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Orthotics and Prosthetics in Neuropathy

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INTRODUCTION

Chapter 17 focussed on footwear and in-shoe orthotic devices which are important in the prevention and management of foot ulcers associated with loss of protective sensation. Unfortunately, some people require more sophisticated appliances than in-shoe orthotic devices and (modified) footwear. Impaired sensory and motor nerve function and amputations at different levels may have a great impact on daily activities. The use of orthopaedic appliances (prostheses and orthoses) can enable people to overcome difficulties in mobility and in their "Activities of Daily Living" (ADL). Sometimes the appliance is used for a short time only for therapeutic purposes. An example of this is a backslab, as described later in this chapter. Often however, an appliance has to be used permanently if optimal mobility is to be maintained. Examples of these are orthoses for foot-drop and prostheses.

An orthopaedic workshop is essential in a tertiary referral hospital where reconstructive surgery is offered. Some orthopaedic appliances are leprosy specific, but most are also beneficial for those whose disability is unrelated to leprosy.[9] It can be advantageous for a leprosy institution to produce appliances suitable for those with leprosy and other conditions. The number of prosthetic and orthotic personnel in developing counties can not meet the need in general physical rehabilitation.[17,19] Therefore using the resources available at the leprosy hospital for non-leprosy related conditions can provide a service to the local community, while at the same time it may generate income for the hospital. This can also help in reducing the stigma related to leprosy.

Successful rehabilitation often requires the skills of a number of different professions. Prosthetists and Orthotists combine with other paramedical and medical personnel to form the rehabilitation team. A multidisciplinary approach will increase the quality of care (Chapter 24). Therefore having the workshop situated near or as part of a hospital is advantageous.[19]

There are a few general guidelines for orthopaedic appliances:

- *Good fitting*. When protective sensation is lost, it is not always possible for the user to provide feedback on the fit of the device. If pressure points are not observed in time and the necessary alterations carried out, ulceration can result, so good fitting is essential.
- *Affordability and availability* often go together. When local materials are being used the availability will increase. At the same time prices can be kept reasonably low.
- *Cultural appropriateness.* Whenever possible, cosmetic/ cultural aspects should be kept in mind.[22] When appliances are not culturally acceptable, people will not be motivated to use them. It is better to have a reasonable but accepted appliance, than the best appliance, which is not accepted.

This chapter gives an overview of orthopaedic appliances commonly used for people with conditions resulting from leprosy.

Many of these conditions are secondary to peripheral neuropathy. There are several ways to classify orthopaedic appliances. In general terms, *prosthesis* is a device which replaces a part of the body, while an *orthosis* assists the body to regain lost function. In this chapter we look at how orthopaedic appliances for the lower limb can be beneficial for those with loss of sensation, loss of muscle power, loss of joint stability and loss of a limb.

LOSS OF SENSATION

Sensory neuropathy in leprosy can result in "glove and stocking" anaesthesia as the peripheral nerves innervating the upper limb distal to the elbow and the lower limb distal to the knee are affected. The main danger arising from this results from neglected injury.[1] This neglect is due to lack of pain following injury, and can be combated by education in terms of an increase in awareness of the need for vigilance in self-care and protection of vulnerable areas of the body.

A number of different devices can be used to reduce the likelihood of injury. Footwear with special insoles are the key in the battle to protect the foot from ulcers which can ultimately lead to infection and even amputation.[1,3] This has been discussed in detail in Chapter 17, so will not be covered here.

People living in cultures where cross-legged sitting is common may develop ulcers on the lateral malleoli.[1] Cups or rings made from micro-cellular rubber (MCR) can be used to off-load the malleoli when prolonged sitting in this position is expected.

Repetitive or extensive use of hand tools or kitchen utensils can also be a cause of concern. The use of gloves or a thick cloth to protect the hands from hot items, for instance when cooking, is second nature to those with intact sensation, but may need to be reinforced as an essential part of the self-care routine when peripheral neuropathy is present.

Adapting or modifying tools is also an option (see also Chapters 10 and 24). The grip of a neuropathic hand can be very strong, resulting in high pressure points, which need to be eliminated or reduced substantially if the hand is to be safe. Two laws of physics come into play here. Firstly, it is to be remembered that the force applied by the hand on the tool will be equal and opposite to the force applied by the tool on the hand (Newton's First Law). Secondly, the pressure applied on the hand is equal to the force used to grip, divided by the area of the hand in contact with the tool. Therefore by distributing the forces over a larger surface of the hand, peak forces can be reduced.

This can be achieved simply by covering the grip of the tool with MCR, or by changing the shape of the grip of the tool to the anatomical hand-shape of the user. Anatomical grips can be made by carving wood, Appropriate Paper-based Technology (APT) or the use of epoxy resin putty.[29,30]

The latter two methods use a soft grip, which is moulded to the required shape and then sets to form the definitive handle.

