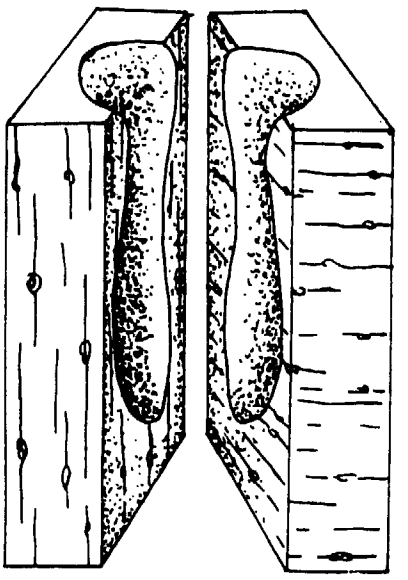


Prosthesis with direct fitting



8) Remember that bony bumps should not touch the wood. Also, ensure that the end of stump does not touch the wood, and that there is a space of at least 1" (2.5cm).

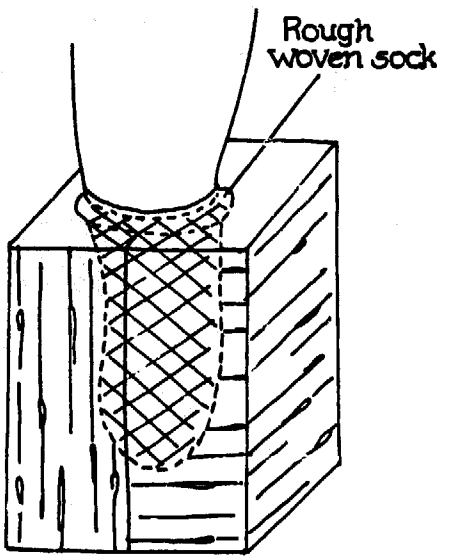
9) As guidance, you can use coloured chalk to indicate where the stump must be stopped from touching the wood, to avoid touching sensitive areas.



10) When this stage is ready, mark the stump at the top of the wooden block with a pencil. This is a guideline and allows precise carving of the other wooden part.

Prosthesis with direct fitting

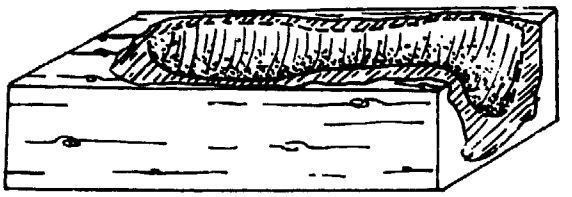
11) Put a rough woven sock on the stump. Then, fit the wooden parts carefully together, and try putting the stump inside the socket.



Any pressure areas on the stump will be indicated by an imprint on the stump from the sock.

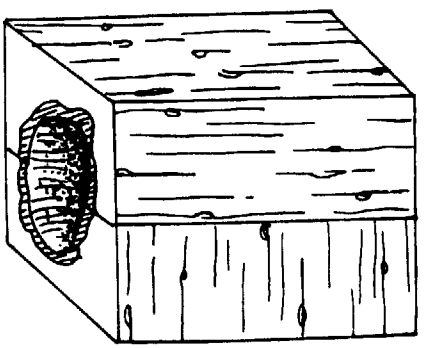
Remove wood where necessary.

12) Make a soft leather insert in the wooden parts. If you haven't any leather, microcellular rubber would be effective, though not as good.



13) Try fitting the stump into the socket again, using a rope to hold the block together.

Glue the blocks together, and let the complete block dry in a vice grip. In addition, you may wish to use some big screws for extra security. However, screws can make it difficult to shape.



Prosthesis with direct fitting

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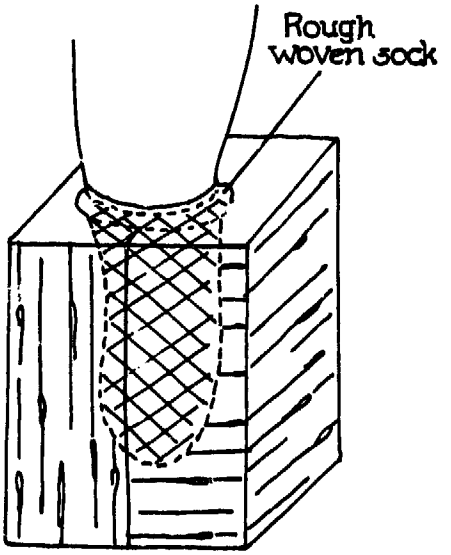

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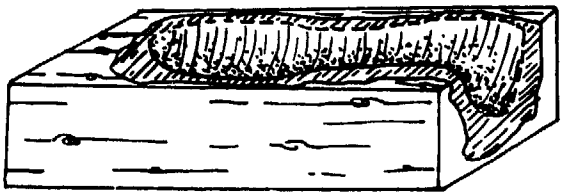

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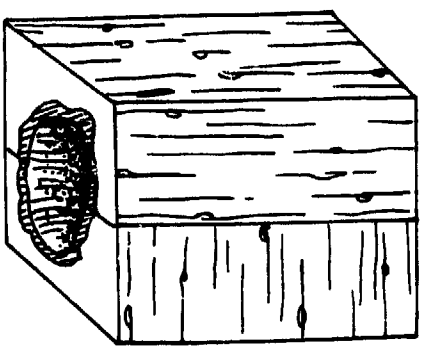
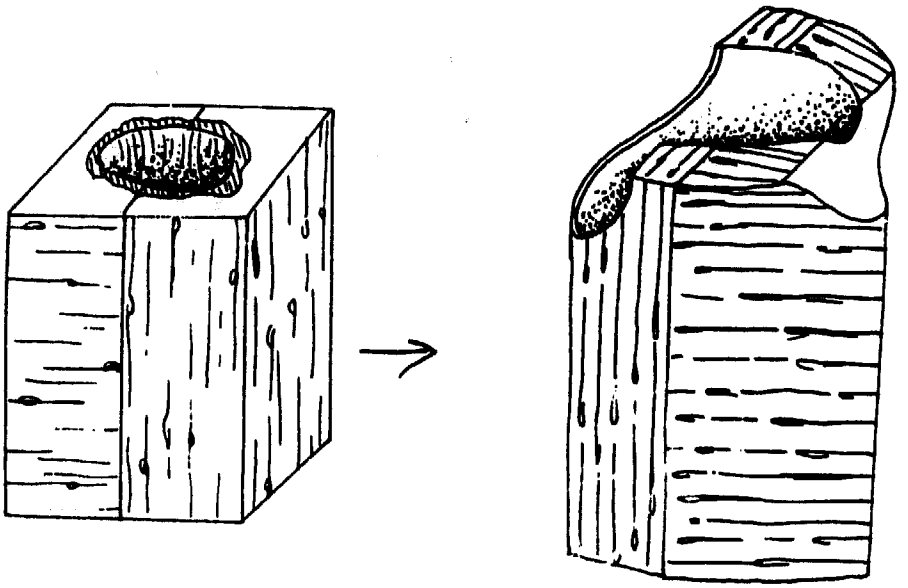


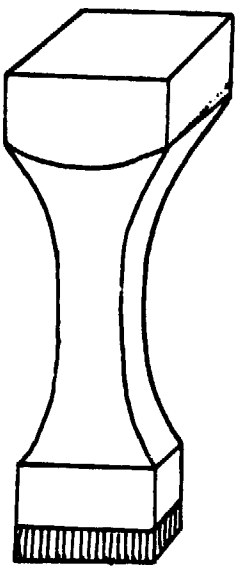
Prosthesis with direct fitting



14) Shape the wooden block as shown above. The top part may be circular, while the lower part remains squared at this stage.

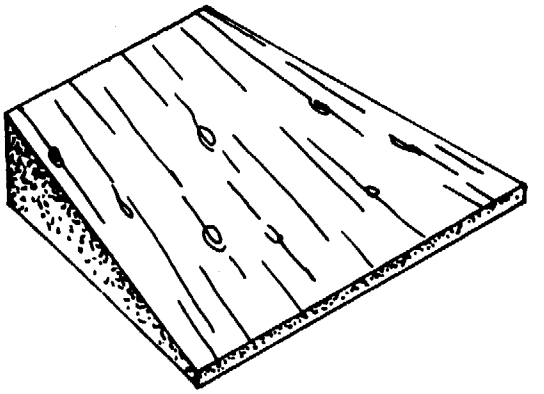
15) A pylon is prepared, similar to the technique described in the Cameroon prosthesis (see page 45). The length of the wood will be about 10" (25cm), depending on stump length and body length.

Glue or nail a piece of tread rubber to the bottom of the pylon.



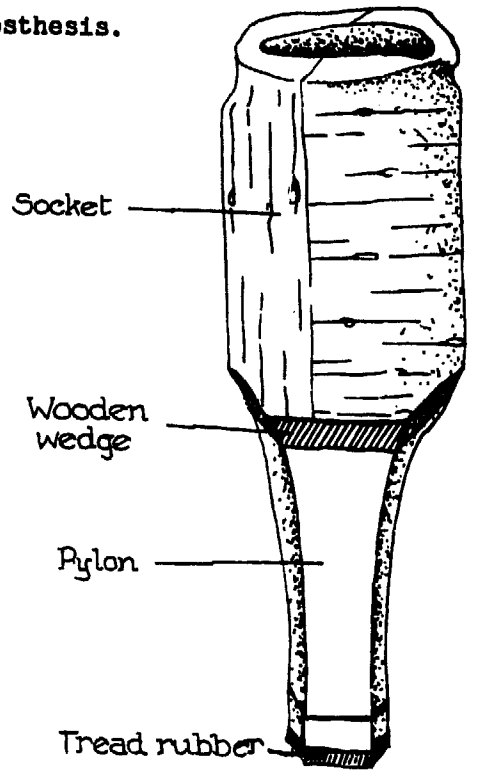
16) A wooden wedge will enable you to achieve some kind of alignment.

By sliding and/or rotating the piece, the socket is adjusted on the pylon in the required direction.

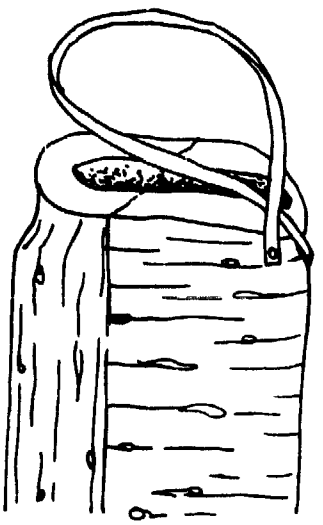


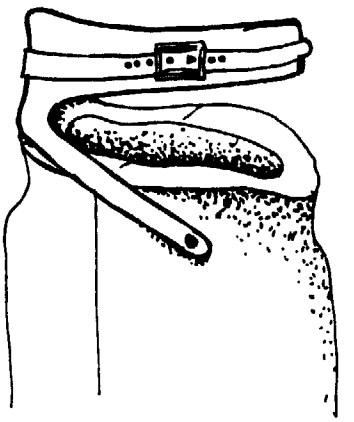
17) Glue the wooden wedge firmly on the prosthesis.

Smooth the entire area.



18) Suspension is added, see chapter 6.





Prosthesis with direct fitting

Comments

1. If you are not sure about the comfort of the fitting, or you expect the stump to shrink, you could close the socket blocks with rope, rubber tyre or three bolts instead of using glue. This allows an easier re-fitting.

2. You can also make a positive model of the stump out of plaster, wood, beeswax or other suitable materials. Modify the model (see chapter 4), then shape the wooden parts so that they fit closely to the cast model. This is easier than making many trial fittings on a patient.

CHAPTER SIX : SUSPENSION

1. Introduction
2. Cuff suspension
3. Thigh corset

Suspension

1. Introduction

Once a limb has been prepared for the patient, it is necessary to pay close attention to the finishing process.

The final stage of limb manufacture is just as important as the previous stages. With proper care it can greatly influence the comfort, acceptability to the amputee, and durability of the aid.

In order to suspend the prosthesis on the stump during the swing phase, a cuff should always be provided. The only time a cuff would not be required is when the socket covers the patella. This is a more sophisticated technique. If the stump is relatively short, and there is likely to be too much pressure on the skin, a thigh corset is recommended.

Both the cuff and corset are described on the following pages.

Some patients with hand deformities, such as those with leprosy, may have difficulties taking the prosthesis on and off. This may be made more difficult as a result of a poorly designed cuff.

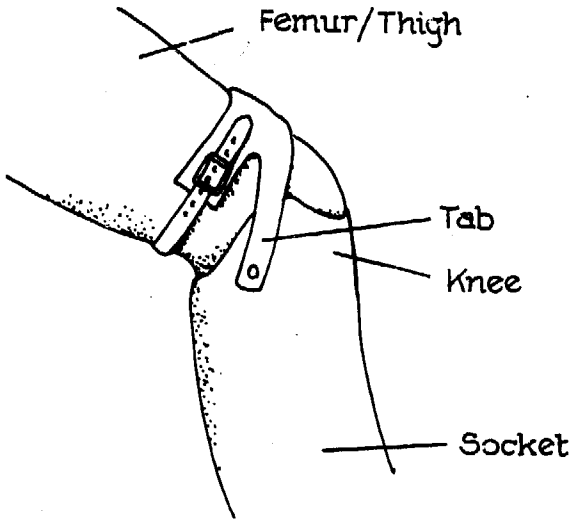
Therefore, it is important to ensure that the cuff you make and fix on the socket is easy to handle.

Suspension

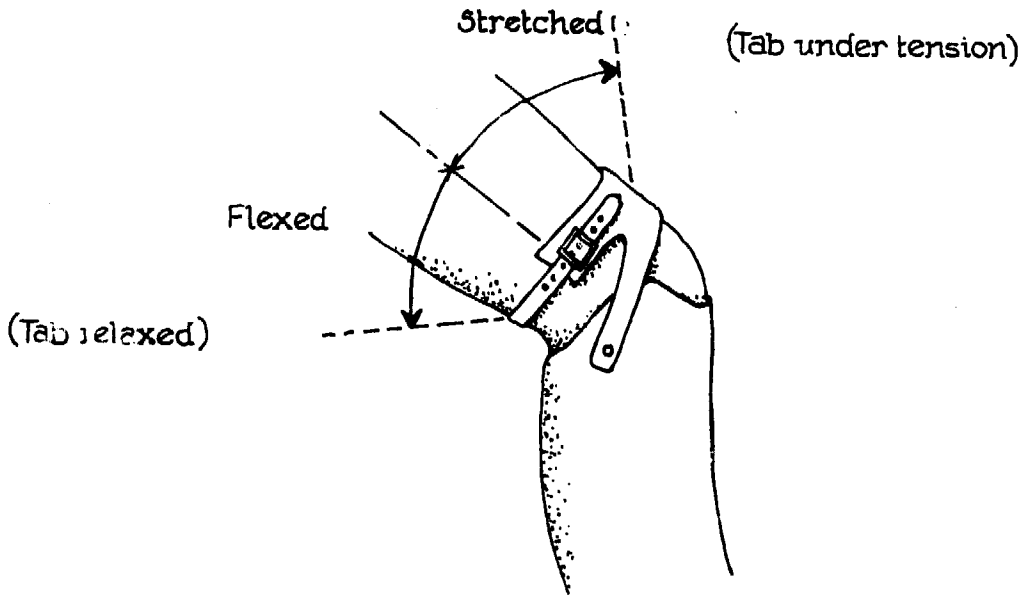
2. Cuff suspension

A cuff, as shown below, has two separate functions:

- to suspend the prosthesis on the stump in the swing phase
- to provide a check against extreme stretching (hyperextension) of the knee joint.



This means that careful consideration must be given to the shape of the cuff and how it is attached to the socket.



The cuff must maintain tension over a wide range of stretching and flexing of the knee. The cuff must only relax when the knee is heavily flexed.

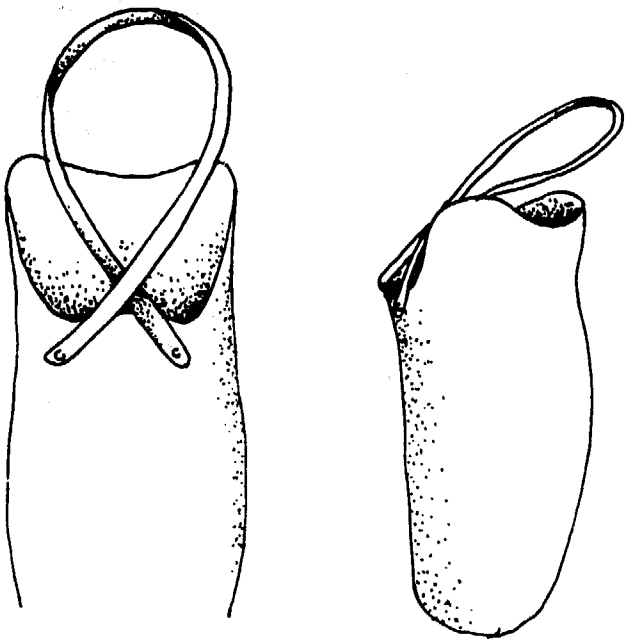
Suspension

Cuff 1

The easiest way to make a cuff is to use a rubber strap made from a bicycle tyre - you will need about 14" (35cm) for this.

Costs : $1-$2

Labour time: 1/2 hour



Screws or rivets are attached to the back of the socket or any vertical uprights. The rubber strap is then tightened in a figure 8 around the stump, as shown above.

During the attachment of the cuff, the patient should stand in the socket with his/her weight equally distributed on both legs.

A patient with no fingers at all can still slip this strap up over their knee. To remove the stump from the socket, slip the strap down over the prosthesis.

To prevent a crack developing from the hole made by the screws, that area can be strengthened with an extra layer of rubber.

Suspension

Cuff 2

A more durable and stronger cuff can be made using leather.

Costs : $2-$3

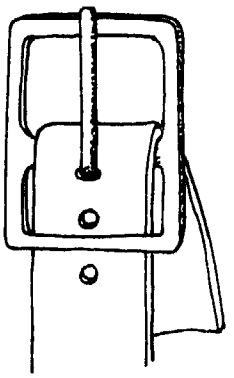
Labour time: 1-2 hours

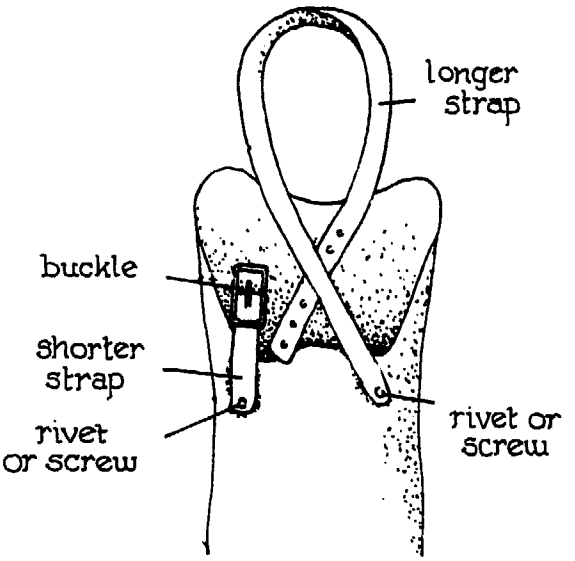
You will need:

a leather strap, about 1" x 14" (2.5cm x 35cm)

a buckle (5/8" [80mm] or bigger)

basic leather tools





The leather strap is cut into two pieces, one with a length of 3" (7.5cm). The buckle is attached to that piece as shown above. The end is folded over and glued and/or sewn.

The longer and shorter pieces of leather are attached with screws or rivets as shown above, and wound around in a loop as the rubber cuff (cuff 1).

Suspension

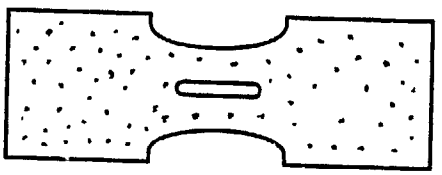
Cuff 3

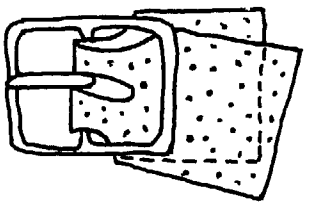
An even better type of cuff can be made as follows.

Costs : $8-$14

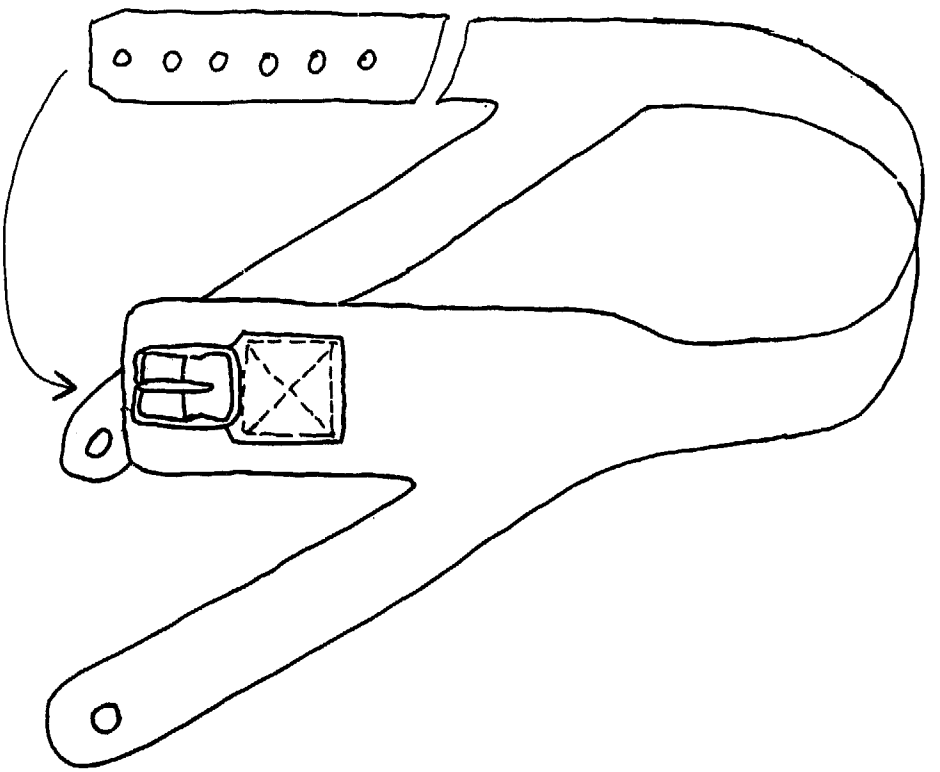
Using the pattern on page 98, cut a piece of strong but soft leather. If the tabs need reinforcing, glue small strips of nylon or cotton cloth onto them. The size of these reinforcing straps may be 1/2" x 4 1/2" (1.25cm x 11.4cm. In addition, the cloth could be covered with soft leather to add extra strength.

The buckle is attached using a small piece of leather in the shape shown below. The piece of leather is folded inside the buckle and the ends glued together.





It is then sewn to the cuff as shown in the figure below.



Suspension

Make holes in the end of each tab for attachment to the socket, depending upon the size of the screw or rivet. Make buckle holes, starting at the end.

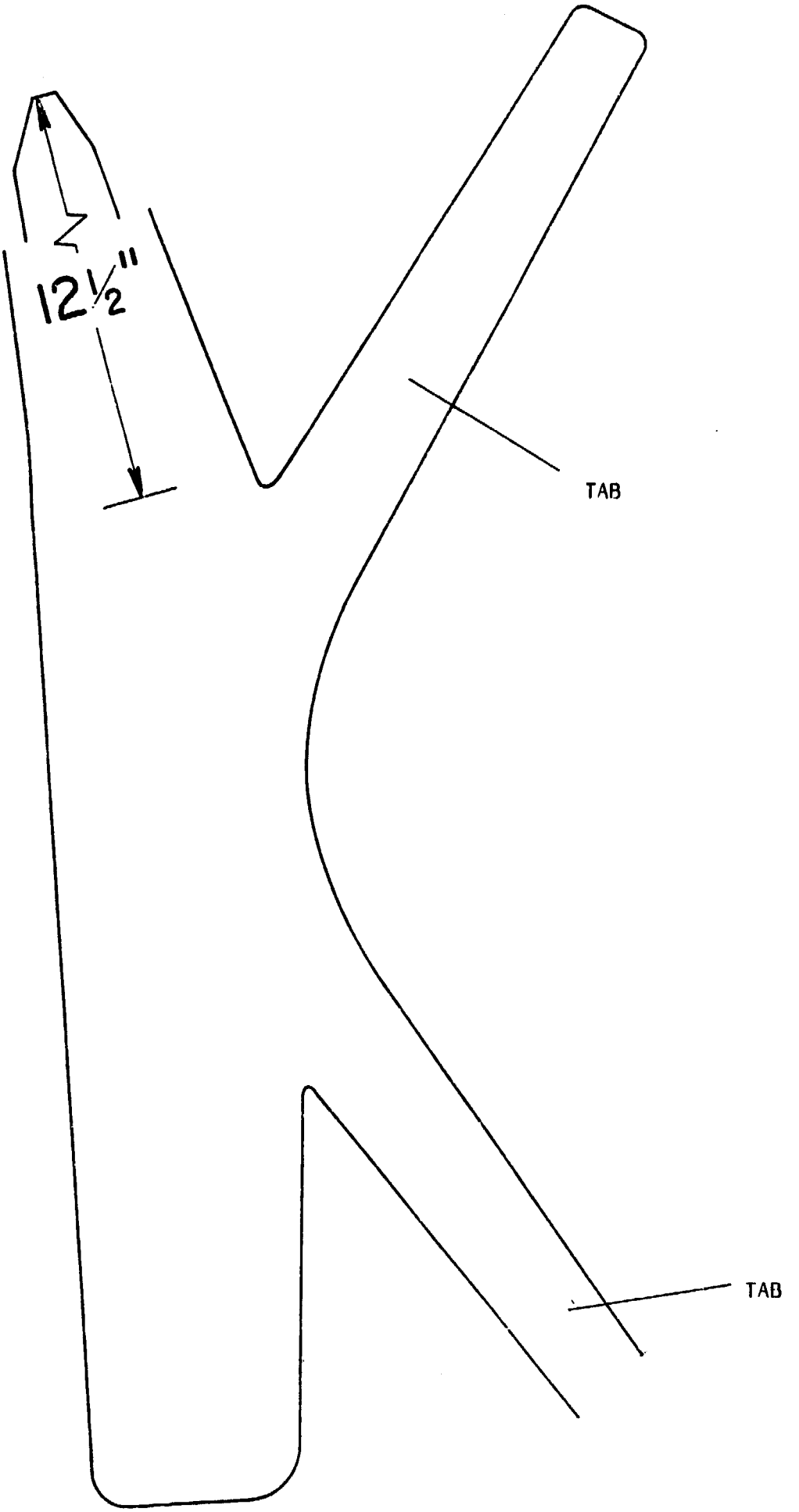
Finally, attach the cuff to prosthesis so that in a stretched position the tabs are tensioned, and in a flexed position the tabs are relaxed.

Comments

1. It is important to consider how this cuff can be adapted for children and small adults.

   The angle between the cuff and tabs must be as shown in the figure on the next page. Usually it is sufficient simply to scale down the size.

2. Temporary attachment of the suspension cuff may be advisable, using screws. When, after having tried it out, the cuff is proved to be satisfactory, tabs can be attached permanently with rivets.



Pattern for making a cuff

Suspension

3. Thigh Corset

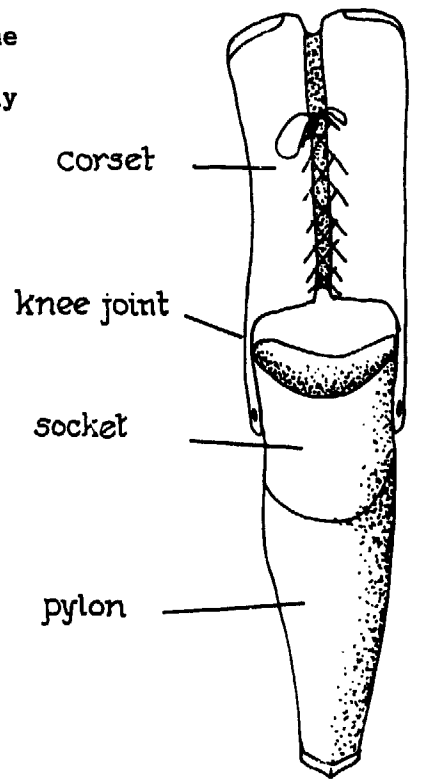
Costs : $30-$45

Labour time: 5-7 hours

Below knee amputees usually have their knee joint functioning well. In order not to hinder the widest possible freedom of movement of the affected leg, it is important to place as little suspension on the thigh as possible. However, if the stump below the knee is shorter than 3" (7.5cm), the total weight of the artificial limb cannot easily be borne on the remaining limited skin areas of the stump alone. To help reduce the amount of weight carried by a short stump, you can

Firstly, build the socket on the prosthesis in a slightly more flexed position. This encourages the patella tendon to take more of the weight.

Secondly, a corset can be provided on the thigh. The corset takes some of the weight load, transmitting it directly through the prosthesis to the floor.



Suspension

Using a thigh corset has many disadvantages, however, which must be considered before providing an amputee with one.

Disadvantages

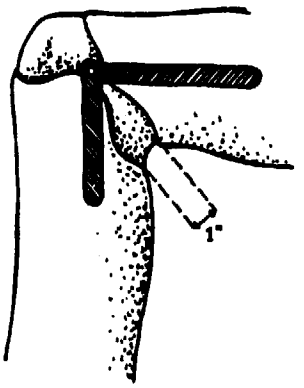
The major disadvantage is that, unlike the natural knee joint, a mechanical knee joint of a thigh corset is only a single axis joint. This means that either the stump moves in the socket during flexion or the thigh is affected by friction in its corset during flexion.

Other disadvantages of using a thigh corset are:

- it can cause the thigh muscles to waste
- the joints often have to be repaired after heavy use of the prosthesis
- the corset is made of stiff leather, which can be expensive
- to put on the corset, amputees must have good use of their hands. When the hand is deformed, such as by leprosy, a thigh corset can be extremely difficult to manage.

Suspension

The best position for the mechanical joint can be worked out as shown in the figure opposite. With the joint flexed at 90°, the lower edge of the corset will be 1" (2.5cm) above the brim of the socket.



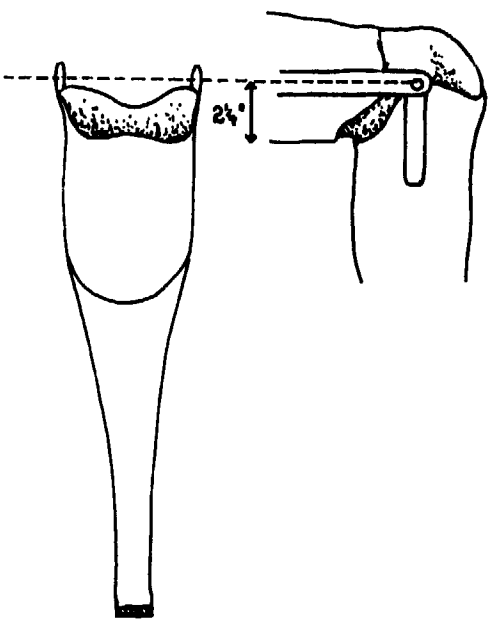
The joints must be attached at either side of the socket, and approximately 2 1/4" (6cm) above the lower brim.

We will now describe how to make a simple thigh corset.

There are three stages:

- manufacture of the side bars
- preparation of the corset
- fitting of the corset

the joints must be attached at either side of the socket

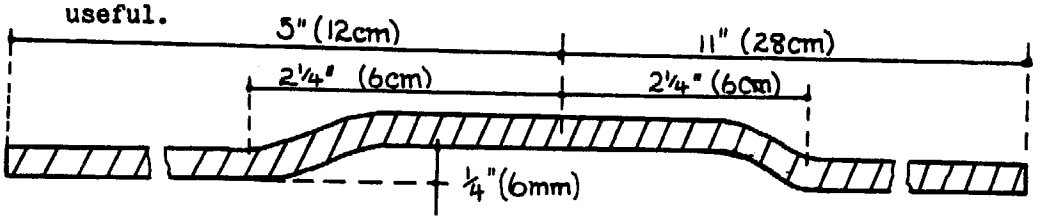


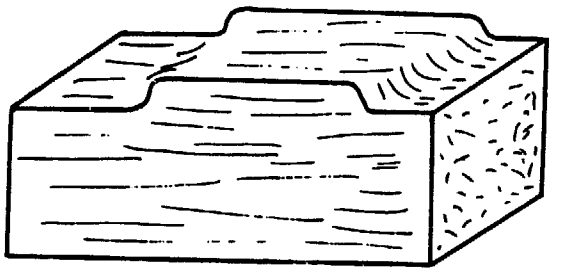
Suspension

Manufacture of the side bars

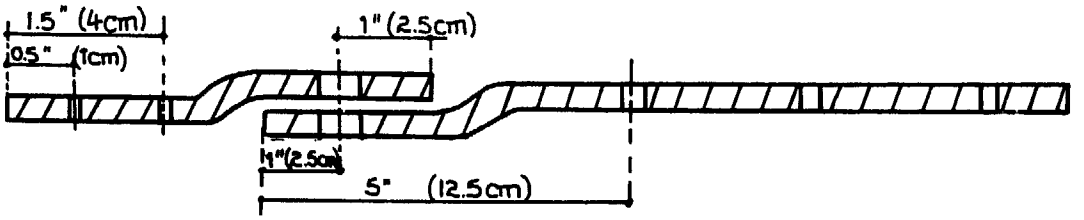
1) You will need 2 bars of mild steel, with a thickness of approximately 1/4" (4mm). The length of each bar should be approximately 16" (40cm), depending on the type of socket and size of the thigh.

2) The bars are are bent as shown below. It is best to heat the steel until it is red hot before bending it. An iron or hard wooden die can be used to get the correct shape. Bending tools are also very useful.

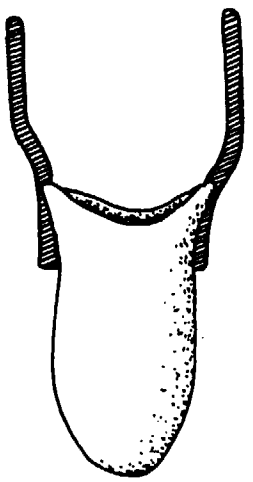




3) Now cut each bar into 5" (12cm) for below the knee joint and 11" (28cm) for above the knee joint. Then drill holes through the bars as shown in the figure.



4) Align the shorter bar along the socket and check if you need to bend it any more or not.



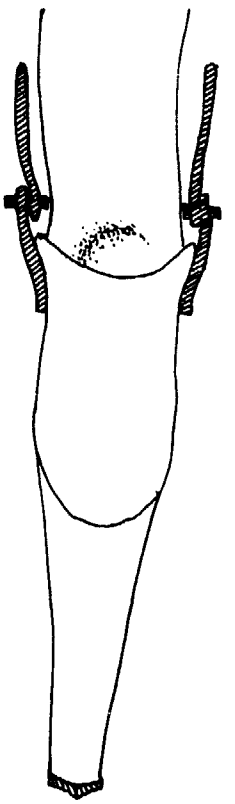
Suspension

5) The shortest bars are securely attached to the prosthesis, using screws, impregnated resin bandage, plaster bandage, or other suitable materials. This depends on the type of prosthesis you intend to make.

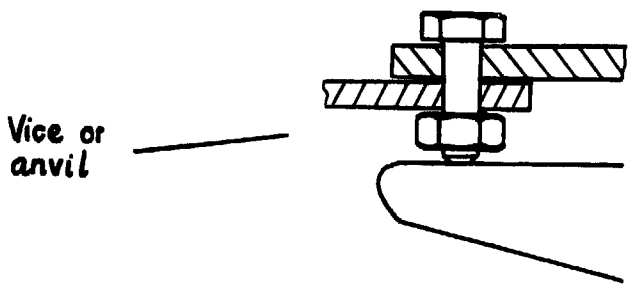
If you are using resin, the metal bar is fitted onto the socket.

If you are using an aluminium frame, the corset bars could be fitted on the vertical uprights using rivets (phase 5.6 on page 49).

6) Whilst the amputee stands on his/her prosthesis, take the two parts of each corset bar and check if any more bending is required. The bars should not touch the thigh in use.



7) Attach the two parts of each upright together, using a bolt and nut.
To get a proper connection, tighten the nut and bolt, until the parts move smoothly. Then flatten the top of the bolt using anvil and hammer. This will prevent the joint loosening.

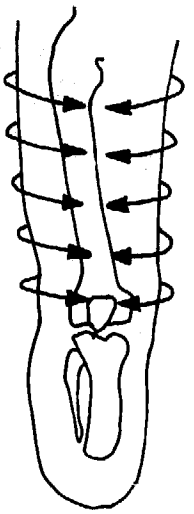


Suspension

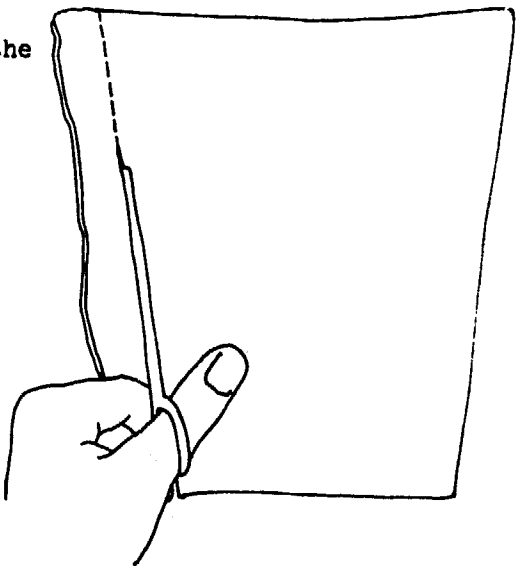
Preparation of the corset

The bars are now ready, and the corset itself has to be made.

8) Measure the circumference of the thigh as shown.

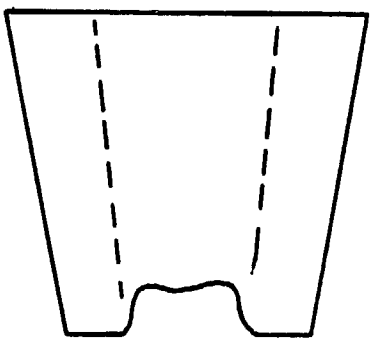


9) Copy these measurements onto a piece of paper. This is the pattern for the piece of leather for the corset.



10) The lower edge of the corset is shaped as shown in the picture.

A line should be drawn halfway down each side to show where the uprights must be attached.

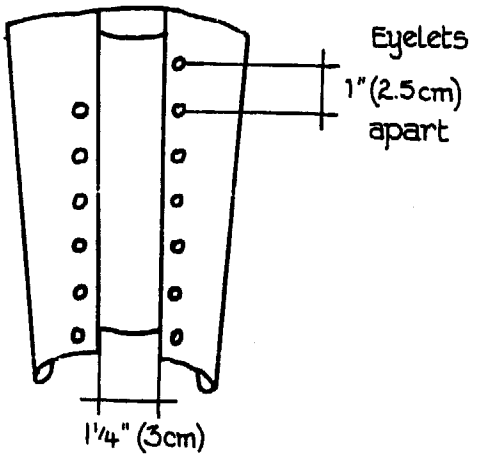


Suspension

11) Wrap the corset around the thigh while the amputee is standing.

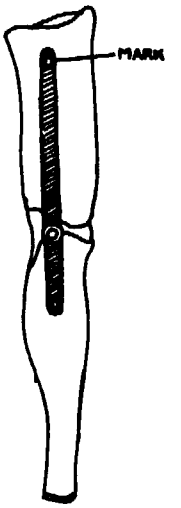
12) Mark 2 lines on the front of the corset so that after cutting along these lines there is a gap of about 1 1/4" (3cm) between the two edges.

Cut eyelets 1" (2.5cm) apart and 3/8" (1cm) from the front edges.



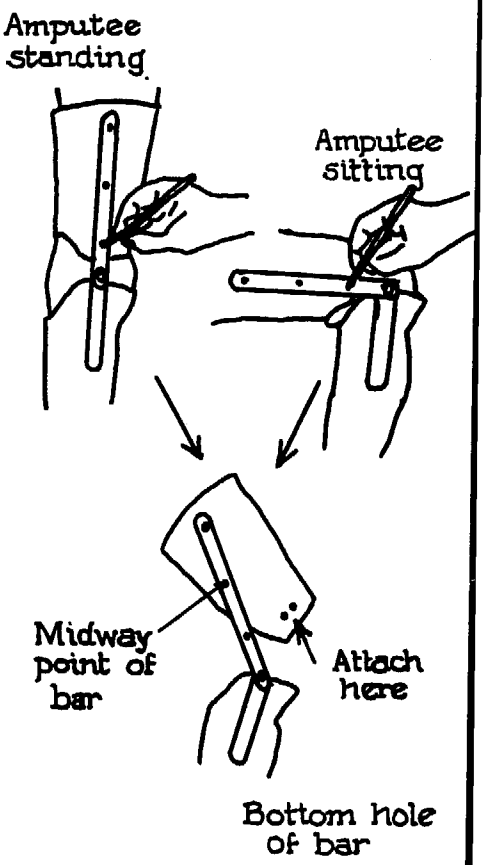
Suspension

Stage 3. Fitting of the corset



13) Ask the amputee to stand again wearing his/her prosthesis and corset.

Mark the corset through the top holes of the side bars, punch a hole in the leather, and attach the corset to both the bars.



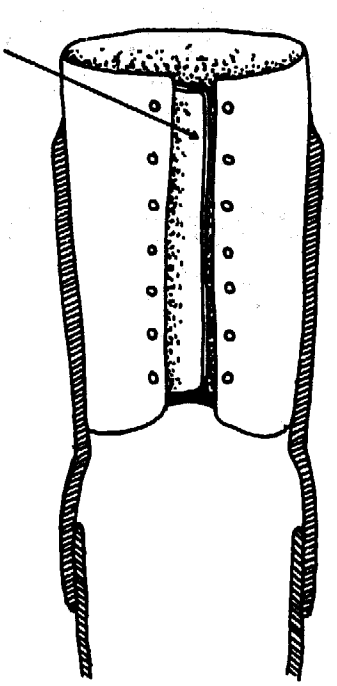
14) With the amputee standing, mark on the corset the bottom hole of each side bar.

Mark the bottom hole of each side bar with the amputee sitting.

Attach the bottom hole of the side bars to the corset midway between these two marks. Do not fasten the midway point of the bar at this stage, since this is a temporary attachment.

15) If the alignment seems correct, attach a rivet at the midway point of the bar.

Suspension



16) Cut a strip of leather to act as a protection to the skin. Smooth the sides, and sew it on the inside of one of the sides. The strip must extend approximately 1" (2.5cm) beyond the row of eyelets.

17) Check the leather cuff for any sharp edges which could hurt the skin.

CHAPTER SEVEN : FOOTPIECES

Footpieces

1. Introduction

It is not surprising that in every society throughout the world, amputees, faced with the loss of a limb, wish that limb to be replaced by as natural an artificial limb as possible. For instance, the shank needs to be equal in size to the original limb and a flesh coloured covering is greatly preferred. If such a limb, together with a footpiece, can be provided, this will naturally have considerable advantages, certainly in the eyes of the amputee, over a simple peg leg.

It is important to remember however, that sometimes there may be disadvantages to the attachment of a footpiece to an artificial lower limb. These disadvantages are now discussed.

Firstly, a footpiece causes higher pressure on the tibial skin of the stump during gait, as compared to a peg leg. Therefore better fitting skills are required of the prosthetic technician. If the stump is partly insensitive, extra care has to be taken.

Secondly, stiff footpieces often cause discomfort when walking on uneven ground due to medio-lateral instability.

Thirdly, the footpiece is often the only component of a prosthesis which needs frequent repair. The wooden core is liable to break, especially when the limb is used on rough ground. In addition, the micro cellular rubber deteriorates due to exposure to water and air. Therefore, because of the greater fragility of a footpiece, the amputee may need to return more often to the rehabilitation workshop for replacements, even though the rest of the prosthesis remains in good condition.

Fourthly, if an above knee prosthesis has a footpiece yet no knee joint, the amputee has to lift his/her hip considerably more in the swing phase to clear the ground.

It is important to discuss this matter with the patient before fitting him/her with a limb. Show the appliance with and without a footpiece, and explain the advantages and disadvantages regarding an individual's personal situation and activities. Wherever possible, the patient should be encouraged to make his/her own choice.

Footpieces

General comments on footpiece manufacture

In this chapter, the manufacture of various footpieces is assessed. Materials such as rubber, wood and leather are commonly used. Some suggestions for the handling of such materials follow:

- before glueing leather, rubber and/or wood, surfaces should be thoroughly cleaned of dust and fat.

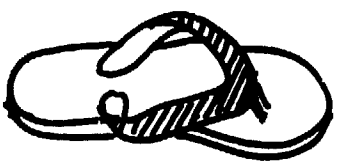
- to improve bonding, surfaces should be roughened to enlarge the bonding surface.

yes no

A surface may be roughened with a file or a piece of glass.

- bonding between leather and wood may be improved with the use of small screws. The same is not true for bonding rubber and wood.

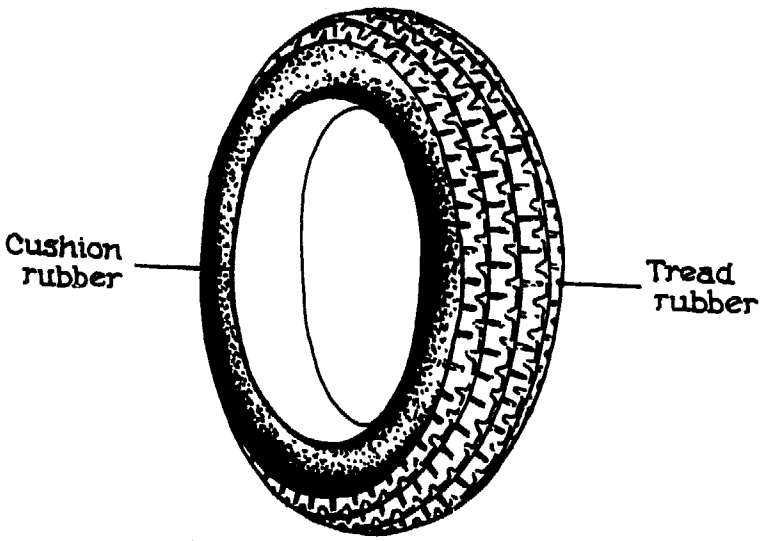
- micro cellular rubber is the same rubber that is used for rubber sandals. Rate of hardness is given in shore A from 0-90; general purpose cellular rubber has a hardness between 40 and 45 shore A.



Footpiece

- tread rubber is the strong rubber used for the external part of car tyres. It is largely wear resistant, though not easily compressible.

- cushion rubber is the rubber usually used in the side wall of car tyres, and is resistant to repeated flexion.



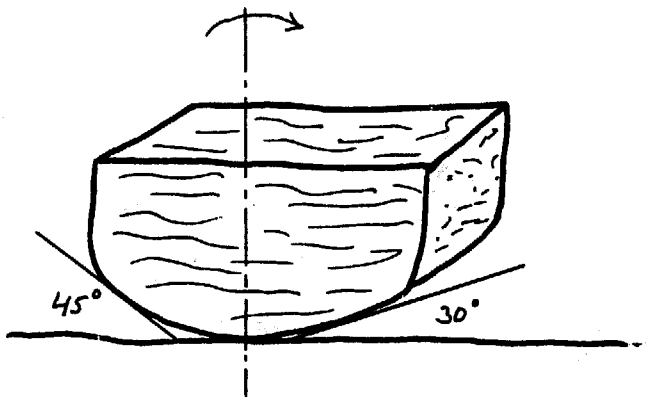
- rubber vulcanisation - see Appendix 4.

Footpieces - Rocker Foot

2. ROCKER FOOT

Material costs	:	$5-$25
Costs of tools	:	$20-$25
Labour time	:	2-3 hours

The Rocker footpiece is the simplest footpiece after the peg leg. Its curved shape enables the wearer to be propelled forward, as the point of contact with the ground naturally rocks the footpiece forward into the next step phase.



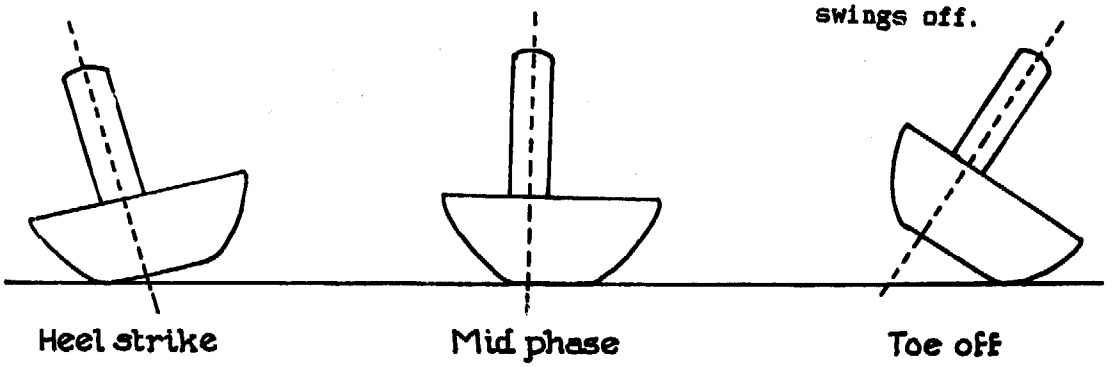
Footpieces - Rocker Foot

The step has three phases:

A) heel strike, when the heel touches the ground

B) mid phase, when the body stands squarely on the artificial foot

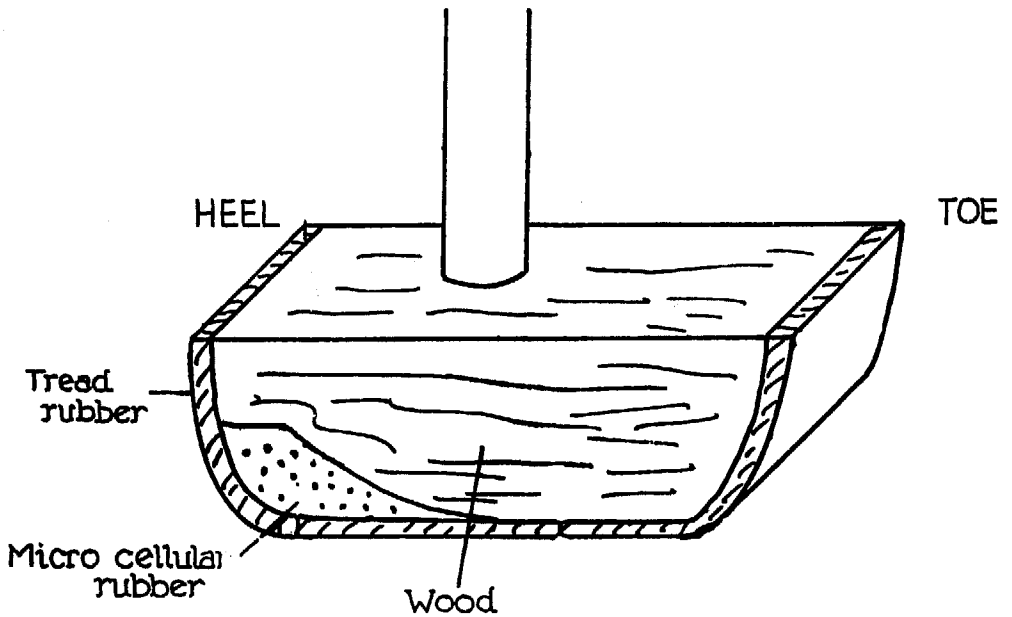
C) toe off, when the toes briefly touch the ground, before the foot swings off.



1) Unnecessary shocks may be exerted by the prosthesis on the stump when the heel strikes the ground. This may be avoided by building up the heel with some extra layers of rubber. Micro cellular rubber can be used for this, but it may not be very long lasting. Car tyre rubber (tread rubber) may be better. The rubber is glued onto the wooden block.

2) To ensure a stable grip on the ground during mid phase, the middle part of the foot should be flat.

3) To achieve the toe off phase smoothly, the front part of the foot should be rounded.