LOSS OF MUSCLE POWER

A second effect of neuropathy is loss of muscle power. As this effect is not universal, an imbalance occurs affecting the resting position of various joints as well as the more obvious functional loss. This can occur in both the upper and lower limbs. However, this chapter concentrates on lower limb problems. The posterior tibial and peroneal nerves are commonly affected in leprosy. The posterior tibial nerve innervates the intrinsic muscles of the foot, and when affected clawing of the toes and flattening of the arch can result (see Chapter 14).

Paralysis of the common peroneal nerve results in loss of function of the muscles which are responsible for dorsiflexing and everting the foot. The common term used for this condition is "foot-drop". Foot-drop has an enormous effect on gait. Dorsiflexors are active during the swing phase of gait when they lift the foot to clear the floor and also immediately following heel strike when they control the rate of plantarflexion. A person with this condition, therefore, struggles to clear the ground in swing, the effective length of the leg below the knee being longer than normal.

There are two common ways to compensate for this. These are "high-stepping" gait and circumduction.[5] High-stepping gait is most commonly seen when knee and hip function has not been affected. In this type of gait the person lifts the foot higher from the ground by using extra flexion of the hip and knee. When compensating for foot-drop with circumduction, a combination of abduction, flexion and hiking of the hip is used to advance the leg.

Reduction in the ability to use the dorsiflexors of the foot in early stance will result in a condition known as "footslap", as the descent of the forefoot to the ground is not well controlled and sometimes an audible slap can be heard. If dorsiflexion is severely affected, then the forefoot will contact the ground before the heel in the classic "toe-heel" gait.

Reconstructive surgery can bring a long-term solution compensating for loss of muscle power in the dorsiflexors and evertors. However, this is not always appropriate clinically, or even desirable to the patient. In this case, benefit can be derived from an orthosis to control unwanted movement. According to Neville 1-2% of patients do need some sort of appliance for footdrop.[14]

Ankle Foot Orthoses for footdrop

The function of these orthoses is to substitute for dorsiflexion during the swing phase of gait in order to provide ground clearance. As with all orthoses, comfort, ease of donning and doffing, and cosmetic appearance all need to be acceptable. The device should be both affordable and maintainable. As these orthoses are used to control the ankle and foot, they are known as Ankle Foot Orthoses (AFOs). These orthoses can be custom-made or prefabricated. If the latter are used, small adjustments are usually necessary to make them suitable for the client. The conventional AFOs using metal bars with a joint connected to the shoe are still common, although thermoplastic designs are rapidly becoming more common in Asia and Latin America[7,15,23,29] The main advantages of thermoplastic AFOs are their low weight and more cosmetic appearance. Several designs of AFO are possible. The appropriate choice will depend on clinical appropriateness, the personal wishes of the user, the skills of the technicians and the materials available.

Footdrop springs

The simplest design is the foot-drop spring (Fig. 23-1). This has been used in leprosy since the early 1960s.[1] The basic design uses a leather

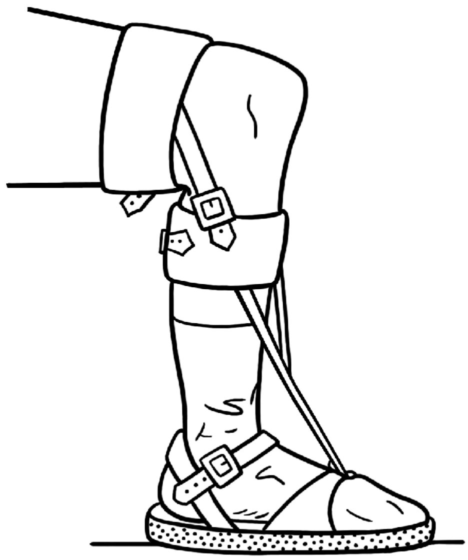


FIGURE 23-1 Footdrop spring. The elastic band keeps the foot in dorsiflexion during the swing phase of gait (with permission from Fritschi[9]).

cuff just below the knee, which is connected to the footwear by means of an elastic strap or a spring. Sometimes a second cuff is used above the knee to prevent the whole orthosis from slipping distally. The connection of the strap to the foot is at the level of the fourth metatarsal head to control the inversion/eversion of the foot.[26]

Metal and Leather AFOs

The use of metal and leather in AFO construction is the classical concept. Prefabricated metal components are produced in many countries, but making the device directly out of metal bar is also possible. Metal is often readily available, and techniques and skills to work with metal are widely known and commonly used. Huckstep and Dartnell both describe such AFOs.[4,10]

The basic design of a conventional AFO is a strong shoe with metal bars on either side of the lower leg, leading to a calf band and cuff. The AFO allows for dorsi- and plantarflexion of the ankle. The design used in Uganda for polio is simple, cheap and effective.[10] It allows plantar flexion after heel-strike and a normal rollover and push-off (Fig. 23-2). The spring pulls the foot into dorsiflexion during the swing phase of gait, allowing for adequate ground clearance. It is very important that the joint centres and axes of the anatomical ankle and of the AFO correspond with each other (Fig. 23-3). If this is not the case, there will be strain on both joints and skin problems are likely. The connection between the metal sidebars and the footwear is made using a metal plate built into the heel and sole of the shoe. The size and strength of this is important to effect a good connection between the shoe and the AFO and the finished product needs to be smooth enough not to cause skin problems in the foot.