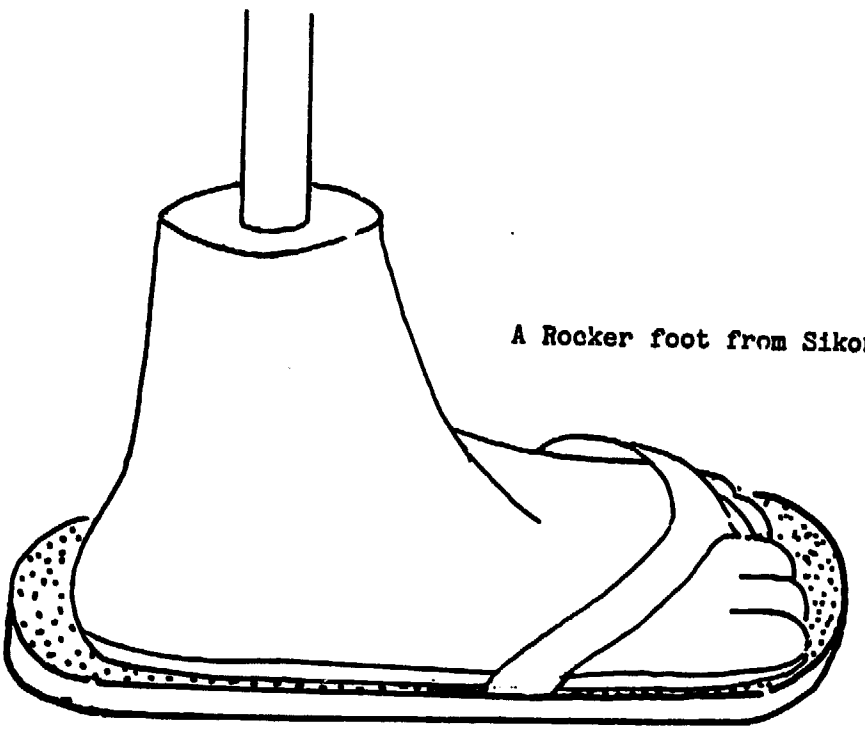
Footpieces - Rocker Foot

Below sample sizes for a small and big footpiece are given. The shank is attached by drilling a hole (approx 1" [2.5cm] width) in the foot. Using glue, the foot is then attached to the shank. A nail will fix the two parts together more securely.

	big size		small size	
	cm	inch	cm	inch
length	22	9	14	5 1/2
width	7	2 3/4	4.5	1 3/4
height	6	2 1/2	4	1 3/4

Sample sizes for Rocker foot

Of course, the shape of the footpiece can be altered so that a slipper can be placed around it, or even to allow it to be fitted in a sandal or a shoe.



A Rocker foot from Sikonge, Tanzania

Footpieces - Sach foot

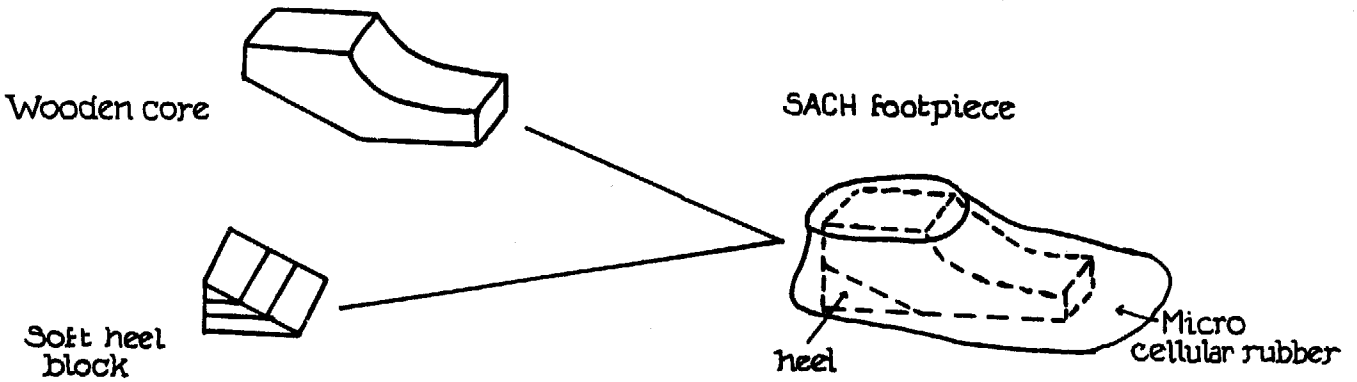
3. SACH FOOT

Material costs : $15-$35

Costs for tools : $50-$140

Labour time : 3-4 hours

The SACH footpiece has become popular all over the world. The letters represent the words Solid Ankle Cushioned Heel. This footpiece has some features in common with the Rocker foot, such as the shock absorption in the heel component. The SACH foot basically consists of a wooden core covered with cellular rubber.



The toe area is very flexible. In modern techniques, the cellular rubber is made by injection moulding around the wooden core. As this procedure is not often feasible in developing countries (due to the high cost of equipment and lack of suitable materials), this manual describes two other ways to produce a SACH foot with similar features. We know, however, that there are many more ways to make a SACH foot and welcome further initiatives and suggestions.

It is important to remember that micro cellular rubber is not very strong and that a footpiece could easily wear out within one year. Old car tyre tread is often used to reinforce the sole but does not help to prevent deterioration of the cellular compound.

Footpieces - SACH foot

3.1 SACH foot: type 1

(Operation Handicap International)

Type 1 consists of a wooden block (with the grains running from heel to toe), covered with some layers of micro cellular rubber. These layers might be obtained from a local shoe or rubber manufacturer. Hardness should be around 40-45 shore A. Thickness of the sheets could be 3/5" (1.5cm).

Figures 1-4 show how to shape the wooden block and how to add the micro cellular layers onto the block. The glue usually contains a rubber cement. Movicol is often used. Take care to close the tin of glue properly and to store it in a cool place when not in use, so that it lasts longer.

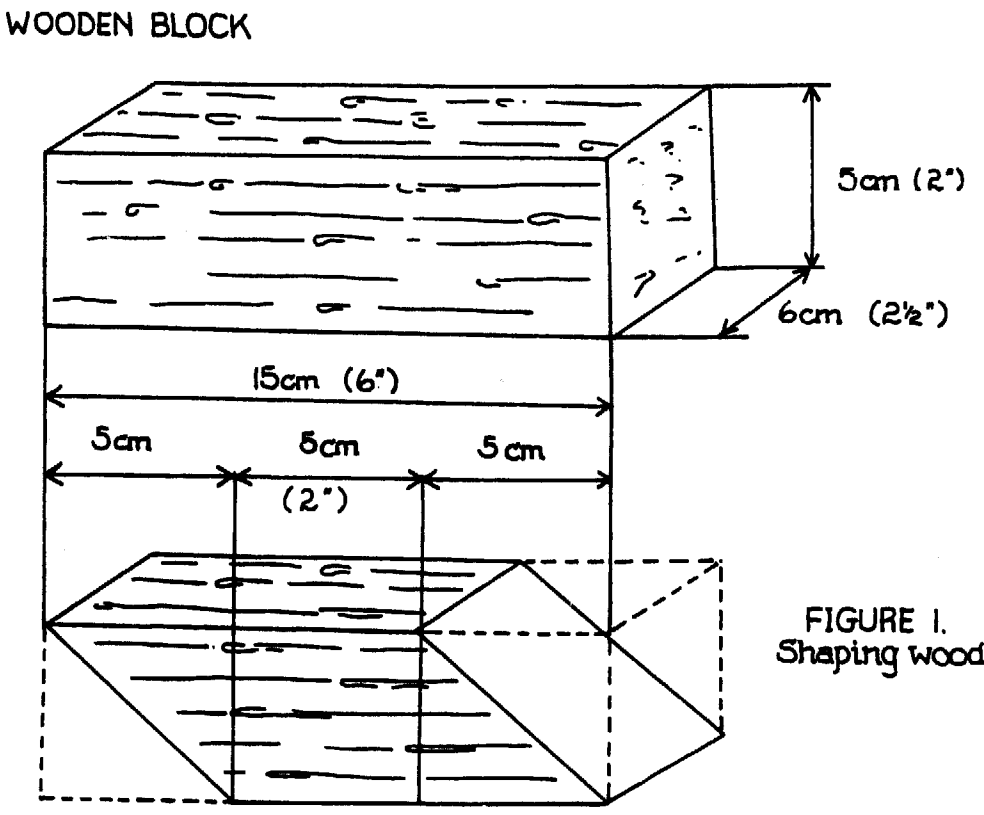


FIGURE 1.
Shaping wooden core

Footpieces - SACH foot

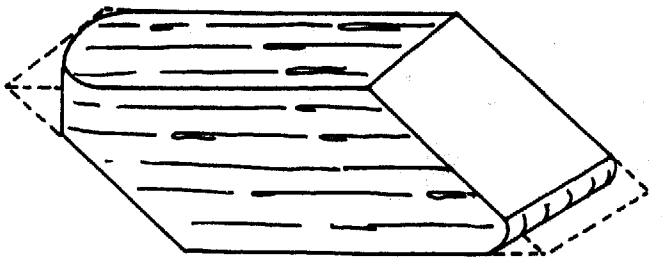


FIGURE 2.
Smoothing wooden core

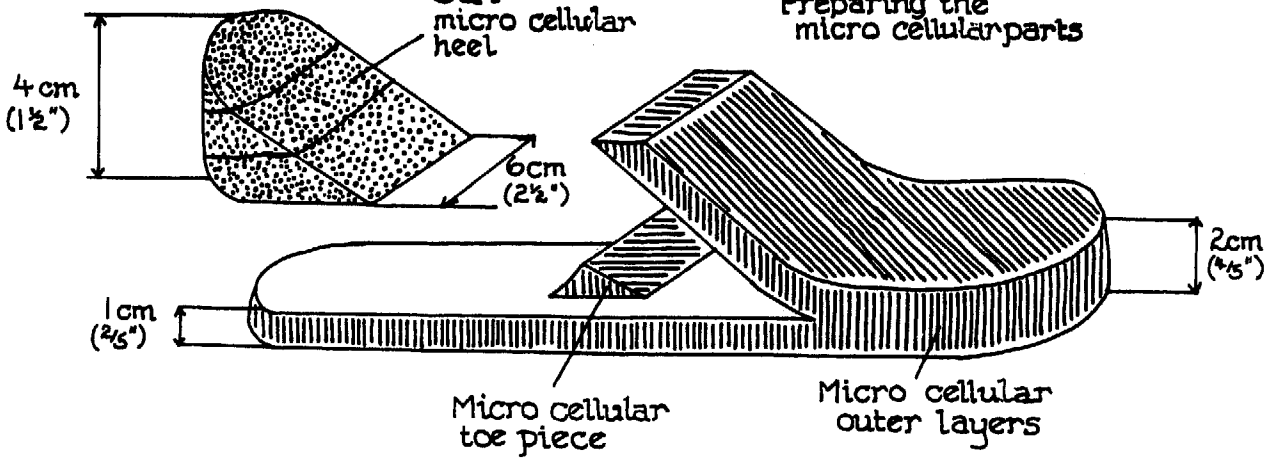


FIGURE 3.
Preparing the
micro cellularparts

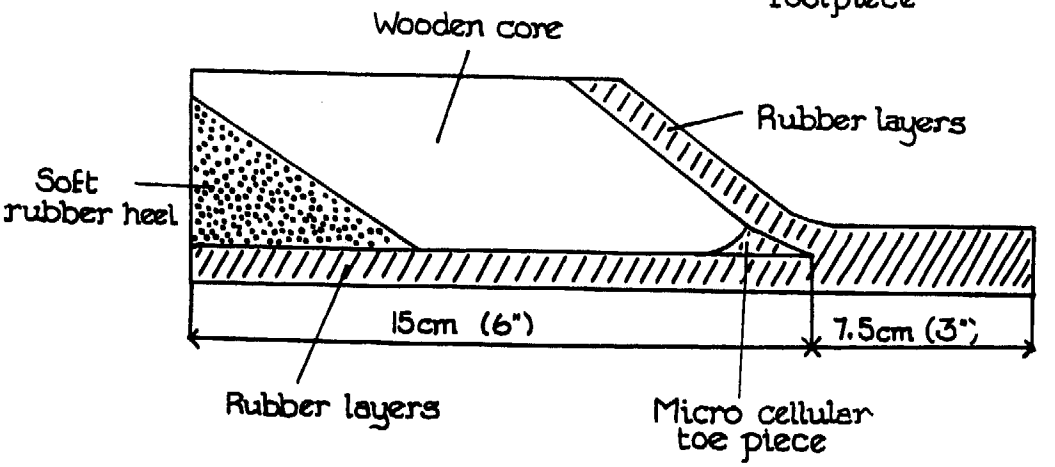


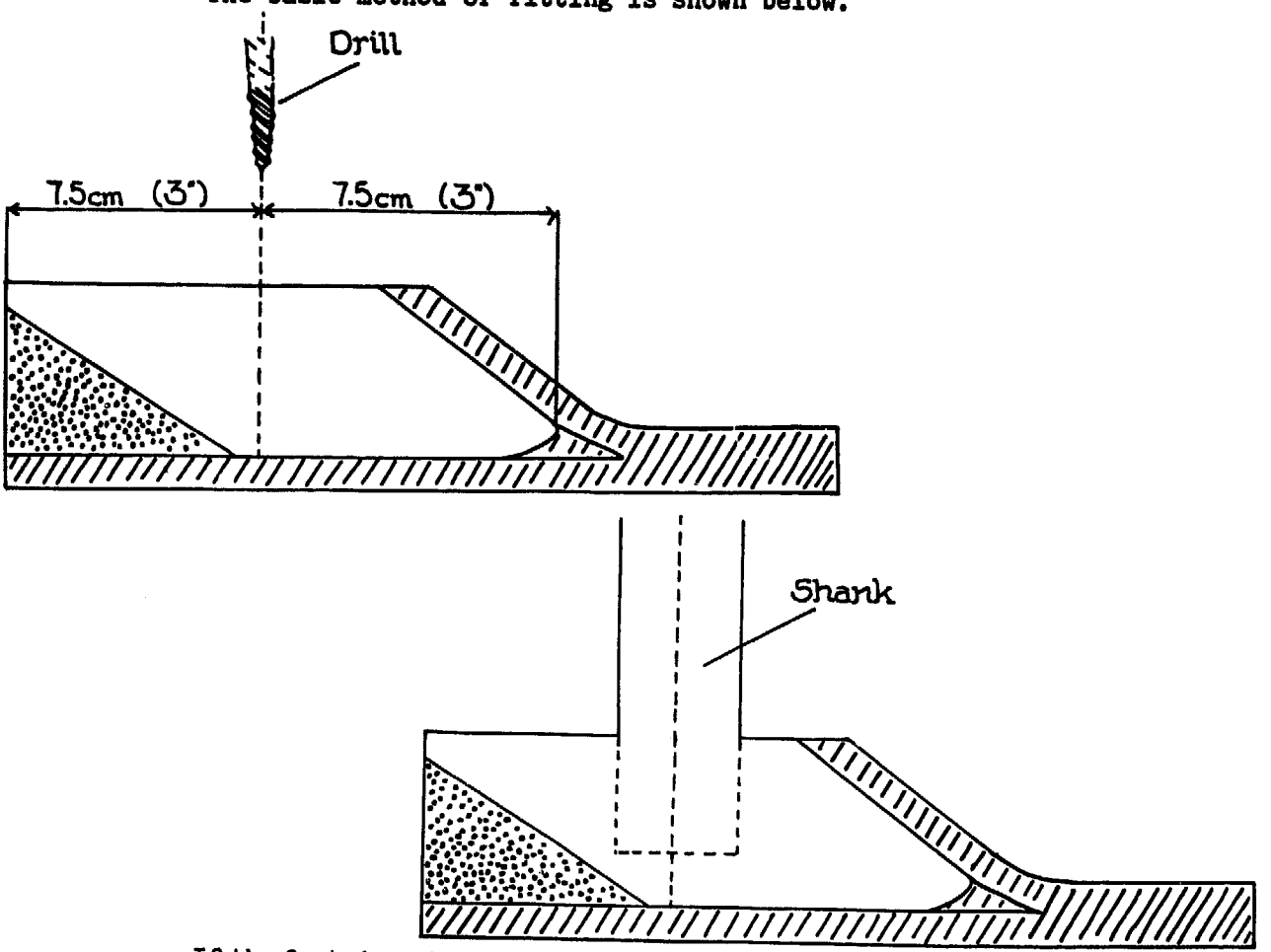
FIGURE 4.
Assembly of
footpiece

Instead of one layer of 2cm (4/5") rubber for the outer layers, two layers of 1cm (2/5") rubber can be used.

Footpieces - SACH foot

Various types of shanks could be fitted to this footpiece using many different materials. For example, an aluminium outer socket, wooden pylon with metal bars and leather socket, or a bamboo pylon with leather socket could be fitted.

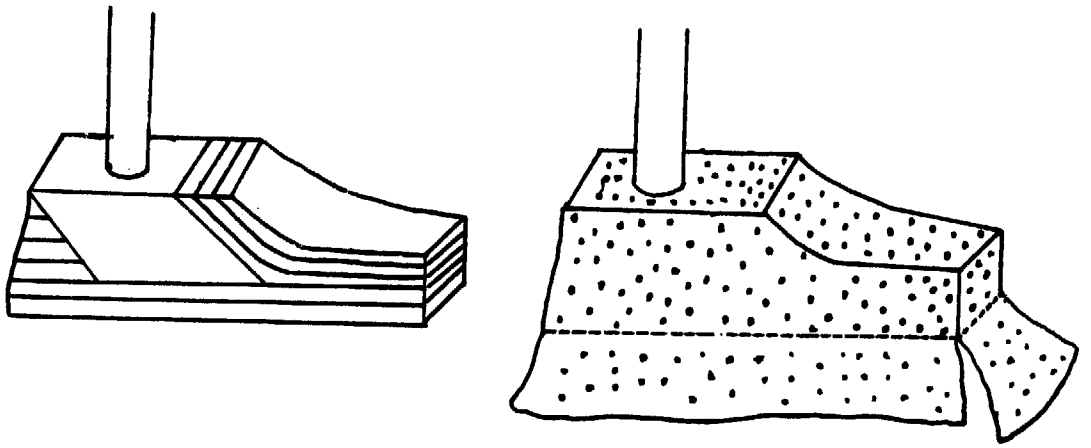
The basic method of fitting is shown below.



If the footpiece is to be used with a shoe, shape the micro cellular sheets precisely. Any movement between footpiece and shoe decreases walking comfort.

Footpieces - Each foot

If the footpiece is to be used for bare foot walking, you may like to modify it slightly. For instance, glue a soft leather piece onto the micro cellular rubber to prevent deterioration. The correct size of the leather is taken from a pattern made from a piece of paper, which is formed to exactly cover the footpiece.

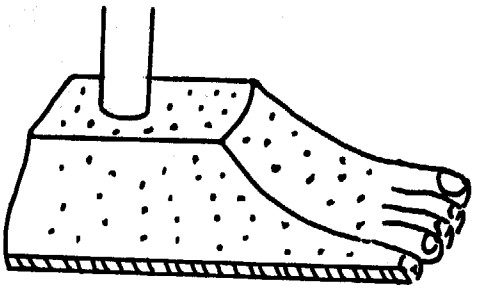


Making a paper pattern for leather

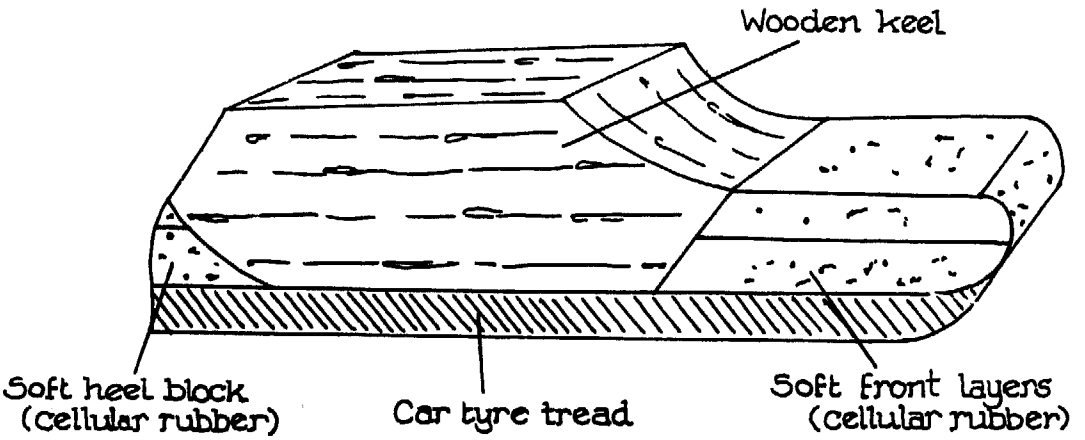
Instead of a leather piece, thick paint can be used. A layer of car tyre tread is glued on to improve resistance to wear.

Footpieces - Sach foot

To improve the natural appearance of the footpiece, you can also shape the micro cellular rubber like a natural foot and then paint it.



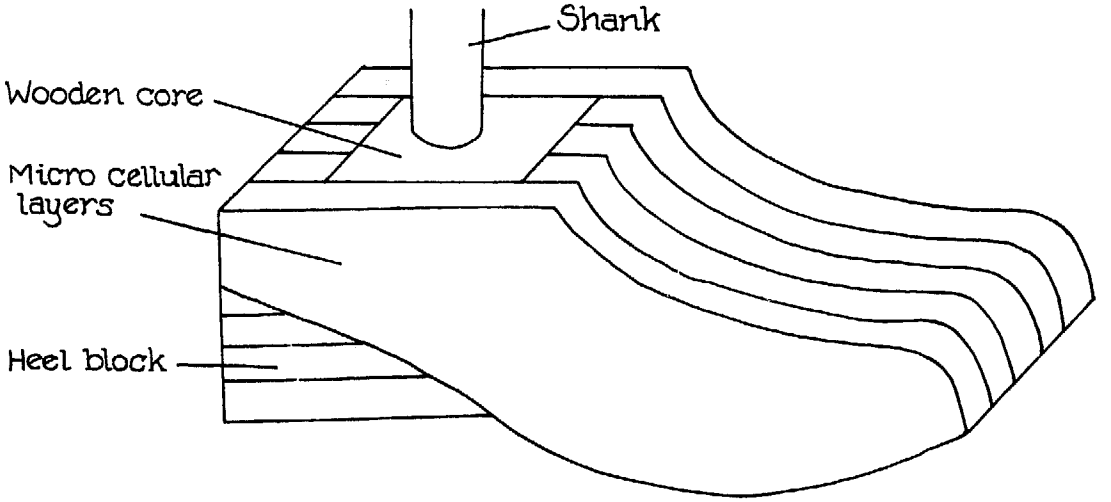
One alternative to this type of footpiece is to prepare a wooden block and micro cellular layers in the shape shown below.



Footpieces - Sach foot

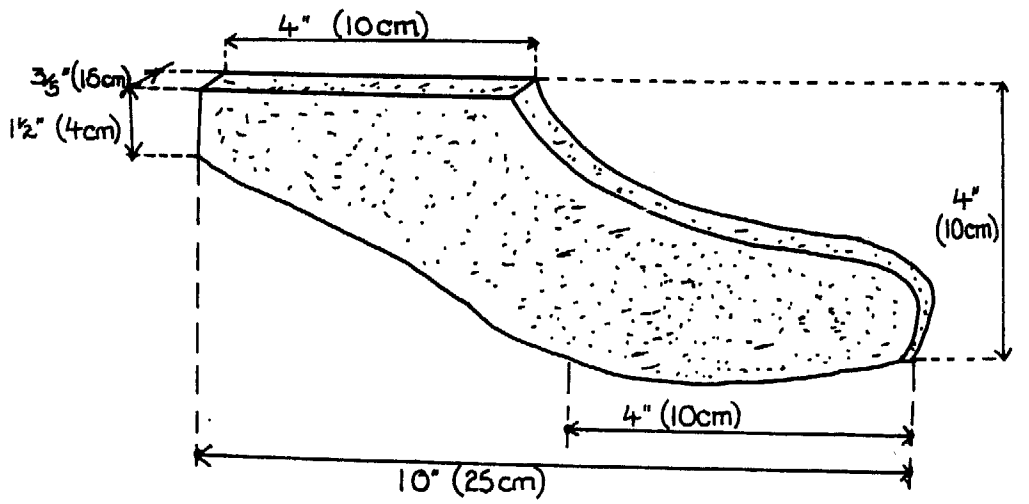
3.2 SACH foot: type 2

Type 2 also consists of a wooden core, a soft heel block and a cover of micro cellular rubber. Hardness of the heel block is around 30-35 shore A, hardness of the cover around 40 - 45 shore A. As with type 1, you can shape the foot according to its use for bare foot walking or for walking while wearing shoes. Type 2 is a little more difficult to make than type 1, but is more attractive to amputees who intend to wear shoes.



First cut some micro cellular sheets of 10" x 4" (25cm x 10cm). If the thickness of each sheet is 15mm, you will need 5 sheets.

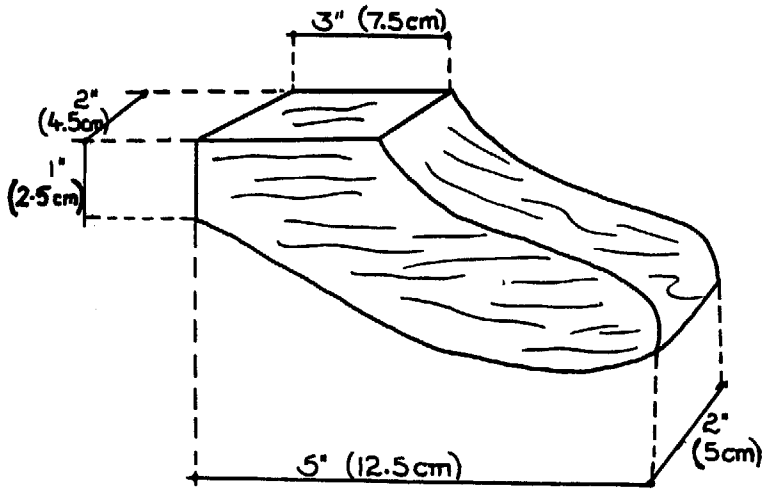
Shape the sheets as shown below.



Footpieces - SACH foot

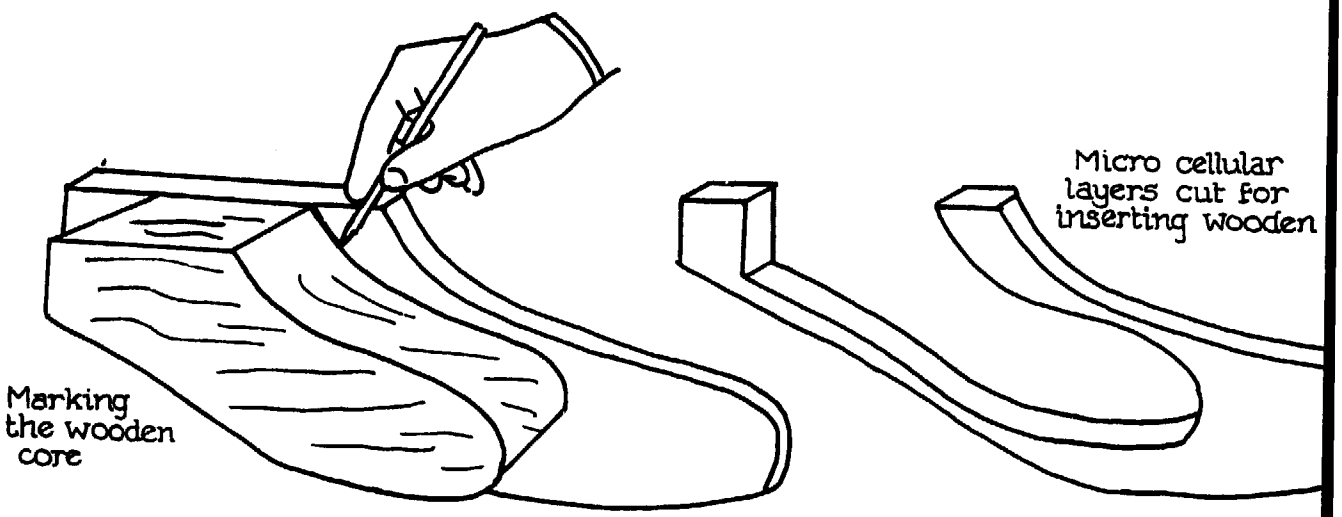
Using a saw, chisel and file, prepare a wooden core. Remember to keep the grain of the wood flowing from heel to toe. This strengthens the footpiece.

Shape the wooden core as shown below.



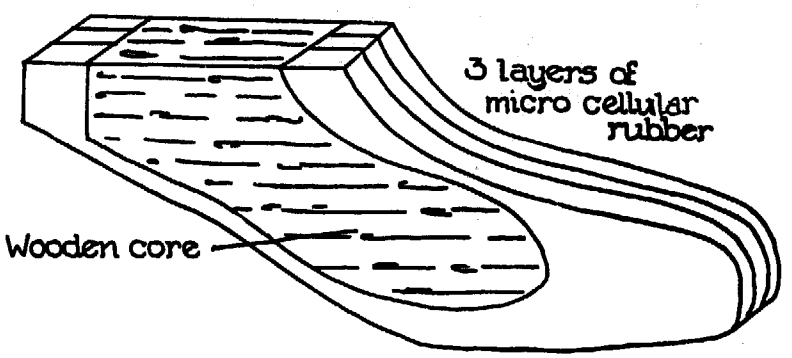
Smooth the wooden core just a little, so that no splinters remain. Remember that a little bit of a rough surface increases bonding with the rubber at a later stage.

If the thickness of each sheet is 3/5" (15mm), take three micro cellular sheets, mark them against the wooden core, and cut them so that the wooden core can be inserted.

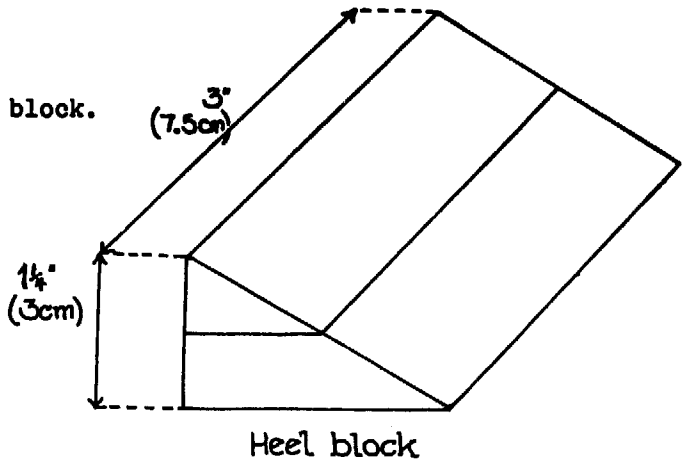


Footpieces - Sach foot

Glue the surfaces together with a rubber cement.

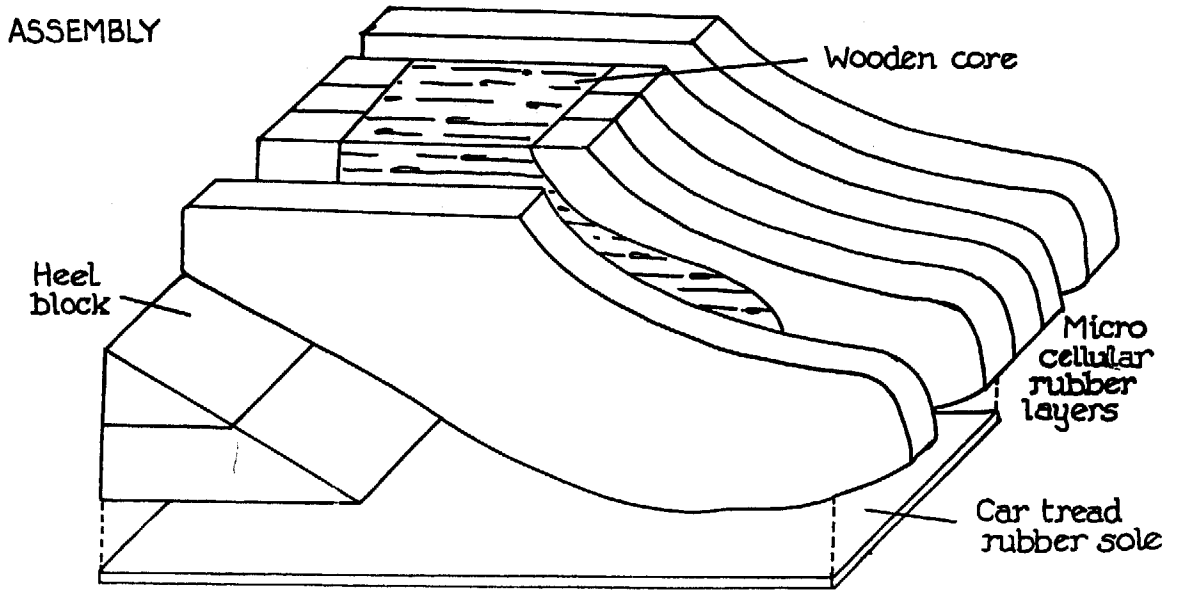


Next make the soft heel block.



Now the parts are ready for assembly. To prevent extreme wearing down of the sole, an extra layer of car tyre tread or leather is glued below the entire surface of the footpiece.

ASSEMBLY

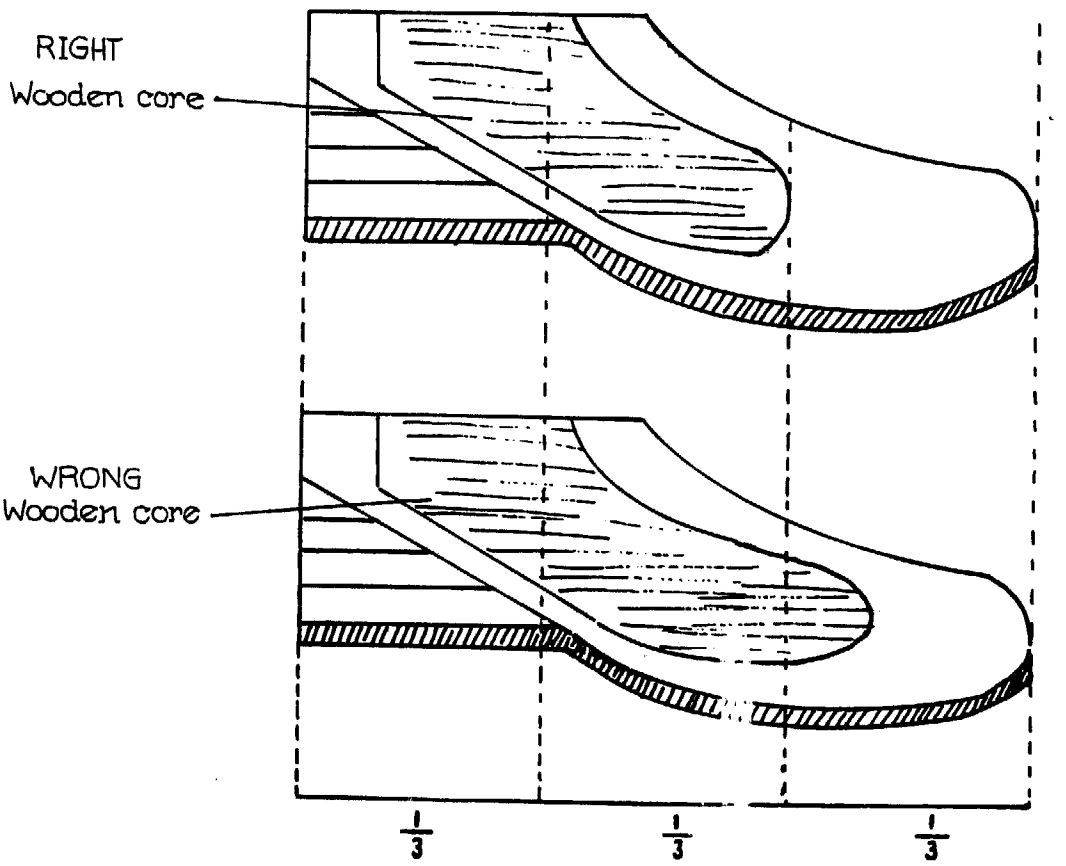


Footpieces - SACH foot

After the footpiece has been assembled it is possible to shape the foot to produce a more acceptable cosmetic appearance.

If the footpiece is to be used with a shoe, shape the foot so that there is no movement between foot and shoe.

While shaping the foot into a smaller size, you should take care that the wooden core does not extend more than 2/3 over the complete foot. Otherwise, the core may crack after only a short time.



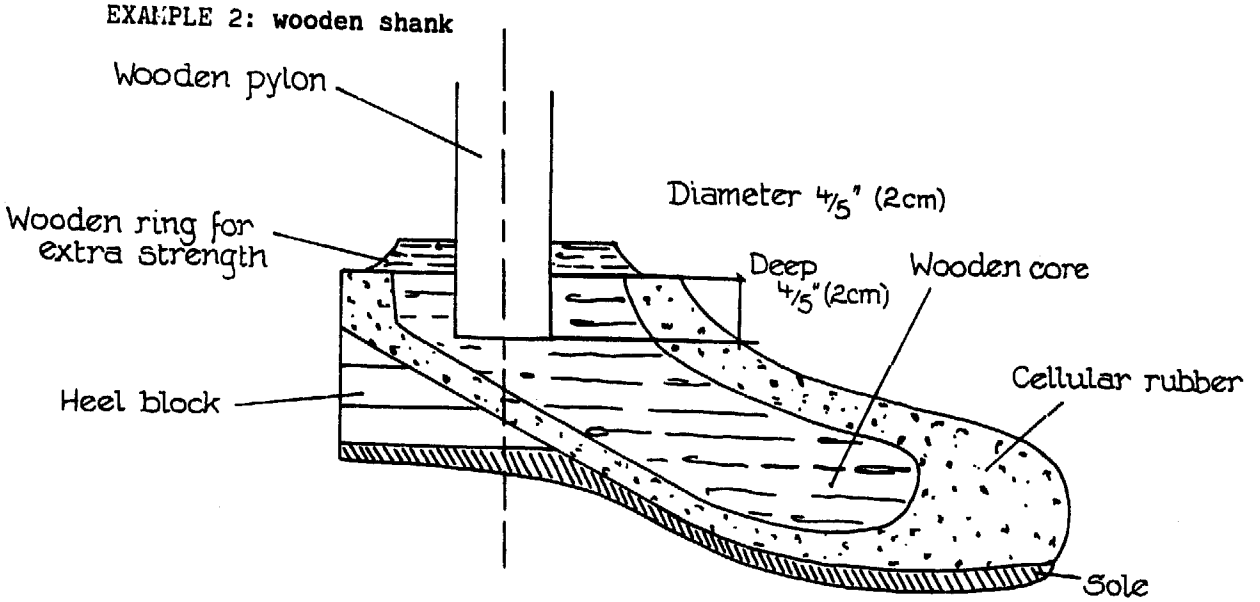
Footpieces - SACH foot

The attachment of the shank to the footpiece mainly depends upon the sort of material which is used.

EXAMPLE 1: aluminium shank

Drill a 1/4" (6mm) hole in the top of the foot and a 1/2" (15mm) hole in the bottom. Put a bolt and washer from the foot up through the sheave and tighten with a nut. See diagram on page 66

EXAMPLE 2: wooden shank



Drill a 4/5" (2cm) hole from the top of the core not more than 4/5" (2cm) deep.

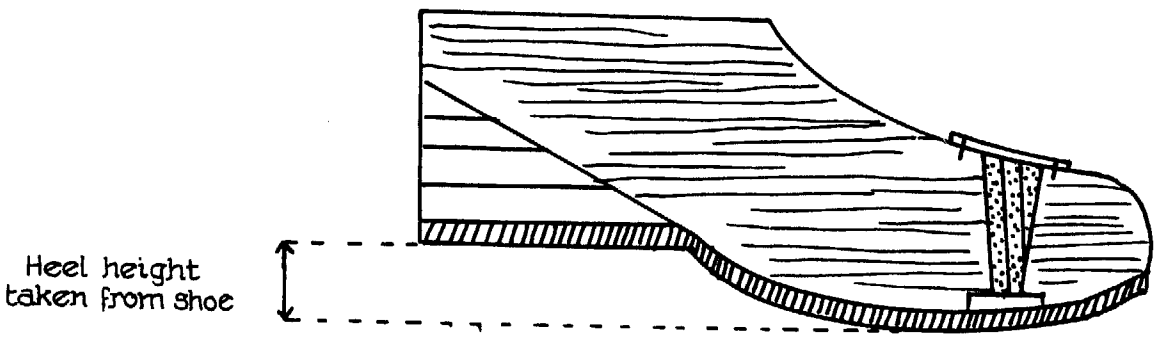
EXAMPLE 3: wooden ankle block

With a SACH foot with toe break, the ankle block is fitted with a bolt, washers and a nut. See page 130 A resin, bamboo or other type of pylon is attached to the ankle block.

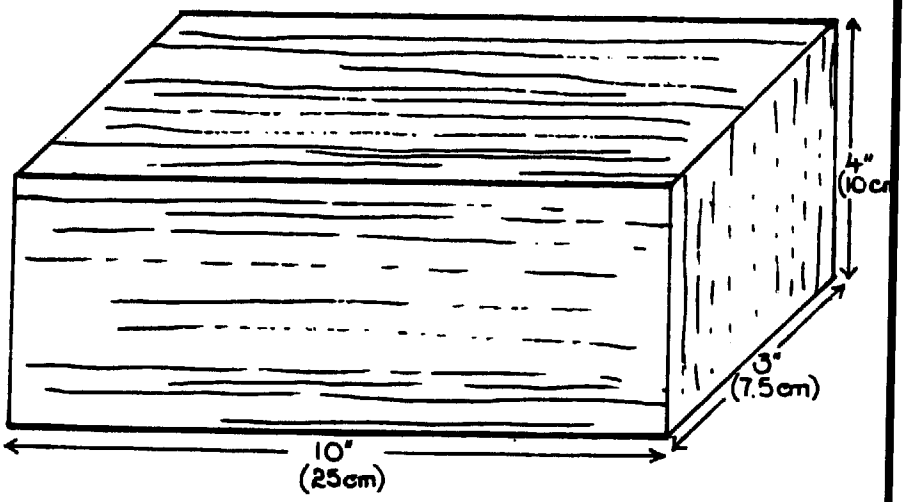
Footpieces - SACH foot with toe break

4. SACH FOOT WITH TOE BREAK

Another artificial foot which is commonly made in developing countries is the SACH foot with toe break. This foot is made of locally available wood, with rubber cushions to encourage a soft heel compression and smooth toe flexion during use. This foot is not very durable as the rubber cushion heel and rubber toe section can wear out with use. Manufacture, however, is relatively easy. When the footpiece is used for barefoot walking, a flat sole is prepared. If a shoe is to be worn, the height of the heel is adjusted accordingly.

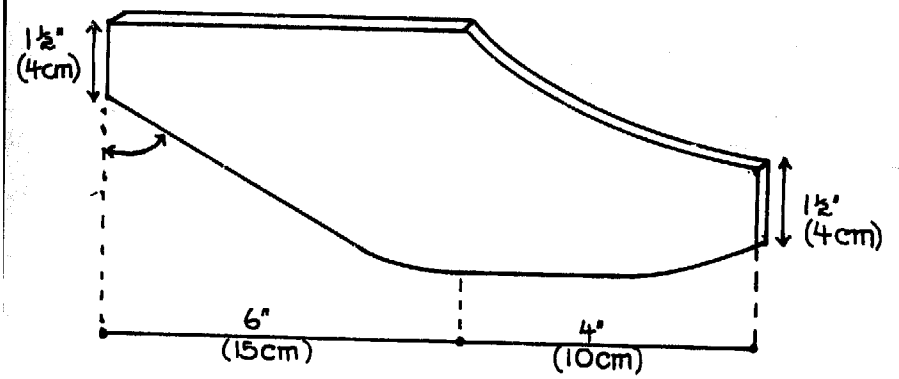


To make such a footpiece you need, firstly, a piece of light weight strong wood. Sizes shown below are for a medium to large foot. Adjustments should be made as needed.



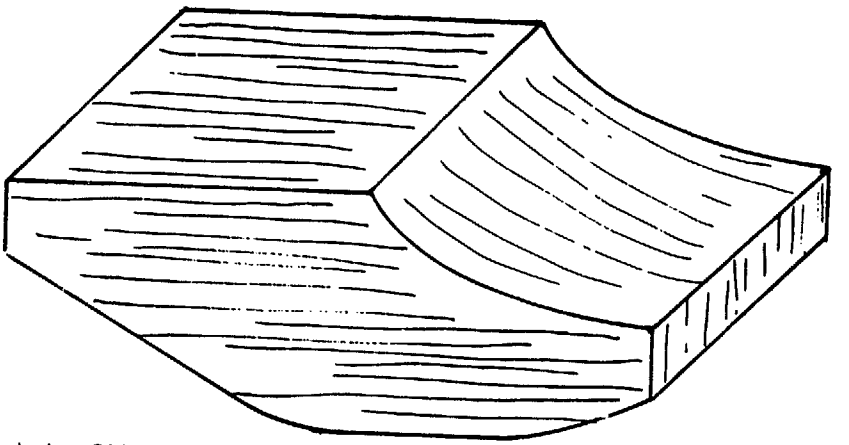
Footpieces - SACH foot with toe break

Using a metal master shape, this wood is shaped as shown below.



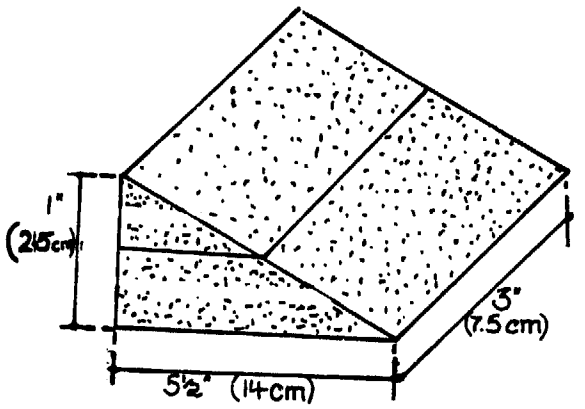
Metal master shape

Shaped wooden block

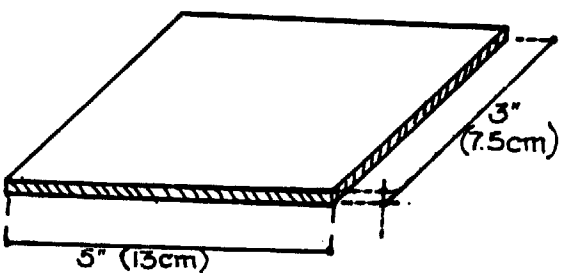


A piece of leather is cut to fit from the toe to halfway up the foot. Layers of micro cellular rubber, hardness about 35 shore A, are also made into a heel block. The layers are usually about 1/2" (1.5cm) thick. The number of layers depends upon the height of heel needed. The figures below show the approximate measurements and shape of the piece of leather and micro cellular rubber heel block.

Micro cellular rubber heel

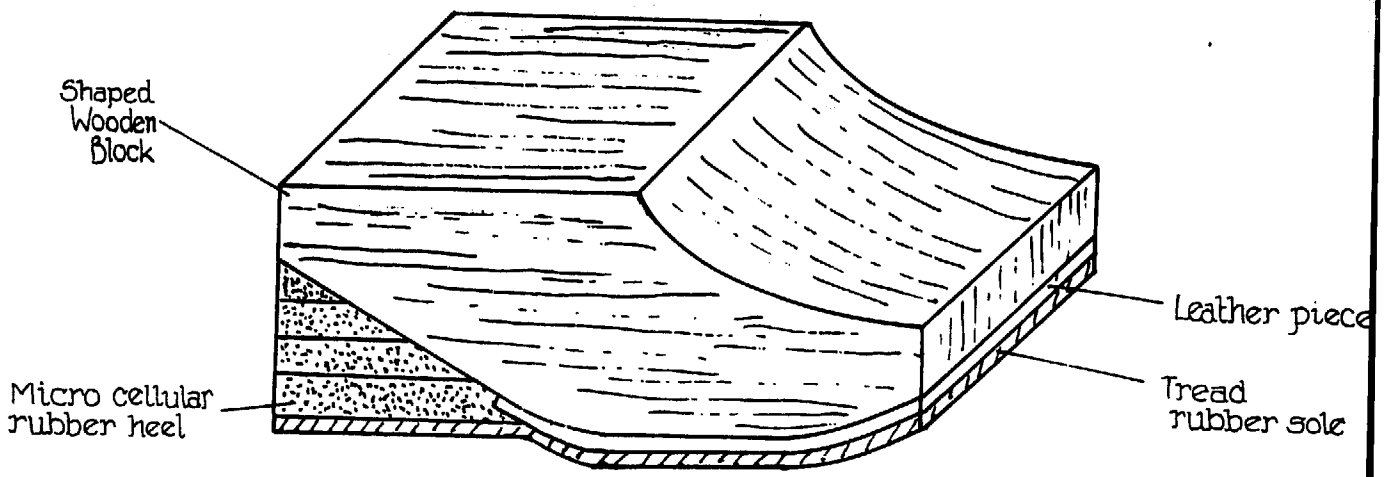


Leather piece

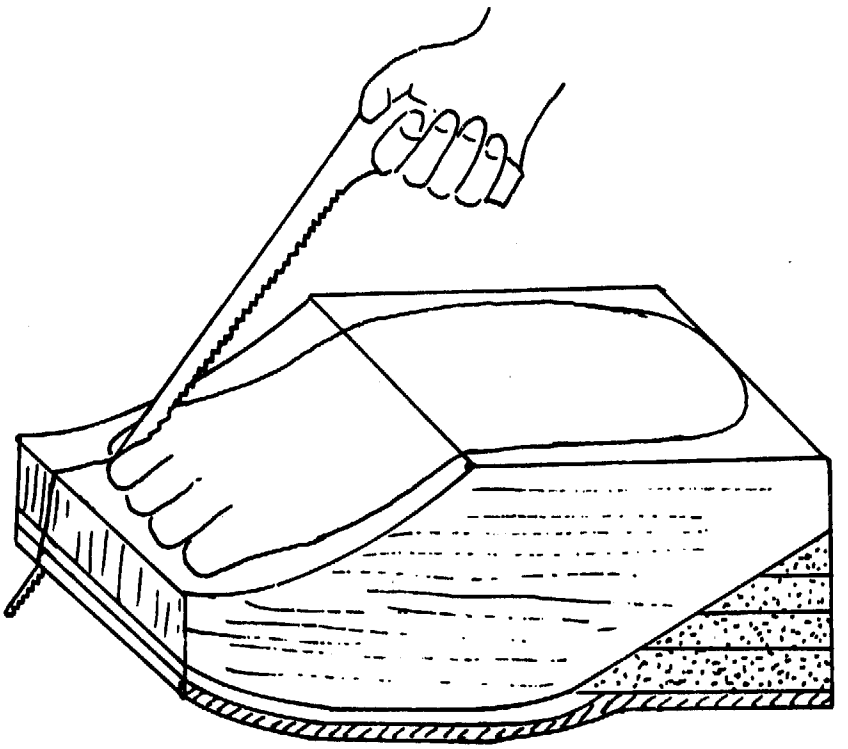


Footpieces - SACH foot with toe break

A piece of tread rubber is shaped as a sole and glued onto the wooden block. The whole foot now looks like the figure below.

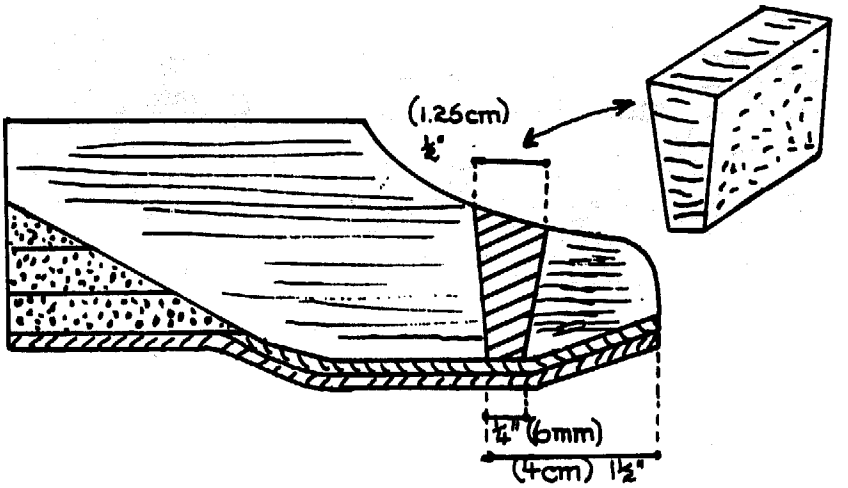


Draw the shape of a natural foot (either left or right) on the wooden foot as shown below. Cut the foot according to this shape.

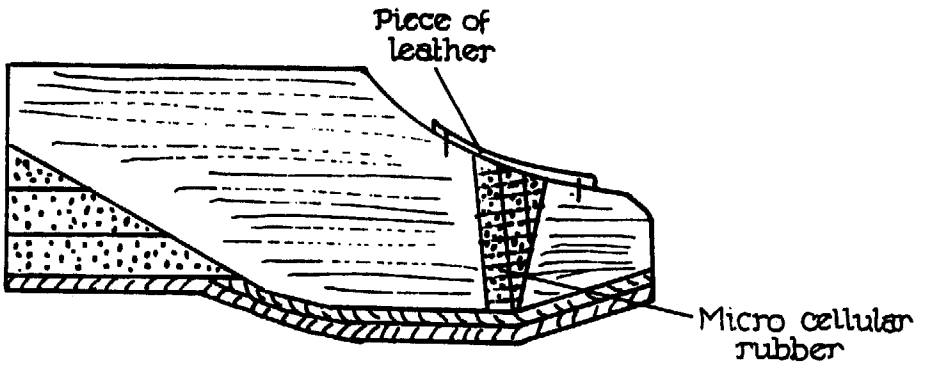


Footpieces - SACH foot with toe break

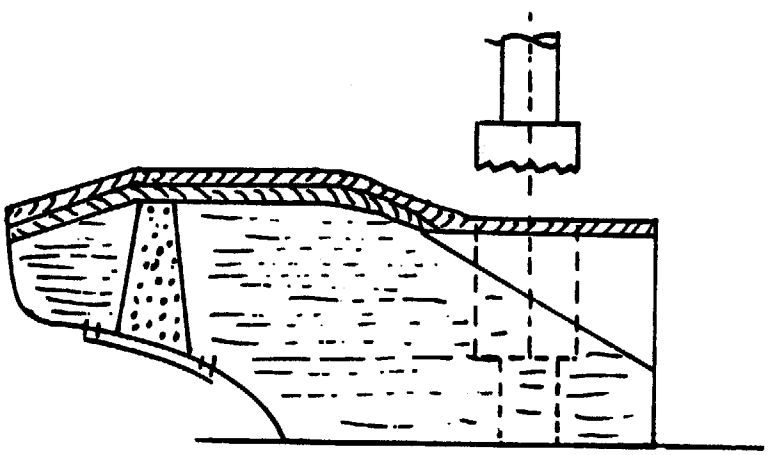
To provide appropriate toe flexion, a piece of the wood is carefully cut out.



The gap is then filled with micro cellular rubber and covered with a piece of leather.

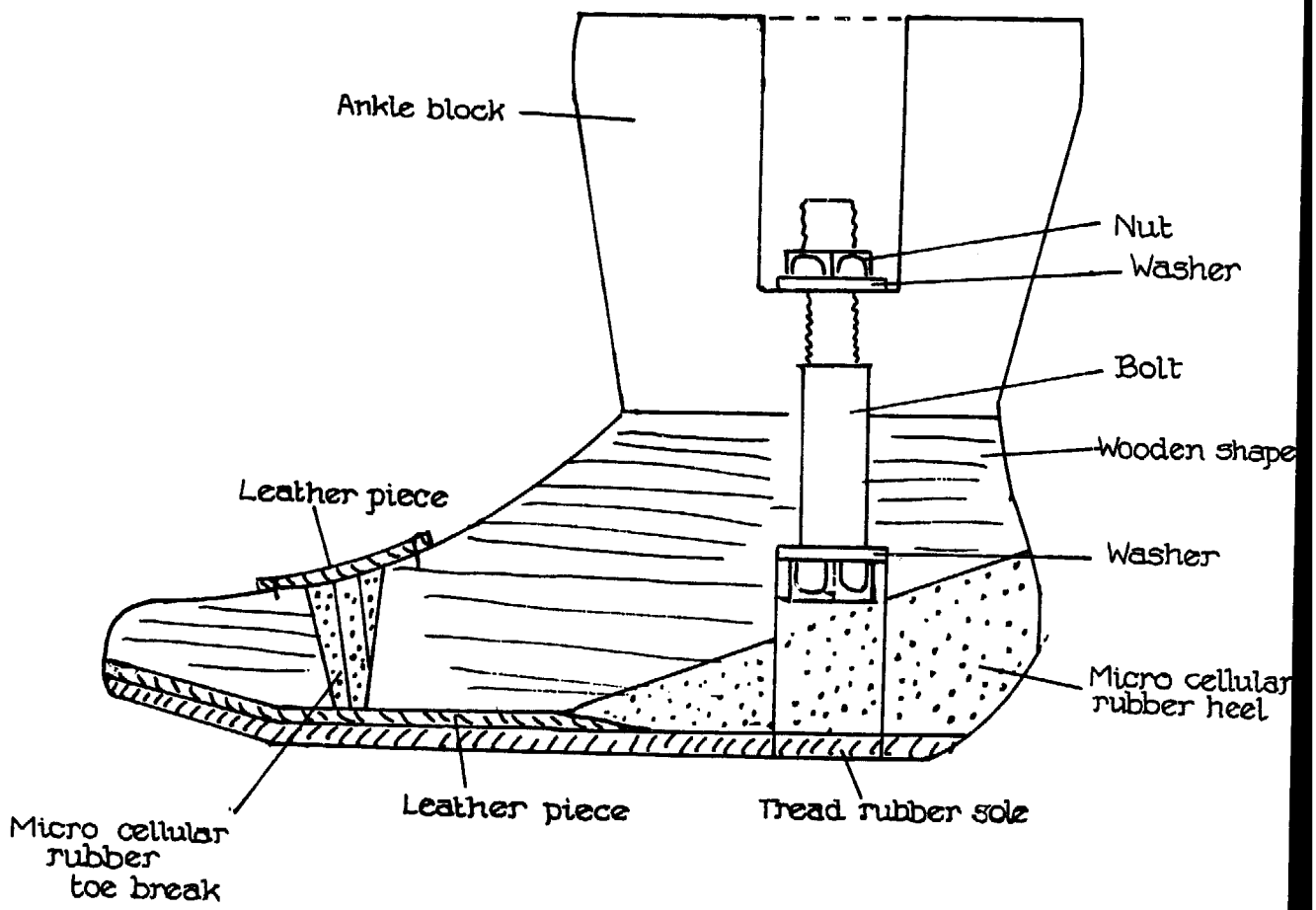


So that an ankle block may be fixed at a later stage, drill a hole as shown below. Do not drill a hole if a pylon is attached. (See page 125.)



Footpieces - SACH foot with toe break

This is a finished footpiece. As you can see in the picture, the heel height is adjusted so that the amputee can choose whether to walk with a shoe or bare foot. It can be helpful to cover the wooden part in thin leather or to paint or varnish it. This makes it stronger and waterproof.



5. JAIPUR FOOT

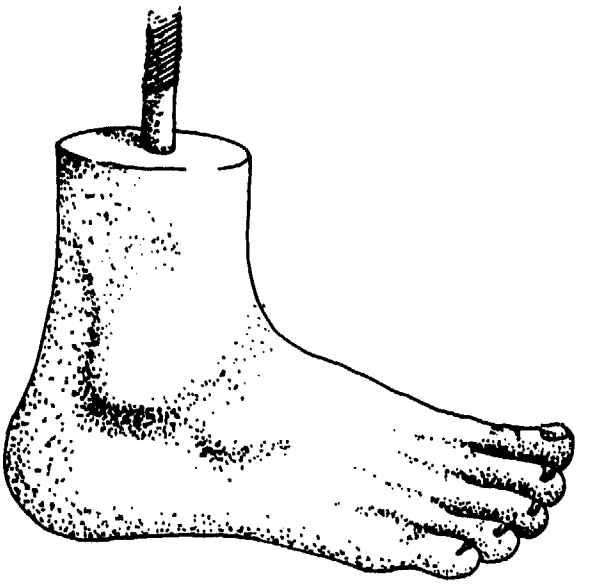
One of the most remarkable footpieces produced in a developing country is the Jaipur foot, designed and manufactured in a rehabilitation centre in Jaipur, Northern India. The foot allows amputees to walk barefoot, and it has reasonable wear. It is also waterproof. If the properties of the material are well chosen, amputees can even squat and sit crosslegged with their footpiece, especially if this is further encouraged by wise design of the shank and socket. It is, however, relatively heavy if compared with a SACH foot for barefoot walking, weighing approximately 2lbs (1kg).

Material costs : $25-$40

Cost of tools : $750-$900 (excluding vulcaniser)

Cost of a die : $300-$450

Labour time : 2-4 hours



Jaipur foot

Materials

- micro cellular rubber sheets, available from rubber sandal manufacturers. Hardness 40-45 shore A. (Ask the manufacturer if this rubber is completely vulcanised; if not, ask him to do so. If the micro cellular rubber is not vulcanised, it could vulcanise during the manufacture of the footpiece. This would cause poor bonding between the rubber compounds. See appendix 4

- rubber black: natural rubber with a high abrasion resistance normally used for car and tractor tyres. Other name: tread rubber, see page 111

- cushion rubber, usually used for the side walls in car tyres. Discuss with the tyre manufacturer the colour required. See page 111

- cord lining; nylon reinforced cushion rubber

- rubber cement

- rubber glue

- wood

- wood adhesive (for instance Movicol)

- iron bolt, nut and nails.

NOTE: The black, cushion and cord lining should not be vulcanised yet. See appendix 4.

Footpieces - Jaipur foot

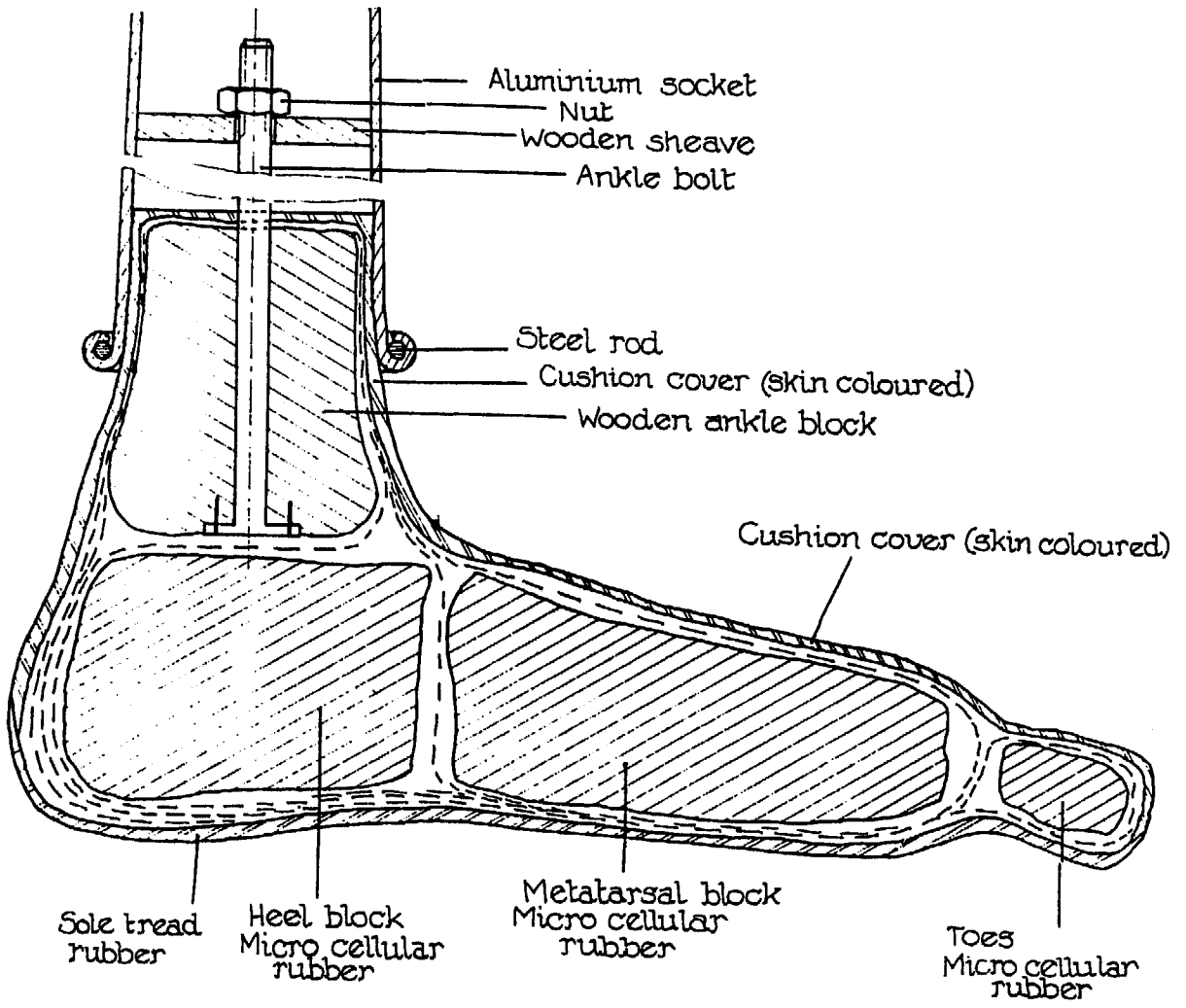
The foot consists of three separate sections:

a wooden ankle block

2 micro cellular blocks - one heel block and one metatarsal block

5 micro cellular toe pieces

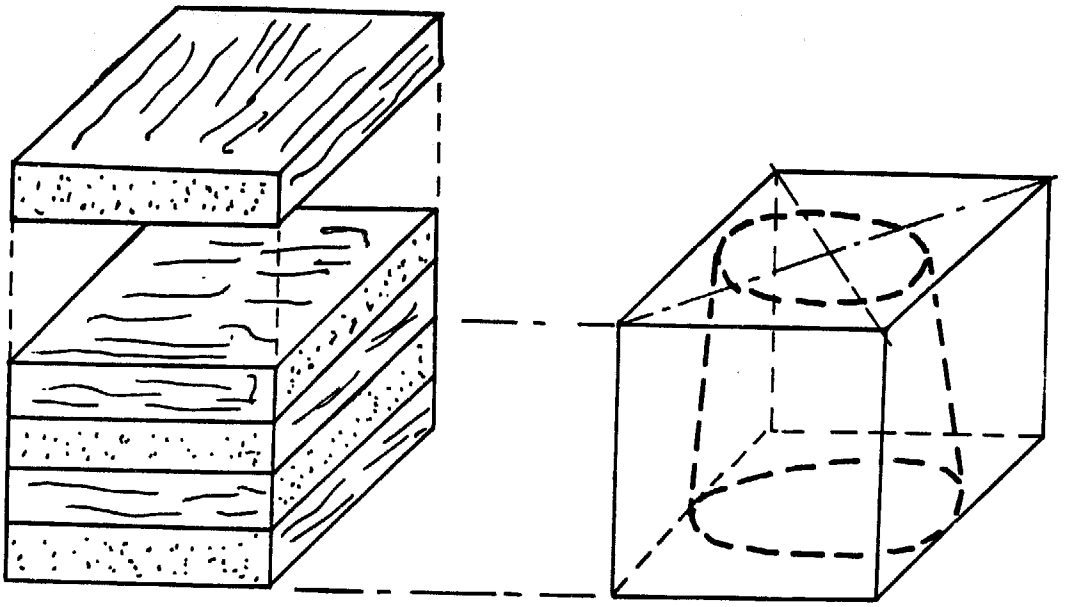
Below is a cross section of the Jaipur foot.



Footpieces - Jaipur foot

Wooden ankle block

- Glue together several squares of (teak) wood (3"x3" [7.5cmx7.5cm]) with their grains at right angles to each other.

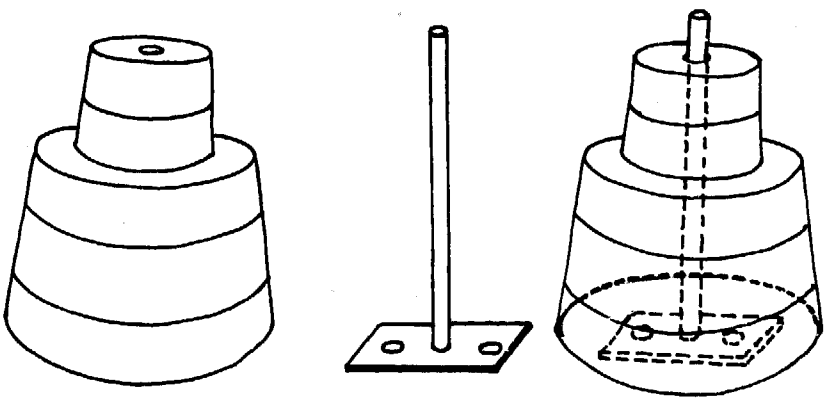


- Let the wooden block dry properly in a vice.

- Shape the wooden block with a chisel and file to correspond to the side dies to be used. The making of these dies is described on page 141

NOTE: Round all the edges carefully, and avoid any rough surfaces.

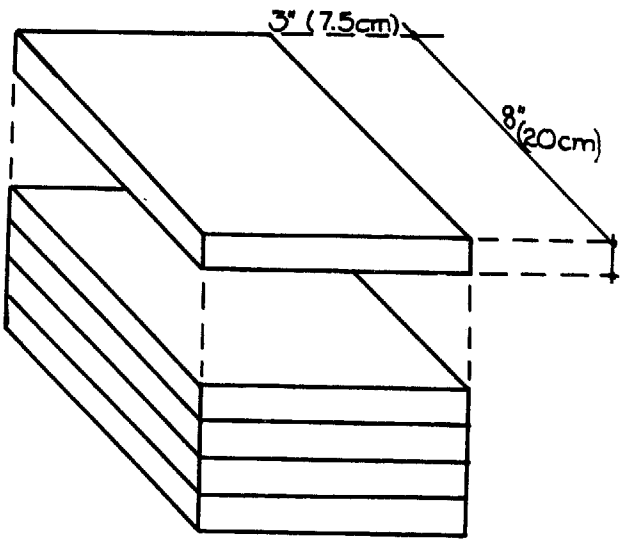
- Drill a hole of about 1/3" (8mm) diameter (corresponding with the diameter of the bolt).
- Fix the ankle bolt. Reinforce the assembly with two nails.



Footpieces - Jaipur foot

Micro cellular blocks

- For medium size, glue together five 8"x3" (20cmx7.5cm) sheets of micro cellular rubber. Cut the block into two equal pieces to make the heel and metatarsal block.

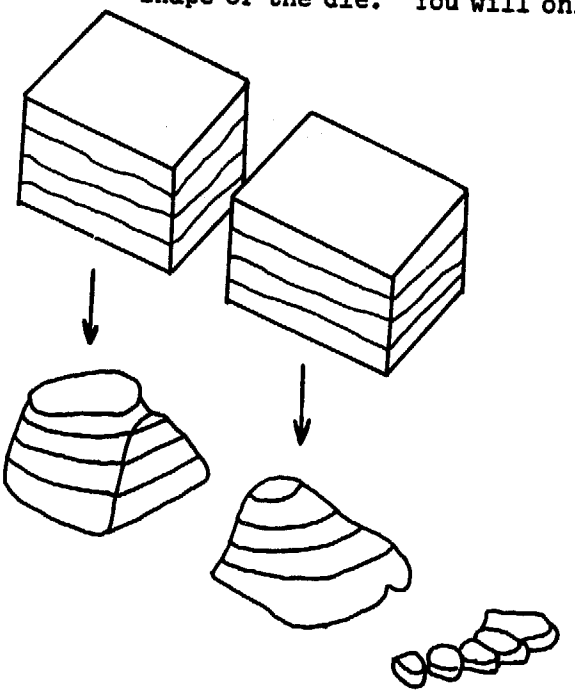


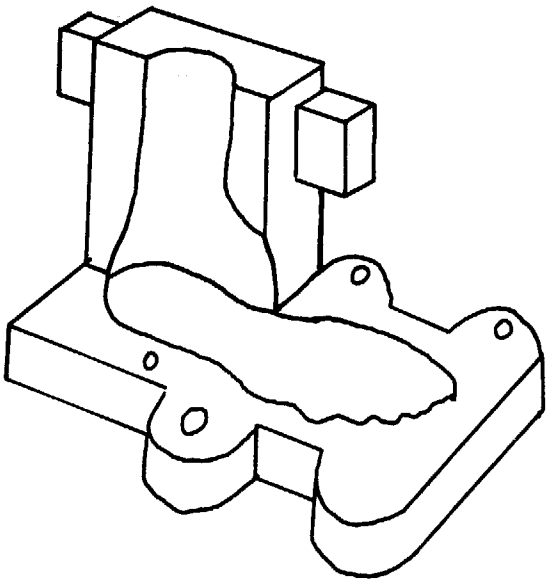
NOTE:

1. Follow the instructions for using the glue carefully. Do not put the sheets together until the glue has almost dried.
2. Clean the sheets before use. Dust reduces the strength of the glue considerably.
3. The sizes of the heel and metatarsal blocks depend on the foot size required.

Footpieces - Jaipur foot

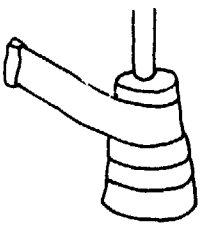
- Shape the two micro cellular blocks and the toes according to the shape of the die. You will only need a file and a knife to do this.

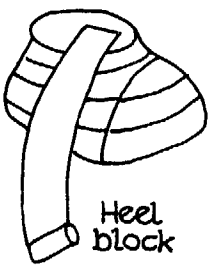


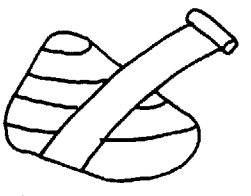


- Smear the wooden block and micro cellular rubber components all over with rubber cement. This rubber cement contains a bonding agent, and improves the bonding of the components to the surrounding rubber compound.

- Cover the parts with cushion compound as shown below.





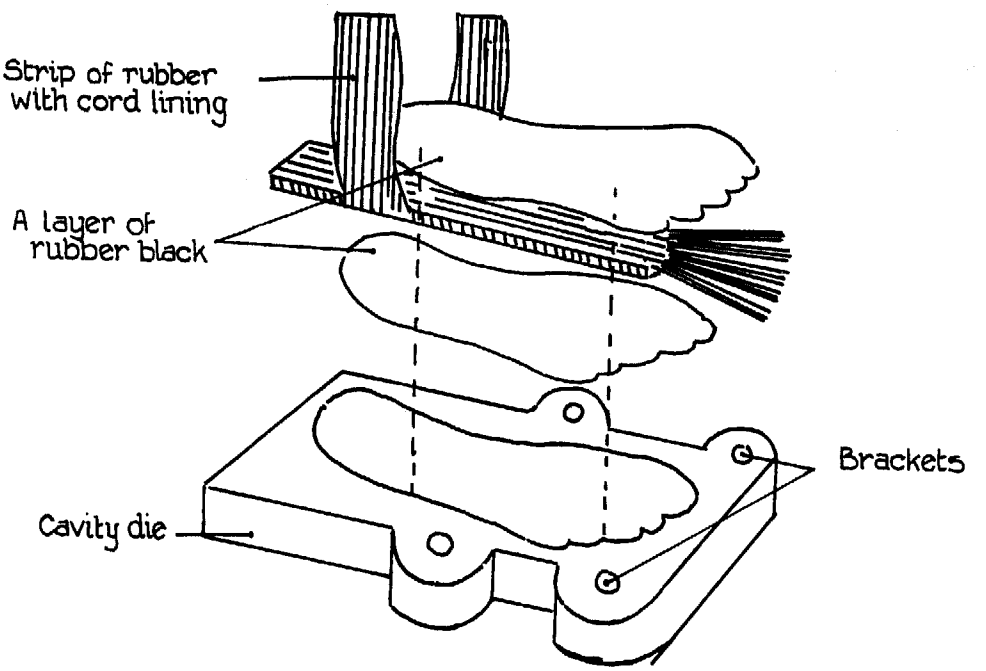


NOTE:

1. Avoid any space or air bubbles between the cushion and wooden or rubber blocks, i.e. press the cushion carefully on the various components.
2. Avoid dust (see above).

Jaipur foot

- Cut three layers of rubber black (unvulcanised tread rubber) to the shape of the cavity die.



NOTE:

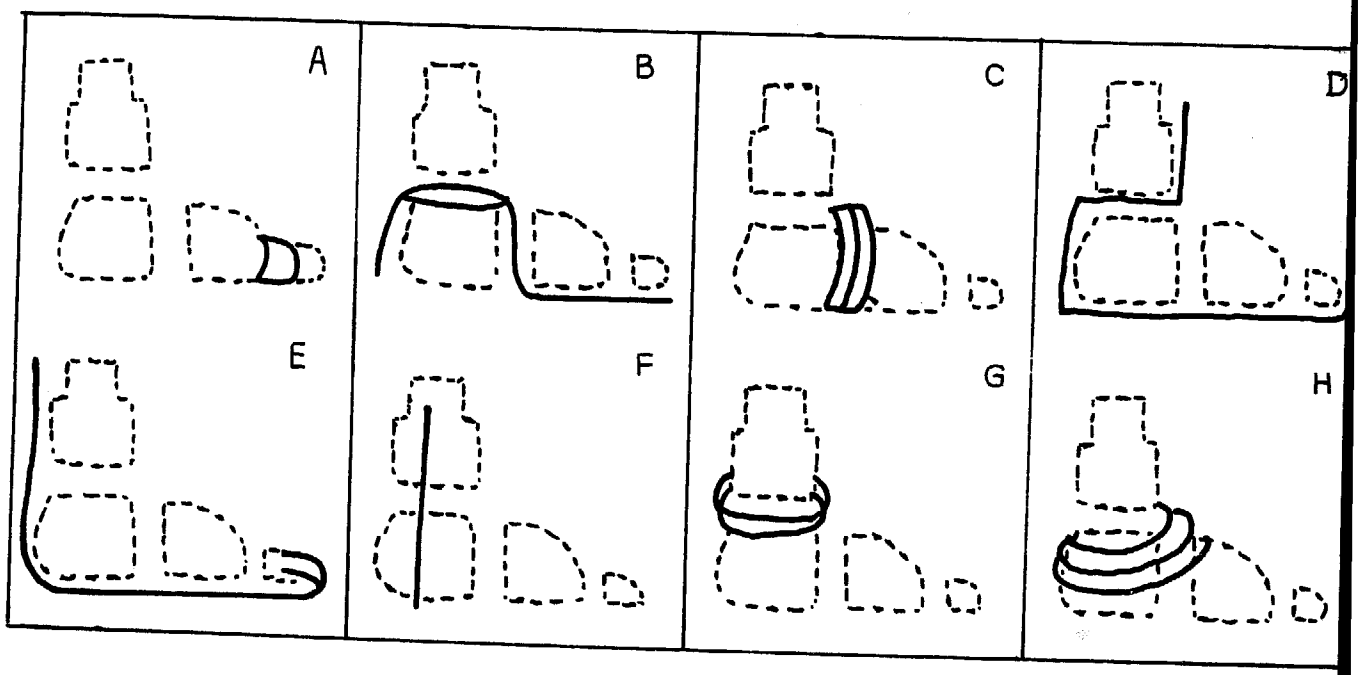
To get the correct shape, press with one hand a broad layer of rubber black on the inner edge of the cavity die. The slight imprint indicates the shape to be cut.

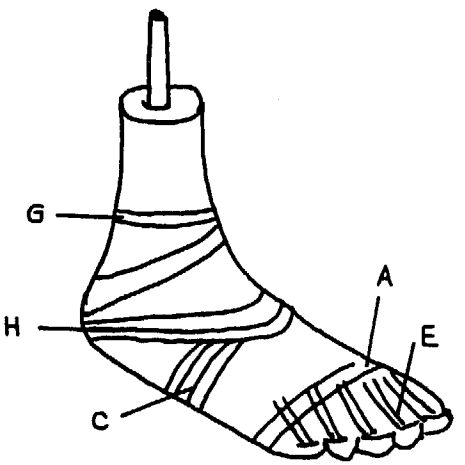
Footpieces - Jaipur foot

The most important phase of the assembly is strengthening the construction with cord lining. These strips are pasted over the framework of the foot. They restrict movement between the different components. Too many strips will cause a stiff and heavy footpiece, while too few will mean less durability.

NOTE: - Avoid dust (see above).

- Follow carefully each step for pasting strips as shown below.





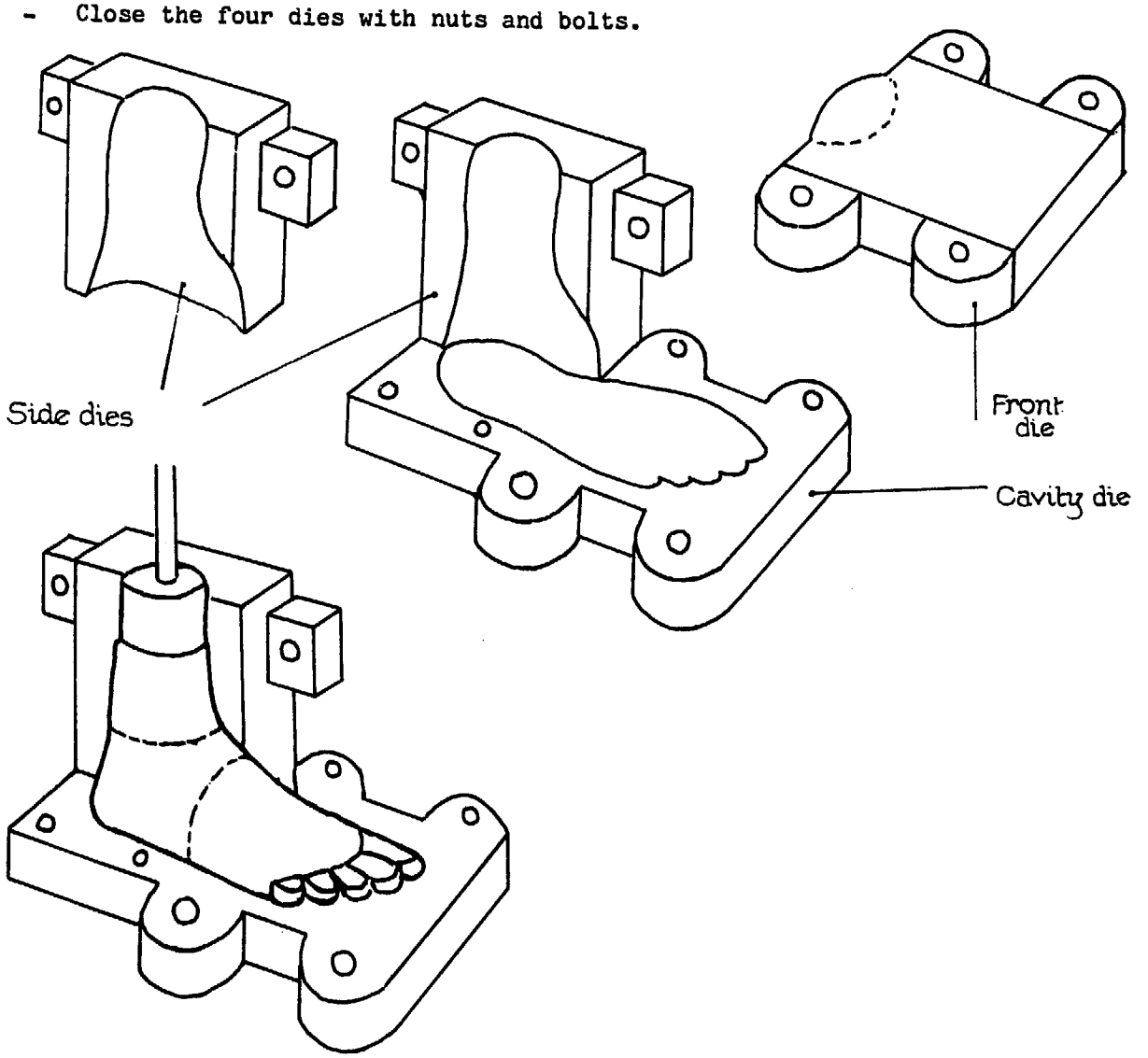
Footpieces - Jaipur foot

- To make the foot look real, pad the upper part of the footpiece with skin-coloured cushion compound. Do not cover the sole with the cushion compound as it would wear off in walking.

NOTE:

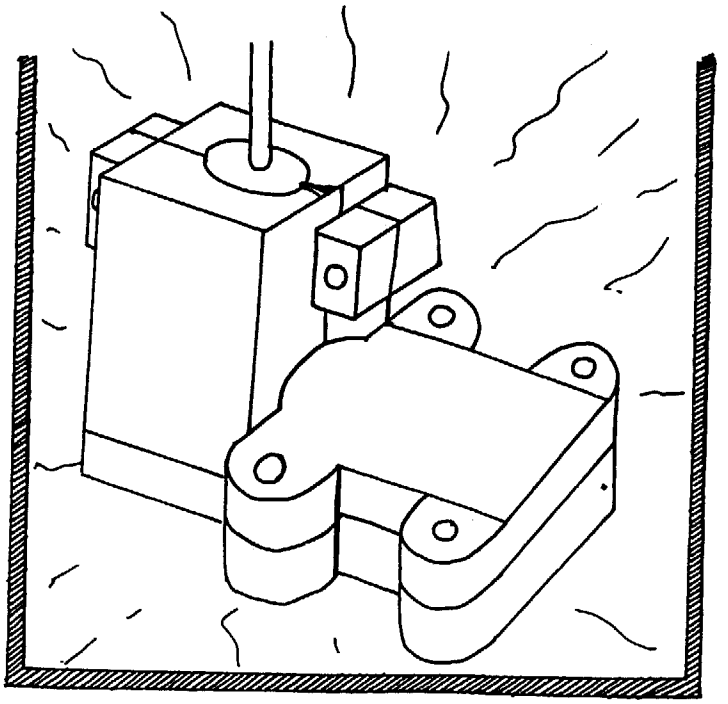
Do not leave space between the inner wall of the die and the footpiece. Micro cellular rubber has a lower density than cushion rubber. Although it saves time to make the micro cellular blocks smaller than the back and to add cushion compound, do not do this because of the extra weight.

- Close the four dies with nuts and bolts.



Footpieces - Jaipur foot

To make the footpiece solid, it must be vulcanised, which is a process described in appendix 4. At Jaipur, a vulcaniser is used with hot steam under pressure as a source of heat. Through trial and error, 100 degrees temperature and 50 minutes vulcanising time have proved to be most satisfactory.



After vulcanisation, the footpiece is ready for use. You might like to imprint information on the footpiece, such as the name of the worker or date of production. Use a small strip or skin-coloured cushion to write the information required on the sole.

NOTE:

Do not store the footpiece in the sun, because sunlight will cause the footpiece to lose its colour and will cause premature skin cracking.

Footpieces - Jaipur foot

DIE MAKING

The die consists of four parts:

- a cavity die
- a front die
- two side dies

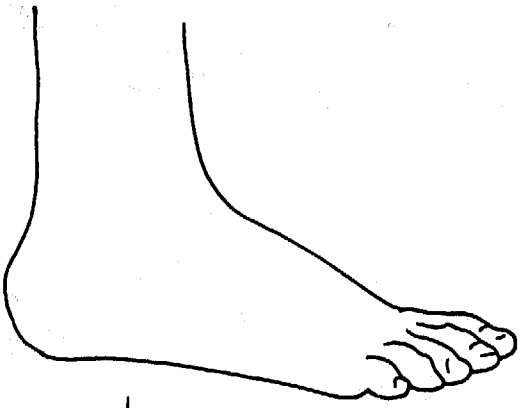
Because of weight, corrosion resistance and modelling capacities, aluminium alloy is used.

The manufacture of a die is a long and complicated process. It cannot be easily described in a manual. However, dies are often used in indigenous technologies so the skills may exist to make them locally. For example, the making of rubber tyres and the casting of metal and plastic for decorative products requires a die.

This describes the basic concept for making a die for the Jaipur footpiece. Details should be obtained from local technicians or industries.

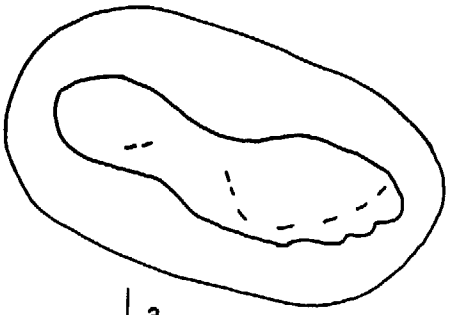
There are 5 stages in making the cavity die:

1. imprint of a sole of a human foot
2. making true plaster copy
3. modifying plaster copy
4. making casting block
5. preparation of cavity die



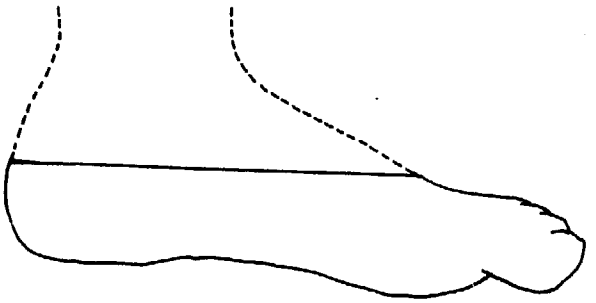
Natural foot

1



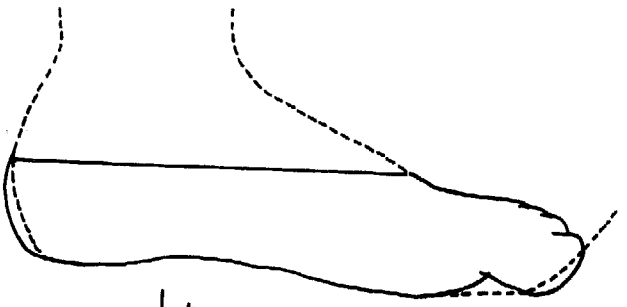
Imprint of the sole

2



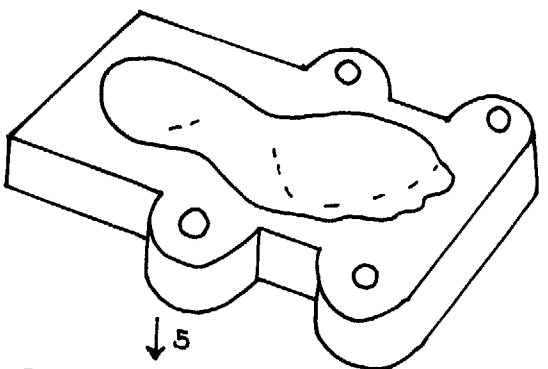
True plaster copy of the sole

3



Modified plaster copy of the sole

4



Casting block, including brackets

5

Preparation of cavity die

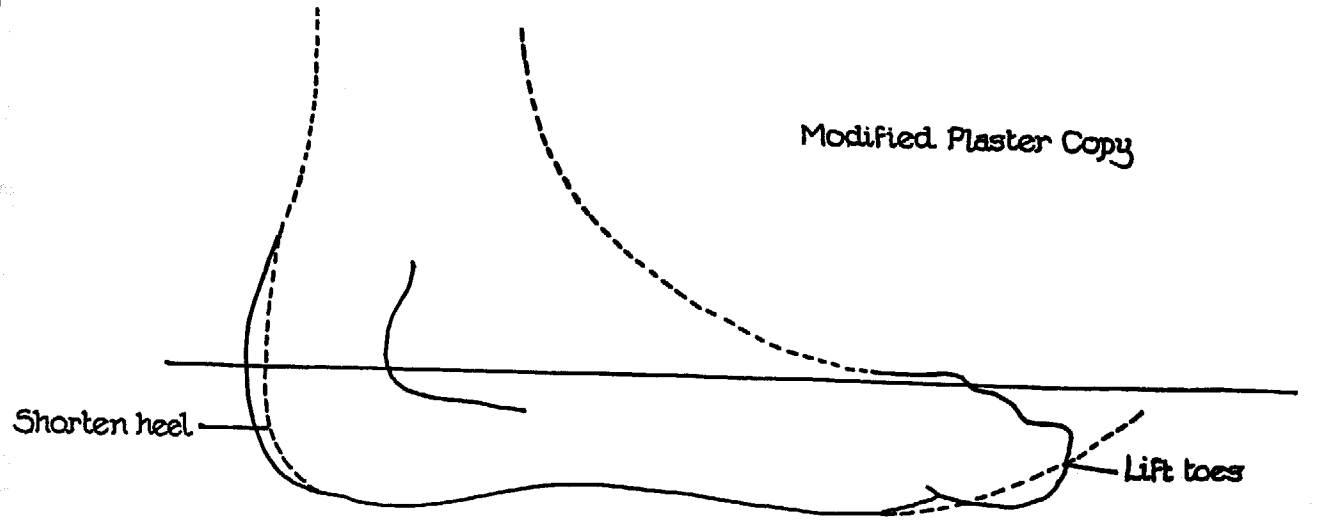
Footpieces - Jaipur foot

Manufacture of cavity die

Imprint the sole of a human foot in plaster and make a true plaster copy of the sole from this.

NOTE: This plaster copy should be modified:

1. **lift the toes (this improves clearance of the ground in swing phase)**
2. **shorten the heel (this encourages a good heel strike)**
3. **a spread fore foot enlarges the bearing surface considerably, leading to a more stable gait. However, if a shoe is to be worn, it is necessary to style the foot accordingly.**



Make a casting block with the plaster copy of the foot. This block could be made out of plaster or wood. Additional brackets should be attached to the block.

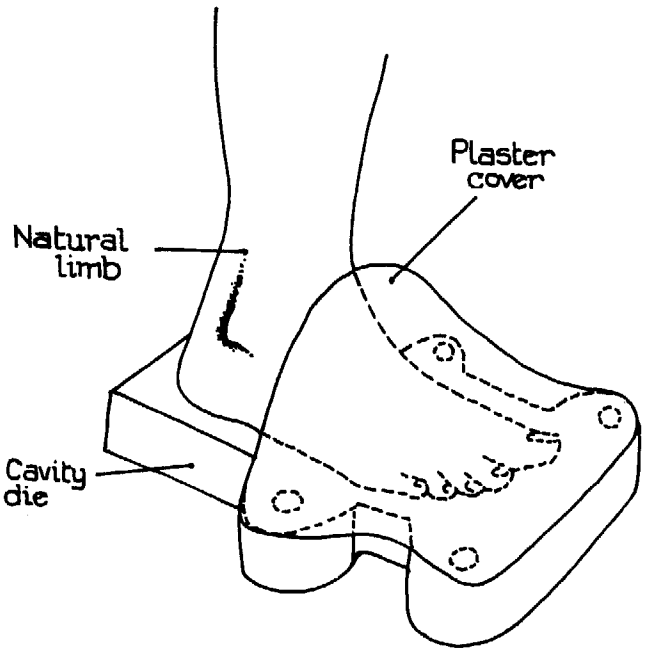
Using the block, the aluminium die can then be cast.

Footpieces - Jaipur foot

Manufacture of front die

The aluminium cavity die is used as a guide for accurately manufacturing the front die.

A natural foot is placed on the cavity die. Then a copy of the forefoot is made with plaster and, using this plaster copy, a block is made for casting the front die. It is the same procedure as for the cavity die.



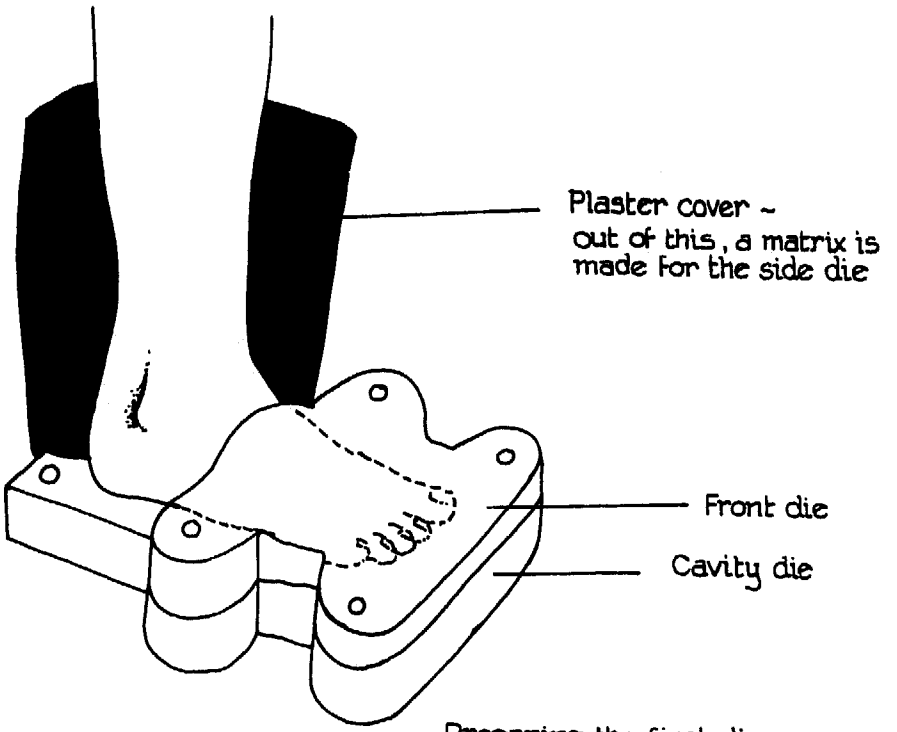
Plaster cover of the front of a foot

Footpiece - Jaipur foot

Manufacture of two side dies

The aluminium cavity and front dies are used as a guide for accurately manufacturing the two side dies.

Follow the same procedure as already described.



Preparing the first die, using cavity die and front die as a guide.

Die sizes

Once you have established a relationship with die-makers and you are familiar with their technology, you might prefer to make different dies for left and right feet, and for different sizes.

The same manufacturing process applies to all dies, as already described.

CHAPTER EIGHT : IMPROVING WALKING COMFORT

1. Introduction
2. Stump massage and bandaging
3. Prevention of joint contracture
4. Assembly of socket, pylon and foot
5. How to recognise and treat a poorly fitted stump
6. Checking for poor alignment
7. Gait training

Improving walking comfort

1. Introduction

The previous chapters dealt with the manufacture of sockets and prostheses. However, to ensure walking comfort, attention must not only be paid to manufacturing techniques. Other aspects of importance are:

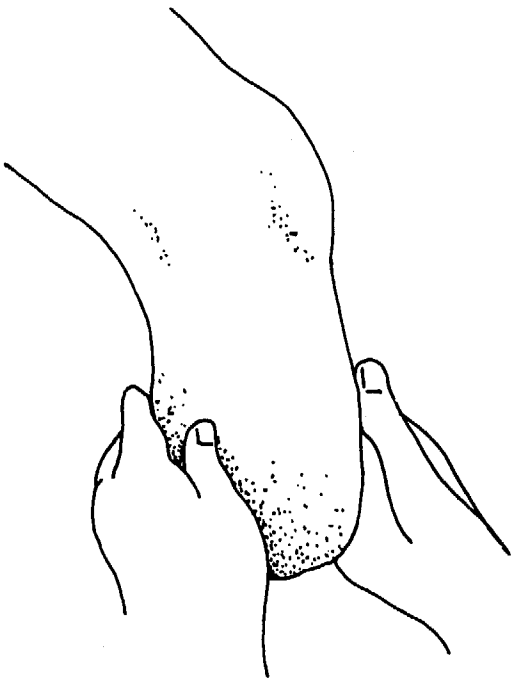
- stump massage and bandaging
- prevention of joint contractures
- assembly of socket, pylon, and eventually a foot
- gait training/getting used to a prosthesis

These subjects relate closely to physiotherapy and therefore professionals are welcome in any limbmaking workshop!

2. Stump massage and bandaging

The stump is often painful after a recent amputation. Continuing pain could possibly be a first symptom of oedema developing at the stump extremity. Oedema is a swelling of the stump tissue which can lead eventually to skin disorders, infections, and a poor distribution of pressure around the stump. Analgesics (anti-pain drugs) could be prescribed where needed, but the surgeon must be informed if pain persists in spite of these medicines.

Massage is of great benefit in stimulating blood circulation and in reducing scar tissue. It will also render the skin more supple.



Improving walking comfort

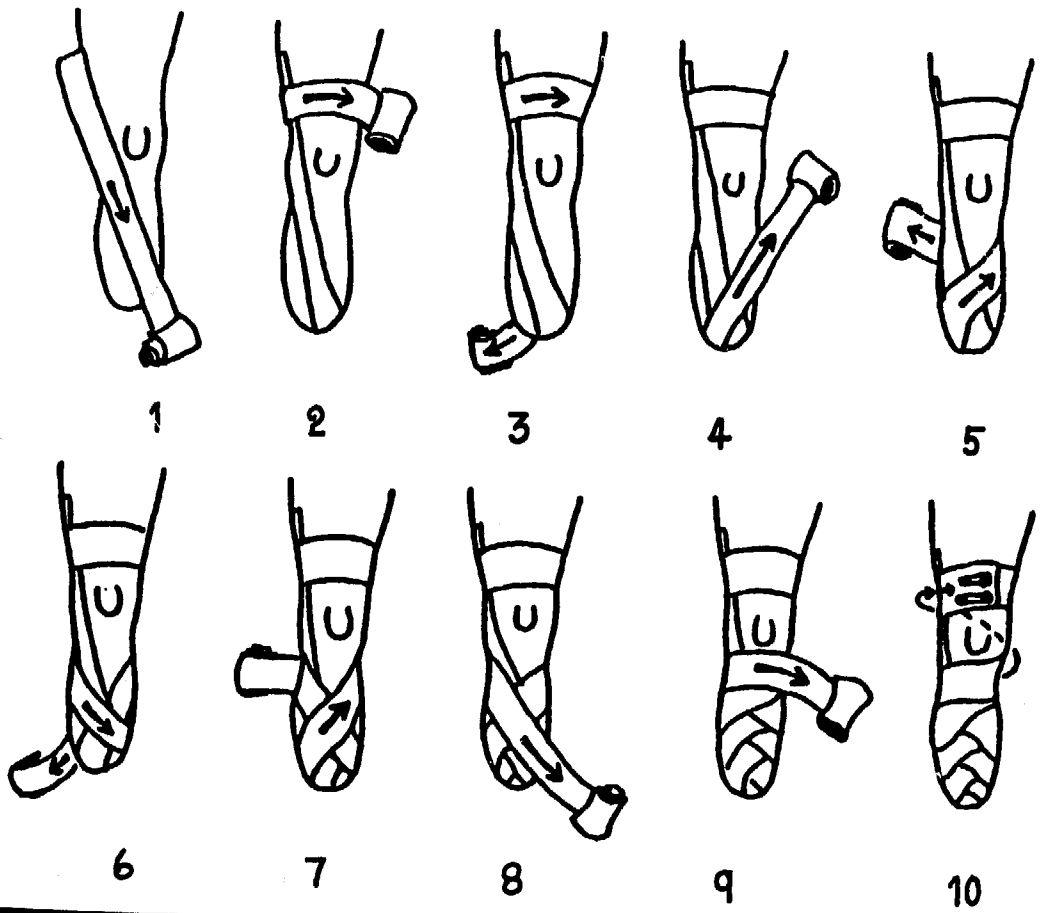
The swelling can be reduced by wrapping the stump with an elastic bandage, or, if that is not available, with a cloth bandage. While it is true that bandaging is a suitable way of preparing a stump for fitting a prosthesis, this method requires considerable expertise in the hands of the person doing the bandaging. For instance, the bandage has to follow the contours of the stump, while at the same time care must be taken not to use too much bandage over any bony bumps such as the fibular head.

Pressure should be greatest at the end of the stump. It decreases as the bandaging moves upward towards the knee. The bandaging is always diagonal to the length of the stump.

NOTE:

1) Take care to bandage the stump with the knee in a straight position, and not in a flexed one!
2) Wrap with diagonal spiral turns from the end of the stump upwards. Be sure to make the bandage more snug at the end of the stump.
3) The bandage may be continued above the knee to prevent slipping.
4) Fasten the bandage.

At first, wrap the stump only moderately tightly, removing the bandage after a short time. Later, increase both the tightness and the time it is worn, until the patient is able to wear the bandage all day in comfort. The bandage is worn when the person is not wearing the artificial limb. Also, show the amputee how to bandage the stump, explain why it should be done, and teach him/her how to bandage the stump by themselves. Take special care when caring for leprosy patients who also suffer from hand deformities. Wherever possible they should be taught how to bandage their stumps themselves.



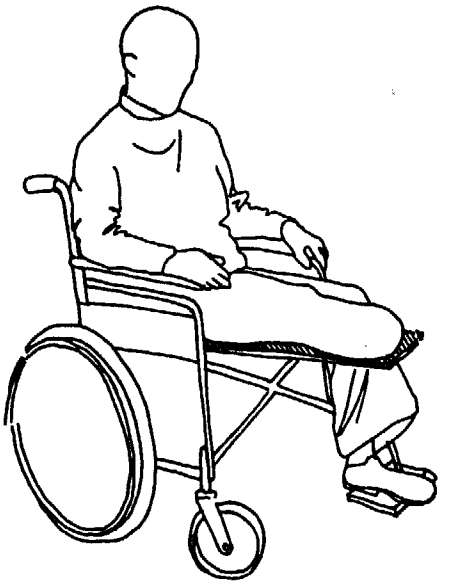
Improving walking comfort

3. Prevention of joint contracture

After amputation, flexion and extension muscles are not always in balance (for anatomy, see chapter 2). This is especially true for short stumps. The stump often shows a tendency to take a flexed position. If such a flexion is not diagnosed and no proper action is taken the position can become fixed. This is known as a contracture.

When a short stump has developed a flexion contracture and the limb is no longer fully stretched it will be very difficult for the amputee to walk on a prosthesis. It is therefore important to prevent the development of a contracture of the knee joint. For example, it often happens that an amputee, while not wearing a limb, unconsciously flexes his/her stump.

Teach the amputee that after he/she is home again, the stump must be stretched frequently. Teaching material could be of use to explain why such exercises are needed. Physiotherapists may also be able to help you. If an amputee uses a wheelchair, it is important to ensure that the stump rests straight out in front and is not allowed to take up a flexed position.

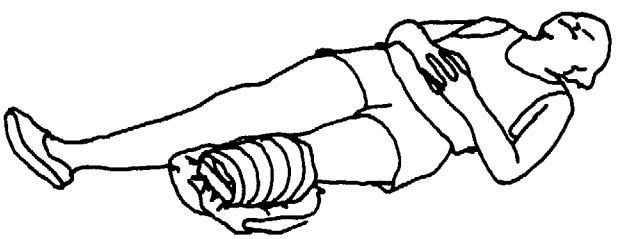


1.

2.

If a contracture is already apparent, surgery might be required to lengthen the tendons and to restore movement to the knee. In some cases physiotherapy is enough to get the stump stretched.

As shown below, a bandage is wrapped around both the stump and a plank. The bandaging should be done as shown on page 148 The tightness of the bandage and the time it is worn is slowly increased during the amputee's stay at the rehabilitation centre. This is always quite painful so special care and attention should be given.



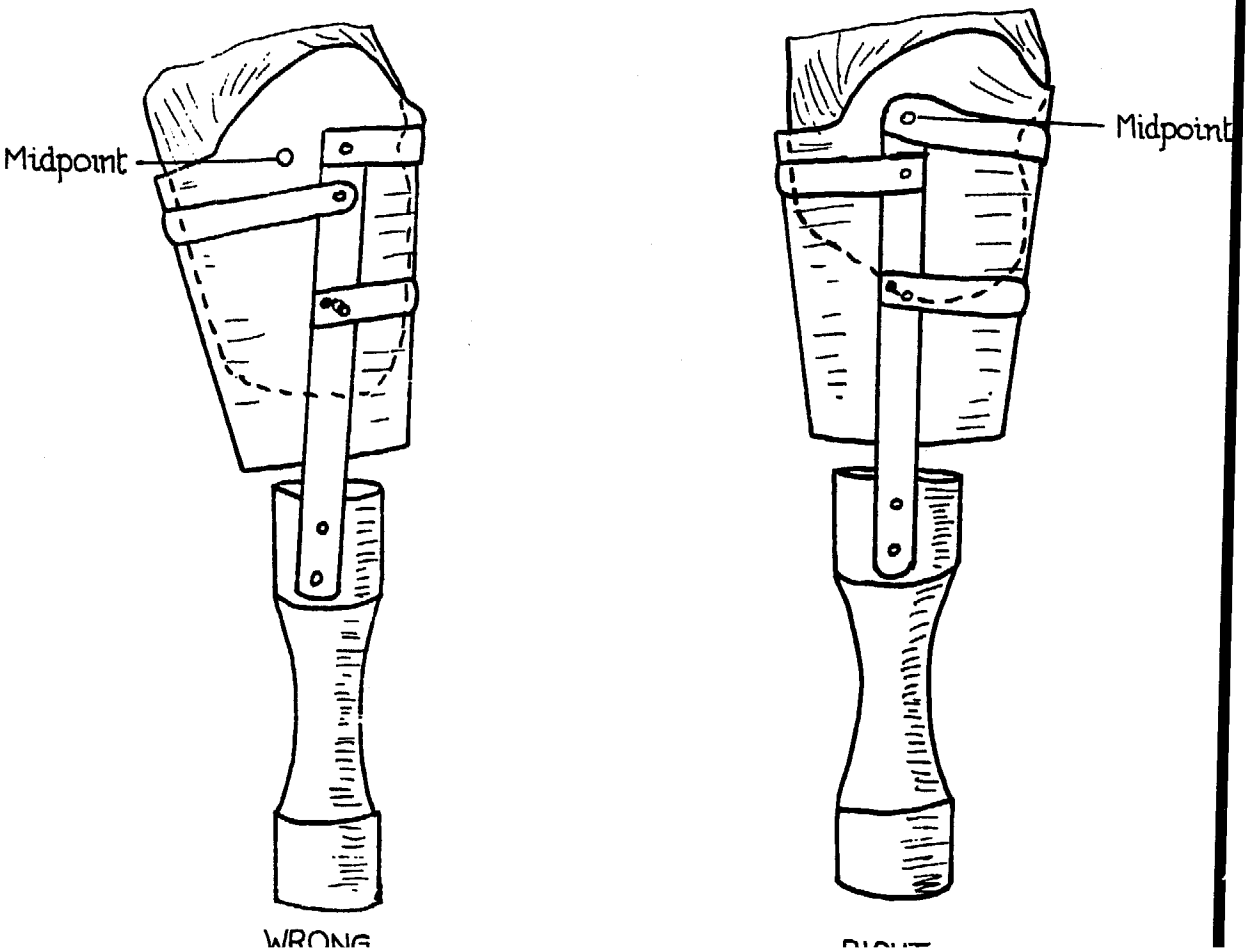
3.

Improving walking comfort

4. Assembly of socket, pylon and foot

Assembly and finishing of the limb can be undertaken once the socket and other components of the prosthesis have been prepared. Also the condition of the stump must be checked to see whether it is ready to wear the prosthesis in comfort.

If, for instance, a prosthesis is built up like the picture below (left), where the socket and pylon are not aligned as straight as they should be, not only will this look odd, but the amputee will find difficulty walking. The picture below (right) shows a limb which is better built up, and therefore more correctly aligned. Nevertheless there must be emphasis on patella tendon bearing because of the shortness of the stump. In this case, more flexion of the socket ontc the pylon is recommended.



Improving walking comfort

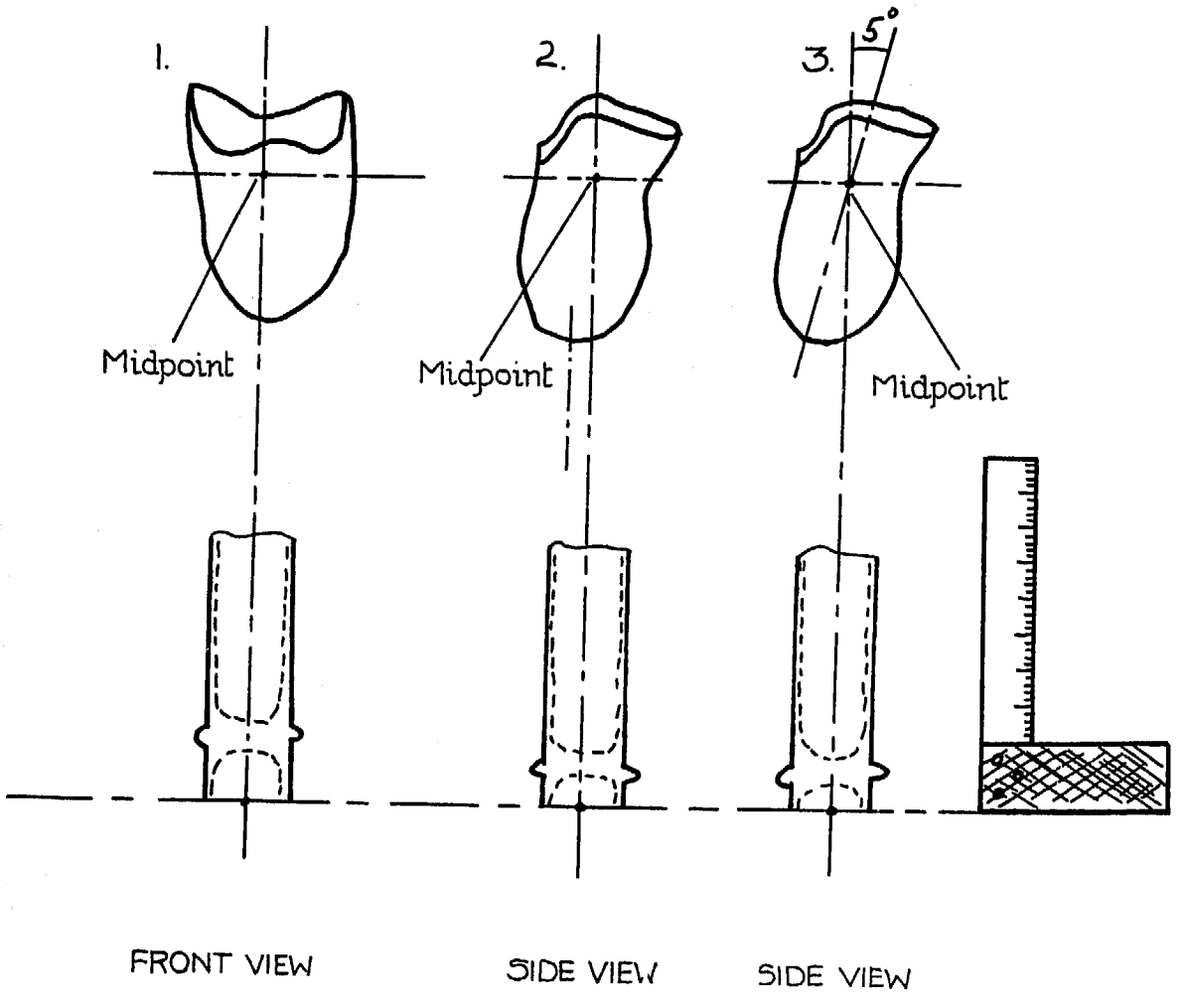
Alignment of socket on pylon without footpiece

1. Front view: the mid-point of the patella area of the socket must be aligned with the middle of the pylon.

2. Side view: the mid-point of the socket at knee level must be aligned with the middle of the pylon.

3. Side view: the socket should be a little flexed. The shorter the stump, the more flexion of the socket is required (5-10 degrees).

see pages 15 and 21



5. How to recognise and treat a poorly fitted stump

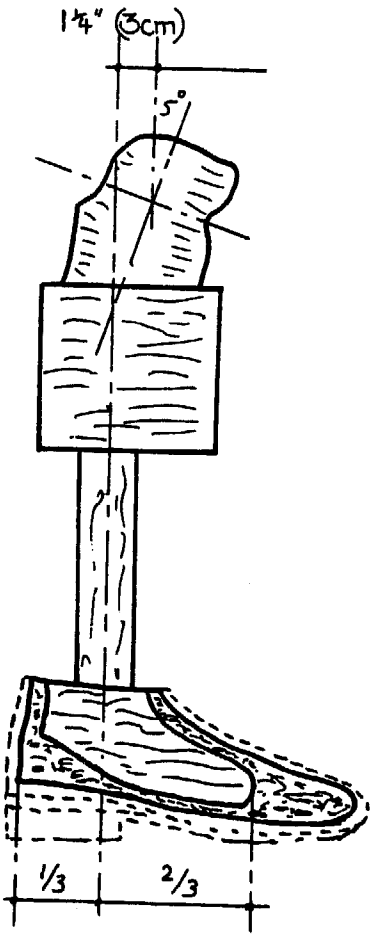
A stump is not a static part of the body. Its size changes throughout the day, smaller in the morning and becoming bigger in the evening. Development of oedema (swelling), ulcers, or the growth of the tibia bone without release of skin tissue will make it impossible for the patient to fit the limb into a prosthesis. It is important to recognise that an inexperienced limbfitter may prepare a socket which, from the beginning, will cause discomfort. Therefore examine the prosthesis very carefully to ensure it functions properly. Question the amputee carefully and pay close attention to how it fits the stump and to correct alignment. At the same time examine the stump carefully.

Close examination of the stump will show up any problems arising as a result of poor fitting, incorrect alignment, and so on. The stump has sometimes been described as the "face" of an artificial limb - it expresses, very closely, any imperfections in the limb. Precise diagnosis of symptoms, however, can be troublesome, and it is a difficult subject to deal with in a manual such as this. Spending sufficient time with the patient and learning to understand the signs will help. When the problems have been diagnosed it will be necessary for the limbfitter to do whatever is necessary to maintain the stump in a healthy condition and to ensure the artificial limb fits satisfactorily.

Improving walking comfort

Alignment of socket on pylon with footpiece

Side view: the socket should be fixed 1 1/4" (3cm) ahead of the pylon. As before, the pylon should be fitted in the middle of the ankle area. Weight bearing should be located on a third of the heel-metatarsal area as shown below.

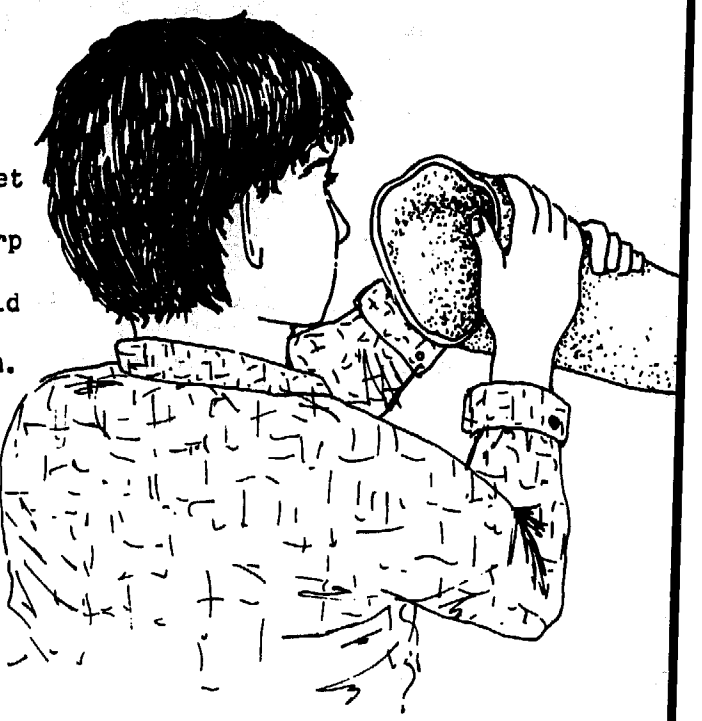


SIDE VIEW

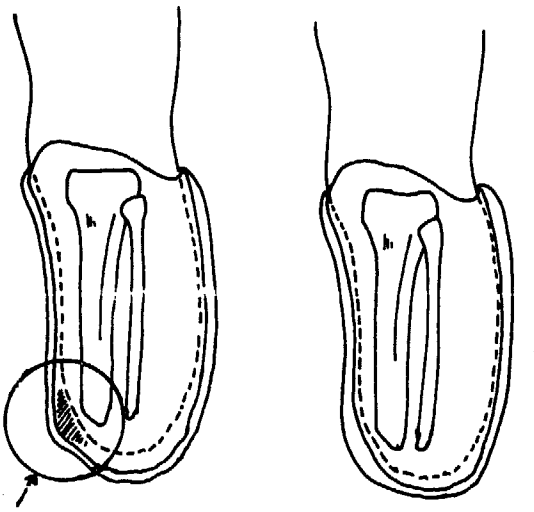
Improving walking comfort

Some solutions to common problems

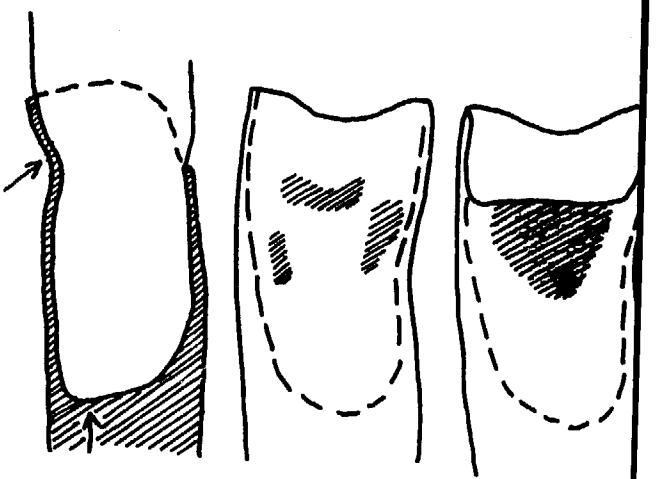
1. Check the inside of the socket for any rough parts or sharp irregularities. These could irritate or damage the skin.



2. If the amputee is suffering discomfort at the end of the tibia, remove material to enlarge the space.

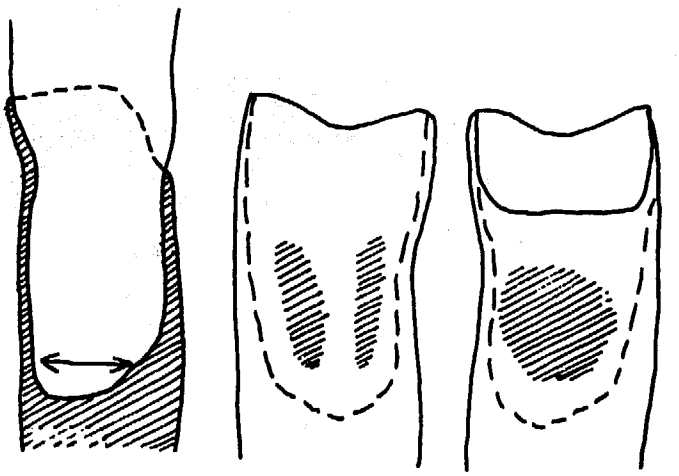


3. If the stump has sunk in the socket and there is a problem with weight bearing, add material to the areas affected as indicated.

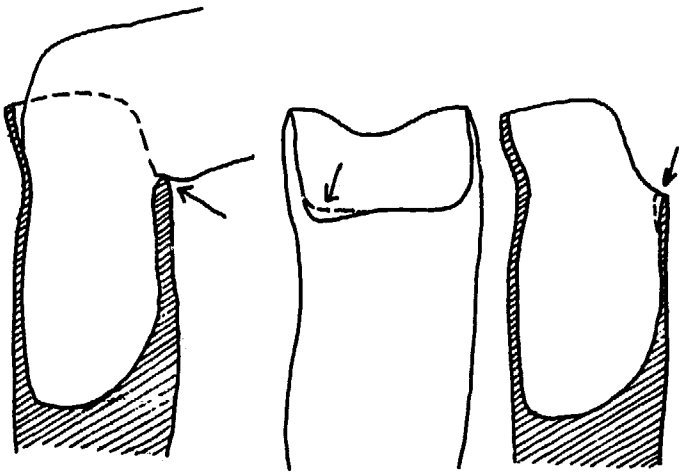


Improving walking comfort

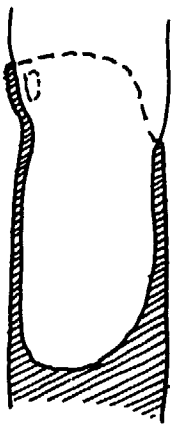
4. If the stump moves in the lower end of the socket, add material to either side of the tibial crest and to the back of the stump.



5. If, when the amputee sits, one of his/her hamstrings catches the edge of the socket, remove material from the brim.



6. If the patella touches the front of the socket, this could be because the pressure on the weight bearing areas is not correct, resulting in the stump sinking into the socket.



Improving walking comfort

6. Checking for poor alignment

Once a stump has been properly fitted in the socket, the next step is to check and make any necessary alterations. First ask the amputee to stand in as relaxed a manner as possible. With a newly fitted limb it may be difficult to stand relaxed at first! Then ask the person to balance from artificial limb to normal limb alternately. The following diagrams may help you to discover where there is a poor alignment and also how to remedy any difficulties you find.

a) shows the problem

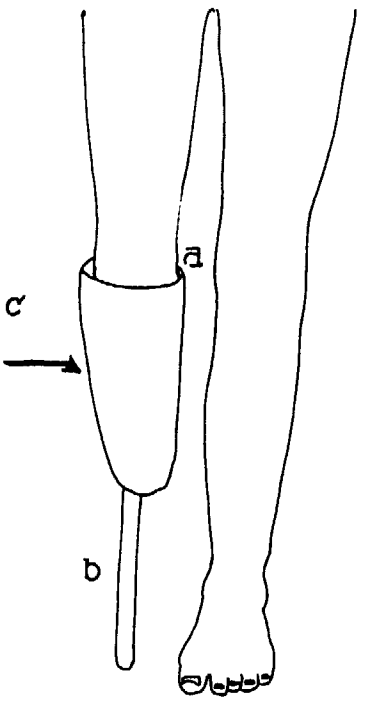
b) shows the check points

c) shows a possible remedy

1. a) medial pressure

   b) pylon is vertical

   c) move socket horizontally as shown.

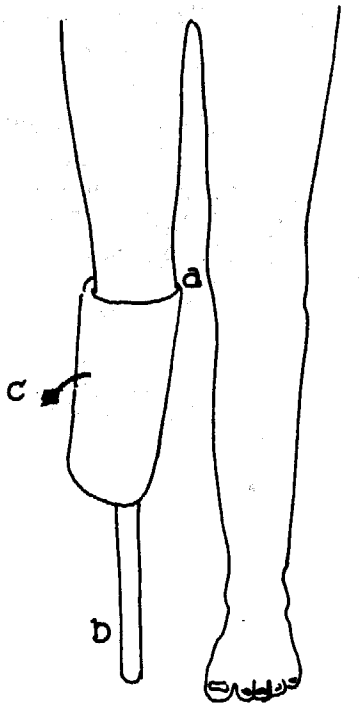


Improving walking comfort

2. a) medial pressure

   b) pylon is not vertical

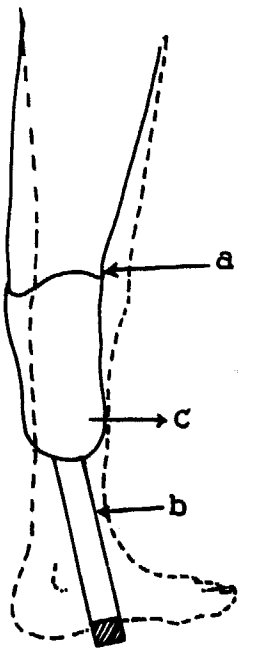
   c) rotate socket outwards as shown.



3. a) knee forced backward

   b) pylon not vertical

   c) move socket forward.



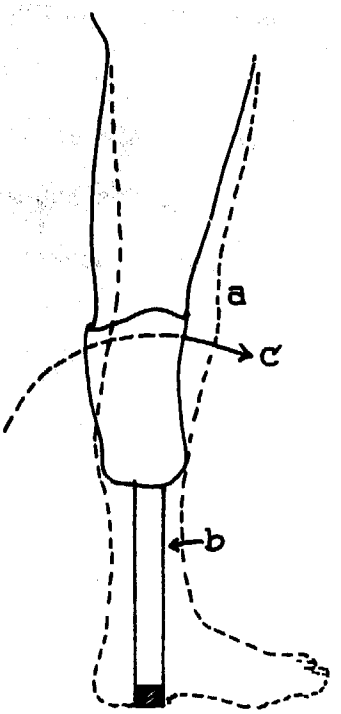
NOTE: If the artificial limb is provided with a footpiece, also check whether the heel may be too soft or too low. If necessary, you could use micro cellular rubber which is slightly stiffer.

Improving walking comfort

4. a) knee forced backward

   b) pylon is vertical

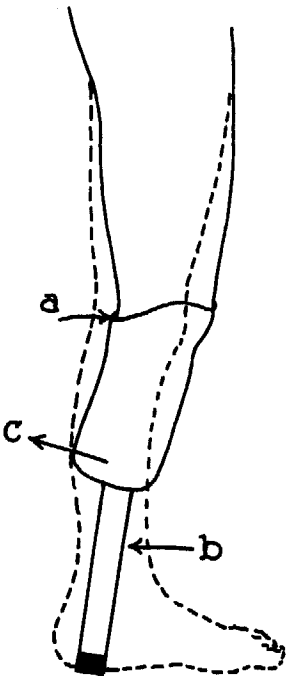
   c) rotate socket forward as shown.



5. a) knee forced forward

   b) pylon not vertical

   c) move socket backward as shown.



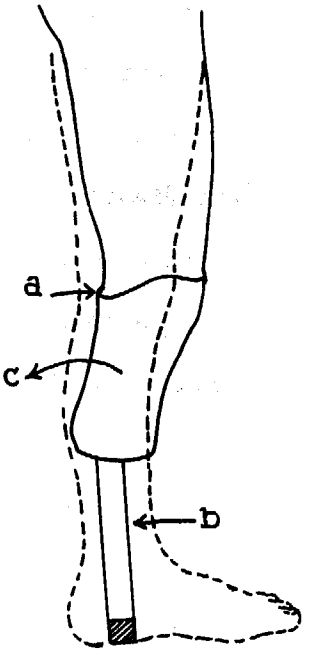
NOTE: If the artificial limb is provided with a footpiece, also check whether the heel is too high or too stiff.

Improving walking comfort

6. a) knee forced forward

   b) pylon is vertical

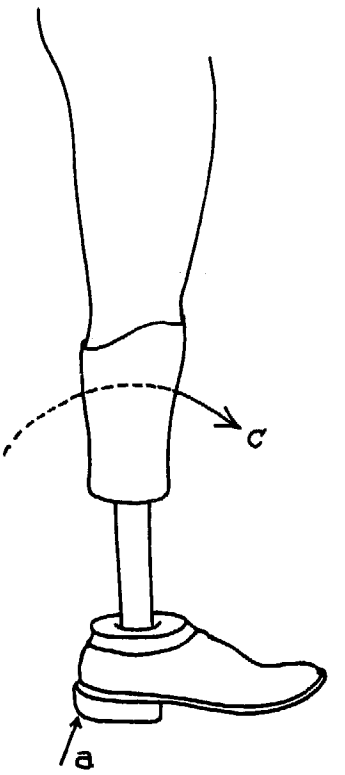
   c) rotate socket backward as shown.



7. Last but not least, an artificial limb with footpiece may have a heel which is raised off the ground (a). The amputee feels like s/he is climbing a slope.

   In this case, rotate the socket forwards as indicated (c).

   Alternatively, if the toes do not touch the floor, the amputee feels like s/he is walking down a slope. To solve the problem, rotate the socket in the opposite direction.

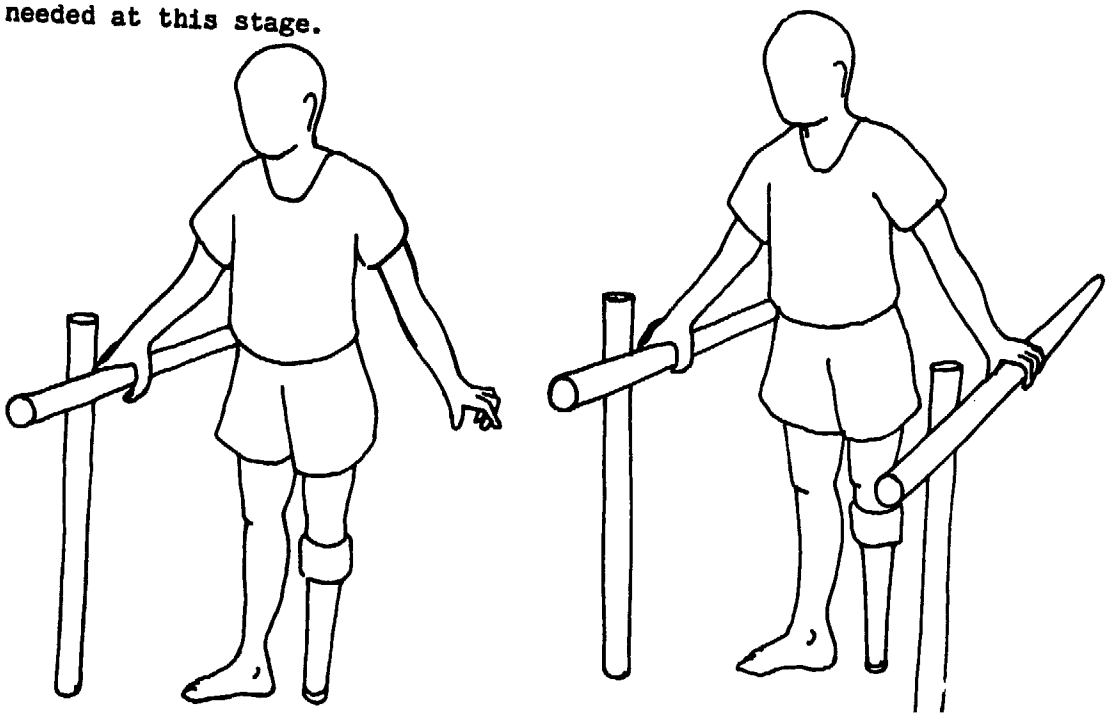


Improving walking comfort

7. Gait training

Visiting a limb-fitting unit for the first time can be a disturbing experience for an amputee. The prosthetist needs to be prepared to provide special encouragement and help when the patient takes his/her first steps. The new prosthesis-wearer will need to slowly learn to walk with the unfamiliar limb. Initially, the pressure below the patella and the strangeness of using thigh muscles again may cause difficulties. The first few days are, therefore, a trial period, and the limb should only be used at intervals - say for periods of half an hour with rests of two hours in between.

Amputees will often find it helpful to use parallel bars while they are learning to use the new prosthesis. The bars, which may be made of bamboo, wood or steel, will aid balance during the first steps. Further aids to walking practice are shown in Don Caston Simple Aids for Daily Living (see back inside cover for details of price etc.). It can also be useful to have a large mirror at one side of the parallel bars so that the amputee can study his/her gait and balance and see where adjustments need to be made. Considerable encouragement and personal attention is needed at this stage.



Improving walking comfort

Once the below-knee amputee has established a comfortable walking pattern, it is unlikely that other aids (walking sticks, crutches) will be needed, provided that the artificial limb has been made as shown in this manual.

Caring for the stumps at home

It is crucial that before an amputee leaves the centre, he/she must learn to put on the stump by themselves. If hands are deformed, for example due to leprosy, then the suspension straps may need to be adjusted for easier use.

The amputee must learn the vital importance of keeping the stump clean. It is best to wash the stump daily at night. In the morning the skin must be thoroughly dried from perspiration before putting the prosthesis on. A wet skin may become irritated when the stump is in the socket.

The patient must learn to develop the habit of examining the stump daily for abrasions, blisters, etc. This is particularly important in the first few weeks of using a prosthesis. If it is at all possible, the amputee should return to the centre immediately any serious skin problems are discovered, to prevent them worsening and becoming serious.

Care must be taken with stump socks, where these are worn. It is important to ensure, when putting them on, that there is no looseness and no wrinkles. Stump socks must be kept clean, washed daily and allowed to dry before they are put on. Two or three stump socks will be needed by each amputee.

Improving walking comfort

Looking after the prosthesis at home

The socket should be cleaned by the amputee periodically with a damp cloth and allowed to dry thoroughly before being put on. The prosthesis must also be examined regularly by the patient for signs of wear. It may be possible for minor repairs to be undertaken at home, for example if the foot or shank needs attention. However, for more serious faults, such as a broken socket, it will be essential to return to the centre.

Training the amputee

By the time the amputee leaves the centre he/she should be able to walk well and to understand how to look after the stump and the artificial limb. You may find it useful to develop a training programme which would include all those aspects we have mentioned.

The length of time necessary for the amputee to stay at the centre will depend on a number of things including the age of the amputee, the condition of the stump and the general condition and type of prosthesis. The average length of stay is likely to be between 5-10 days. Patients who are well prepared both physically and emotionally for the experience of using a prosthesis will be likely to learn more quickly and to spend a shorter time at the centre.

Aftercare service

Amputees will happily return to a centre when they have problems with their prostheses if they were received warmly on their first visit and if the centre seems to be well managed.

An amputee will be feeling very unhappy if he/she is unable to use the prosthesis. It is important to remember that the psychological effect can be like undergoing a second amputation. The prosthetist will do everything possible to prevent this happening and to put right anything which does go wrong.

Every effort should be made to provide free aftercare service. If this is too expensive, some amputees will not come back and minor problems may become major problems. All the work of the prosthetist will be lost unless suitable, free aftercare is made available.

Prosthetists provide a very valuable service, enabling amputees to walk as normally as possible again. We hope this manual will help them in their task of using limited resources to provide limbs for those who have suffered the disabling effects of below-knee amputation.

APPENDICES

APPENDIX 1: Knee Bent Prostheses

APPENDIX 2: Plaster of Paris and Plaster Bandages

APPENDIX 3: Epoxy or Polyester Resin — use of stockinette/fibre glass

APPENDIX 4: What is Vulcanisation?

APPENDIX 5: Which Limbs is it appropriate for You to Produce?

Appendix 1: Knee bent prostheses

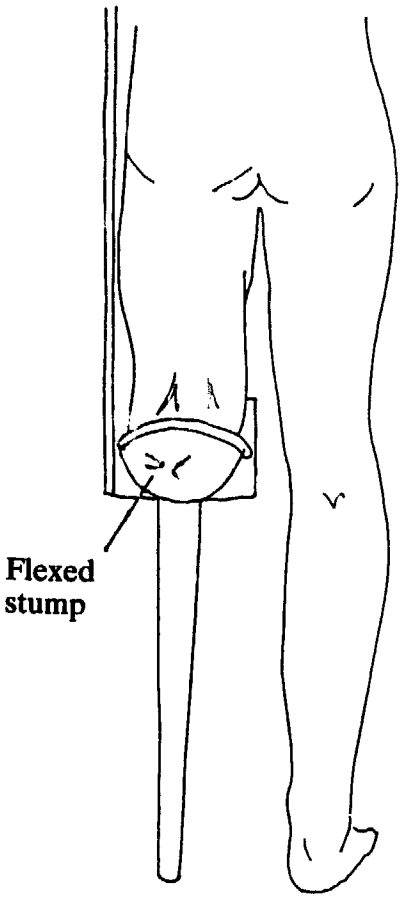
We hope this manual will help you to provide artificial limbs using a 'patella tendon bearing' technique. Such methods have been discussed widely in chapters 3 and 4.

However, there may be some cases when you are not able to make such a limb. The following reasons could apply:
— the stump below the knee is very short
— scarce availability of socket materials
— the stump is contracted in a flexed position, and surgery and/or physiotherapy will not be feasible.

This appendix shows three types of very simple prostheses, in which the knee joint rests on the wooden pylon.

Materials include:
— strong wood
— leather straps
— soft padding (like microcellular rubber)
— rubber tip at pylon end

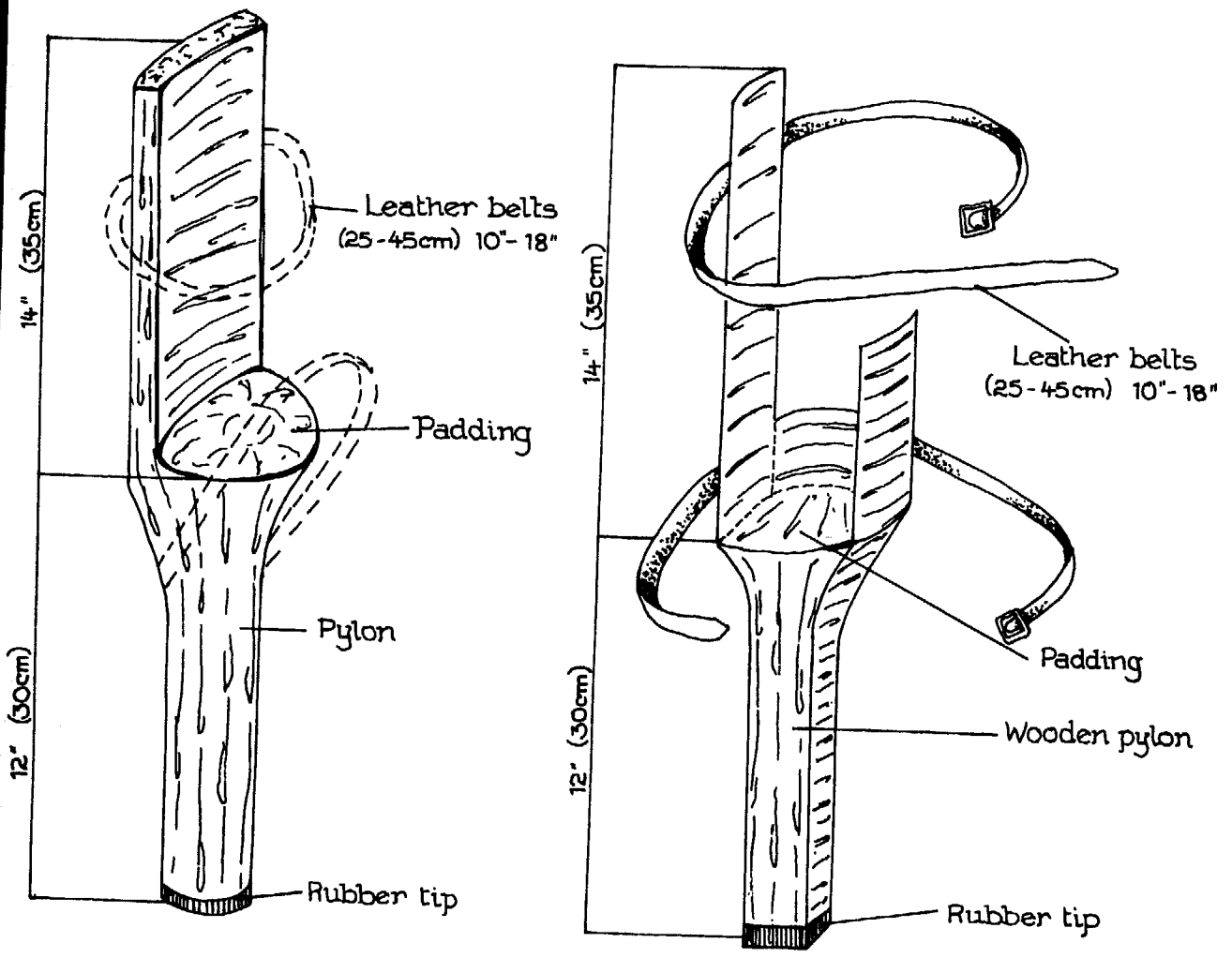
A main disadvantage of this type of limb lies in the fact that, while the stump is often flexed during use of the aid, the knee joint may become set into a flexion contracture.



This kind of contracture is not necessarily uncomfortable for walking using the 'knee bent pylon' type of limb. However, if in the future rehabilitation services improve and a patella tendon bearing limb becomes available, the amputee will not be able to take advantage of the improved limb service.

This is why you should seriously consider the possibility of developing long term services in your area, before providing a knee bent prosthesis.

You need also to consider that it might be better to send an amputee to a rehabilitation centre a distance away where there is a sufficient limb service, rather than making a knee bent prosthesis on your own.



Appendix 2: Plaster of paris and plaster bandages

Plaster of paris is made from gypsum, a soft mineral found in large deposits in many parts of the world including African and Asian countries. Plaster reacts with water and as a result sets to a solid cast.

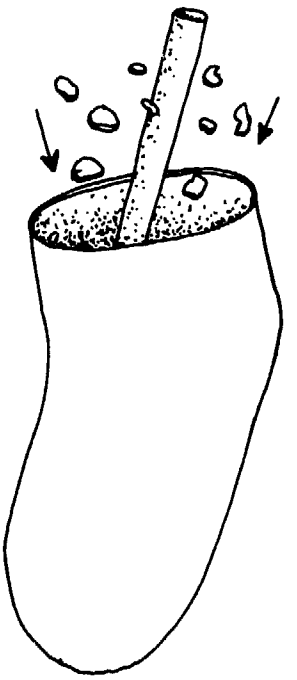
It is important to bear the following points in mind:

1. The ratio of gypsum to water is crucial if you are to achieve a good plaster model. A poor mixture gives a brittle material which is difficult to handle. It is wise to pay careful attention to any recommendations the factory may make, and also to learn from your own experience.
2. Heavy gypsum, when it is mixed with only a little water, dries quickly. During the drying stage, the material will only shrink a little. Thin gypsum, when it is mixed with a lot of water, dries and hardens slowly. During the drying stage, the material shrinks, you will find it most satisfactory to use medium to heavy gypsum.
3. Gypsum should not be mixed with a lot of water (we say gypsum has been drowned). Always add water to gypsum and not the other way round. For the same reason, a cast should not be smoothed with wet hands or with a wet towel or sponge, as this will cause the surface to break off.
4. Thin and wet gypsum does not stick to a dried and hardened plaster. To modify a plaster cast, you should first plunge it into a basin of water for half an hour. This will help the fresh plaster to stick to the cast.
5. Plaster of paris must be kept dry. Powder stored in a humid atmosphere will not react properly.

Filling in stump casts

You can re-use old plaster pieces as a filler in large size stump casts. The plaster pieces should be clean and free from grease before they are recycled.

First break down and grind down the old pieces into smaller sizes. Leave them in water for one night. They will then be ready to use as filler material. You may have problems getting a smooth surface when you take off the wrap. This could make it difficult if you want to cover it with leather.



Plaster bandages

It is not difficult to prepare plaster bandages yourself and saves having to buy them from abroad. A good method is described in Bandages Impregnated with Plaster of Paris by Dr Louis Navias, published by VITA (see useful addresses). This booklet also mentions how plaster is made from natural gypsum rock.

Appendix 3: Epoxy or polyester resin — use of stockinette/fibre glass

The disadvantage of rigid sockets has already been mentioned, in particular for those amputees for whom aftercare from a rehabilitation centre is not available. However, many limb workshops continue to choose to make rigid sockets because this is the pattern made in the more economically developed countries and these sockets are often stronger and more durable.

What sort of resin to use
Apart from polyurethane and acrylate (PMMA) resins which are difficult to get and are rather expensive, polyester resins and epoxy resins are most popular. This is why in this appendix a brief comparison between epoxy and polyester is made. See next page for comparisons.

Further points to note are:

1. Resin hardens when heated. Great care must be taken as temperatures can rise above 100°C (212°F). Always be very careful not to burn the stump with this heat. (Regarding direct fitting see chapter 5). Particular care needs to be taken with leprosy patients whose lack of feeling in their limbs gives no warning of burning.

2. It is possible to lessen the heat produced by reducing the amount of hardener (in the case of epoxy) or accelerator (in the case of polyester). However, by doing this, the hardening time will be longer.

3. The surface of the hardening resin mixture can be cooled down by covering the mixture with a plastic bag and pouring water over it. This method prevents high temperatures reaching through to the skin, because resin is a poor conductor of heat.

4. The brittleness of resin can be a problem and this is why certain reinforcements are needed. Stockinette and glass fibre are strongly favoured as reinforcement. However, these are often difficult to get. Thin cloth, like undershirt material, may be used instead of stockinette. Likewise, women's hosiery, jute cord, rice sack material and also medical bandage can be used instead of fibreglass mats.

5. Reinforcement should be kept clean and away from fat and dust because this leads to premature weakening and failure of the prosthesis.

6. The more reinforcement you add, the less brittle the socket will be. However, too much reinforcement (above 50 per cent) will also lead to premature failure through lack of bonding of the resin in between the fibres or cloth.

7. Always use gloves when handling resin. Wash any part of the skin which comes into contact with the resin using water and cleansing powder. Do not use an indoor sink as it may block the drainage!

POLYESTER RESIN	EPOXY RESIN
With hardener and accelerator 100gm polyester 2gm hardener (40 drops) 4 drops accelerator	With hardener 100 gm epoxy 6 gm hardener
PRICE: $2 - $3 1kg	PRICE: $4 - $7 1kg
STORAGE: Must be stored in a fridge (less than 5°c) (40°F) Storage time limited Hardener can be explosive in contact with accelerator Handle with care	STORAGE: Cool storage not necessary Long storage time
HANDLING/SAFETY: Smelly Not toxic	HANDLING/SAFETY: No smell Hardener is toxic (may cause eczema and diseased tissue growth). Avoid skin contact, use gloves or skin protecting creams/oils.
FUNCTIONING: Strong	FUNCTIONING: Very strong

IT IS IMPORTANT TO ALWAYS READ SUPPLIER'S INSTRUCTIONS THOROUGHLY FOR SAFETY PRECAUTIONS AND CORRECT HARDENER RATIO.

Appendix 4: What is vulcanisation?

Raw rubber is a latex in which the molecules easily slide over each other. Only when the molecules are chemically linked, usually by sulphur, is an elastic and stable material achieved. This process is called vulcanisation, or curing.

The cushion, tread and rubber black mentioned previously are not vulcanised when they are bought in the market, but they do contain sulphur and other fillers. By keeping the material cool, vulcanisation does not happen very quickly. During a high temperature, however, the vulcanisation process is speeded up. (The unwanted vulcanisation by inadequate storage is called scorching).

Time and temperature of vulcanisation depends on material properties. By trial and error, at Jaipur 100°C and 50 minutes has been shown to be reasonable.

NOTE: Wrong temperature or time results in over or under curing. Strength and hardness differ from the ideal situation, manifested by discomfort and early failure of the footpiece.

How can you test whether rubber compound is vulcanised or not?

Test 1 Press the rubber compound with a finger nail or a pin. The imprint should not disappear. If the imprint disappears, the rubber is elastic, and thus vulcanised (see definition).

Test 2 Move away some of the plastic cover of the rubber to be tested. Press two parts of the uncovered rubber together. If it sticks, the rubber is not vulcanised. If it does not stick, the rubber is vulcanised and cannot be used for the assembly of the footpiece.

Appendix 5: What Limbs is it Appropriate for you to Produce?

Personnel
Answers recorded on the following scale 0 to 10:
0=none 5=medium 10=high.

What degree of orthopaedic skills are necessary?

Leather socket	8
Prosthesis with leather socket	5
Alternative prosthesis with leather socket	2
Prosthesis with aluminium socket	5
Prosthesis with wooden socket	5
Prosthesis with resin socket	2
Suspension	2
Footpieces	0
Alignment and gait training	8

What degree of technical skills are necessary?

Leather socket	2
Prosthesis with leather socket	5
Alternative prosthesis with leather socket	2
Prosthesis with aluminium socket	10
Prosthesis with wooden socket	5
Prosthesis with resin socket	5
Suspension	5
Rocker footpiece	2
SACH footpiece	5
Jaipur footpiece	5
Alignment and gait training	5

Do you need expert advice to set up production?

Sockets	expert advice necessary
Prosthesis manufacture	some advice necessary
Prosthesis fitting	expert advice necessary
Alignment and gait training	expert advice necessary
Suspension	some advice necessary
Footpieces	a little advice necessary

Is the product appropriate for a high production rate?

Leather socket	yes
Prosthesis with leather socket	yes
Alternative prosthesis with leather socket	yes
Prosthesis with aluminium socket	yes
Prosthesis with wooden socket	less suitable
Prosthesis with resin socket	not very suitable
Suspension	yes
Rocker footpiece	yes
SACH footpiece	yes
Jaipur footpiece	yes, very suitable

Is the product appropriate for a low cost production rate?

Leather socket	yes
Prosthesis with leather socket	yes
Alternative prosthesis with leather socket	yes
Prosthesis with aluminium socket	less suitable
Prosthesis with wooden socket	yes
Prosthesis with resin socket	less suitable
Suspension	yes
Rocker footpiece	yes
SACH footpiece	yes
Jaipur footpiece	not suitable

Is electricity and/or gas necessary?

Leather socket	no
Prosthesis with leather socket	no
Alternative prosthesis with leather socket	no
Prosthesis with aluminium socket	no but oxy-acetylene
Prosthesis with wooden socket	no
Prosthesis with resin socket	no
Suspension	no
Rocker footpiece	no
SACH footpiece	no
Jaipur footpiece	yes
Alignment and gait-training	no

How long a training period do you expect for personnel before the production is established (assuming specific experience is not yet available)

Leather Socket	1-4 months
Prosthesis with leather socket	less than 1 month
Alternative prosthesis with leather socket	less than 1 month
Prosthesis with aluminium socket	1-4 months
Prosthesis with wooden socket	less than 1 month
Prosthesis with resin socket	less than 1 month
Suspension	less than 1 month
Rocker footpiece	less than 1 month
SACH footpiece	less than 1 month
Jaipur footpiece	1-4 months
Alignment and gait training	longer than 4 months

Manufacture

Are special tools or equipment needed?

Leather socket	no
Prosthesis with leather socket	no
Alternative prosthesis with leather socket	no
Prosthesis with aluminium socket	welding equipment
Prosthesis with wooden socket	no
Prosthesis with resin socket	oven
Suspension	no
Rocker footpiece	no
SACH footpiece	no
Jaipur footpiece	dies and vulcaniser
Alignment and gait training	no

Useful Addresses

1. World Rehabilitation Fund
   400 East 34th Street
   New York 10016
   USA

2. The International Society for Prosthetics and Orthotics
   Borgervaenget 5
   2100 Copenhagen 0
   Denmark
   (some developing countries have their own representatives)

3. National Centre for Training and Education in Prosthetics and Orthotics
   Curran Building
   University of Strathclyde
   Glasgow G4 0LS
   Scotland

4. Intermediate Technology Development Group Ltd
   Myson House
   Railway Terrace
   Rugby CV21 3HT
   UK

5. TOOL — Technical Development with Developing Countries
   Entrepotdok 68a/69a
   1018 AD Amsterdam
   Netherlands

6. VITA — Volunteers for International Technical Assistants
   Suite 200
   1815 North East Street
   PO Box 12438
   Arlington
   Virginia 22209
   USA

7. TALC — Foundation for Teaching Aids at Low Cost
   PO Box 49
   St Albans
   Herts. AL1 4AX
   UK

8. Leprosy Mission
   International Office
   80 Windmill Road
   Brentford
   Middx. TW8 0QH

9. World Health Organisation
   1211 Geneva 27
   Switzerland

10. International Committee of the Red Cross
    17 Avenue de la Paix
    CH 1211 Geneva
    Switzerland

Useful Books

1. Training in the Community for People with Disabilities

   WHO manual for a community based rehabilitation approach available from regional WHO headquarters, or from:

   World Health Organisation
   1211 Geneva
   Switzerland

2. Helping Health Workers Learn by David Werner and Bill Bower

3. Disabled Village Children by David Werner, both available from:

   TALC
   PO Box 49
   St Albans
   Herts. AL1 4AX
   UK

4. The Physiology of the Joints by J A Kapandji

5. Leprosy by A Bryceson and R E Pfaltzgraff, both available from:

   Churchill Livingstone
   1-3 Baxter Place
   Leith Walk
   Edinburgh
   Scotland

6. Insensitive Feet by P J Bland (1981)

7. A Footwear Manual for Leprosy Control Programmes. Part I and II, by Jane Neville, both available from:

   Leprosy Mission
   International Office
   80 Windmill Road
   Brentford
   Middx. TW8 0QH
   UK

8. La Prosthese Africaine — (in French)

9. La Prosthese Tibiale — (in English and French), both available from:

   Handicap International
   18 rue de Gerland
   6900 Lyon
   France

Glossary

ALIGNMENT, RE-ALIGNMENT	arrangement in a straight and correct line
AMPUTATE, AMPUTATION	to cut a limb from the body completely
ANAESTHETIC LIMB	a limb with no feeling completely or locally
ANATOMY	structure of the human body
ANTERIOR	large heavy block of iron on which heated metal is hammered into shape
ATROPHY	wasting away
AXIS	point about which a limb turns
BEARING SURFACE	an area which touches and supports another part of the anatomy
BEVEL	to give a sloping edge to
CAVITY DIE	die to make the sole imprint
CIRCUMFERENCE	the distance around the outside rim of a circle
COMPRESSION	pressing together tightly
CONDYLE	rounded bump at the end of a bone
CONICAL	shaped like a cone
CONTOUR	curved outline of shape
CONTRACTURE	stiffened joint due to long period of immobility
CORD LINING	reinforcing material to make rubber stronger usually made of nylon or cotton
CORROSION	slow destruction of material
CORRUGATED CARDBOARD	see page 77
CORSET	covering for the thigh to take some of the body weight
CREST	top
CUSHION RUBBER	rubber usually used in the side of car tyres and quite durable
DIE	block of hard metal with a shape cut into it used for shaping
DORSIFLEXION	flexion of the foot with the toes pointing upwards
DURABLE	long lasting in poor conditions

ELLIPTICAL	shaped like an oval
EXTENSOR MUSCLE	muscle which allows stretching out
EXTERNAL	outer
FLARE	flat area on the front side of the stump which can usually bear considerable pressure while walking
FLEXION	bending of joints
FLEXION CONTRACTURE	temporary shortening of a muscle used in bending
FLUX	fluid to make aluminium welding easier
FRICTION	heat caused by two surfaces rubbing against each other
GAIT	way of walking
GRAIN IN WOOD	patterns or lines in wood as seen on a surface
HAMSTRING	tendon at the back of the knee. There are two in the inner side and one on the outer side. They are attached to the tibia
HEEL STRIKE	the moment the artificial foot touches the floor while walking
HEREDITARY	a feature that passes from parent to child
HYPEREXTENSION	overstretching
IMPRINT	stamp on a soft surface which marks out the shape, especially of a foot
LATERAL	situated at the sides
MALLET	hammer
MASSAGE	pressing and rubbing muscles and joints with the hands to lessen pain
MEDIAL	situated in the middle
METATARSAL	five bones in the foot between the ankle and the toes
MODIFY	make changes in
MOULD	hollow shape into which liquid metal or other material is poured to cool into a certain shape
OEDEMA	building up of fluid below the skin. Also known as dropsy

ORIENTATION	the exact position of something
OXIDISING	combining with oxygen
PHYSIOTHERAPY	movement, exercise, heat and massage treatment
PHYSIOTHERAPIST	a worker trained in physiotherapy
PLANTARFLEXION	stretching of the foot with the toes pointed downwards
PLASTERCAST	an object made from pouring plaster into a mould and drying
PLASTAZOTE	a polyethylene foam
PLIABLE	easy to bend
POSTERIOR	at the back of, behind
PUMPING	small up and down movement of the stump inside the socket
PYLON	central support of an artificial limb. Also called a shank
RASP	metal tool like a coarse file used for scraping. Also called a grinder
REPLICA	copy
RESIN	chemical sticky substance which can be moulded together with other materials (hardener) — it becomes stiff strong brittle
RIVET	metal pin for fastening
RUBBER CEMENT	glue which thickens, generally used before vulcanisation
SELLOTAPE	sticking tape, used to join paper
SHANK	central support of an artificial limb. Also called a pylon
SHAPING GRIP	positioning and holding the hands on a wet plaster cast to contour the model
SOCKET	support for the stump resting on the pylon
SQUAT	sit on heels with legs bent under body
STABILITY	being balanced securely
STOCKINETTE	elastic machine-made knitted material, especially used for underwear

TENDON	tough thick cord that joins muscle to bone. Also called a sinew
THUMB TACKS	short pins with large flat heads usually used to put posters on walls, also called drawing pins
TIBIAL	belonging to the tibia, such as tibial skin
TISSUE	the soft material which makes up the human body
TOE BREAK	wooden core of an artificial foot sectioned into two pieces to make walking easier
TRAUMATIC AMPUTATION	amputation due to accident
TREAD RUBBER	strong rubber used for the outer part of car tyres
TUBEROSITY	bony bump on the tibia to which the thigh muscle is attached
UPRIGHT	bar to attach the pylon to the socket
VULCANISE	to make rubber strong and durable
WASHER	small flat ring of metal, rubber, plastic or leather for making a joint or screw tight
WEIGHT BEARING SURFACE	any area which carries or supports another part of the anatomy
WELD	join metal together