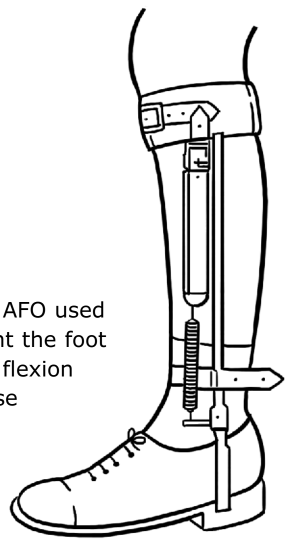
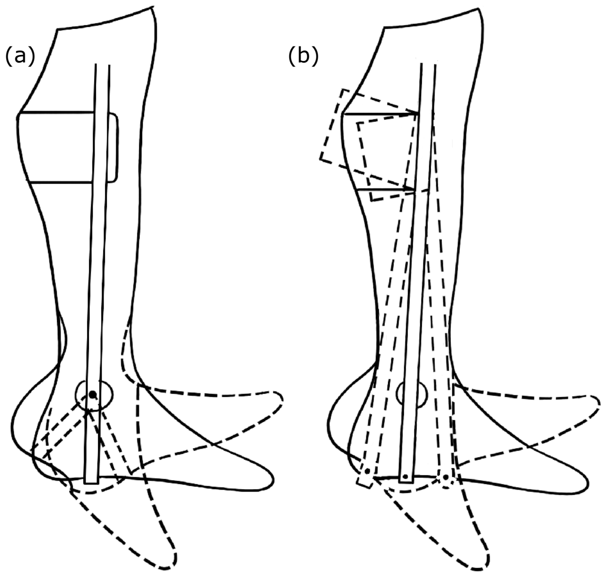


FIGURE 23-2 Metal AFO used for footdrop to prevent the foot from going in plantar flexion during the swing phase (Huckstep[10]).



- • axis of AFO
- O axis of ankle
- ——— neutral position
- ----- dorsal or plantar flexion

FIGURE 23-3 The optimal position is when the axis of the AFO and axis of the ankle are in line with each other (A). If they are not in line (B), discomfort is experienced during plantar or dorsiflexion of the foot.

Cosmetic AFOs

In more recent years a number of materials have been used in order to overcome the bulky nature of the foot-drop spring and the metal

metal-leather AFO. When limb volume is stable, it is often possible to manufacture an effective device which follows the contours of the leg more closely, and is often deemed more cosmetically acceptable. For this reason, they are known as "cosmetic AFOs".

This type of AFO is manufactured on a modified cast of the client's lower leg. To make this, a sock is used against the skin and marked in the pressure sensitive areas with a water-soluble pencil. A wrap cast is taken of the leg with the ankle in neutral or slightly dorsiflexed and the sub-talar joint in neutral. When dry this is removed, sealed and filled with plaster of Paris to provide a basic model of the lower leg. Accurate modification of this is essential to ensure that the close-fitting AFO does not cause skin problems and that it fits into the footwear. The model is then used to provide the desired shape for the AFO, which may be made from several different materials. In this section we look at orthoses made from resin and thermoplastics.

Resin AFOs

The manufacture of resin AFOs is described by Neville.[14] This is a solid ankle AFO, allowing neither plantarflexion nor dorsiflexion. A positive model is made as above and then covered with a padding material such as evazote or plastazote, which can be moulded to the cast when heated in an oven at 130º-150º Celsius. It is then wrapped round the cast with care taken to avoid creases which could cause skin damage and weaken the AFO. The strength of the AFO comes from the reinforced resin layer which is applied on top of this. Polyester, acrylic or epoxy resins are most commonly used, all of which have slightly different properties. These resins come in a liquid form and are hardened by mixing them with a setting agent and allowing a chemical reaction to take place. Fumes from this process can be harmful, so care should be taken to minimise likelihood of inhalation. The resin mix is held in place by means of an inner and outer plastic bag or sheet and is reinforced by layers of stockinette and if available, glass fibre. Resin is poured into one end of the sealed bags and drawn down into the reinforcing fibres to form the desired shape. This can be aided with suction. Once the resin has hardened and cooled the AFO can be finished by cutting it from the model, trimming it to shape and adding a calf strap to hold it on the leg. The orthosis is worn inside footwear, which secures it distally.

Thermoplastic AFOs

In the last 10-15 years thermoplastics have become available and suitable for use in many developing countries. These materials have advantages and disadvantages. They can be moulded easily and if appropriate thermoplastics are chosen, and appropriate designs used, they can be sufficiently strong for orthopaedic applications.[7,15,21,24]

Thermoplastics can be inexpensive and readily available if they are widely used for other purposes. In the west, they are available in sheets. ALIMCO, a major supplier in India, also markets them in this form.[a1] In some countries where HDPE (high density polyethylene) or PVC (polyvinyl chloride) drainpipes are common, these pipes can be used in the manufacture of orthopaedic appliances.[7,13,23]

In order to become sufficiently malleable to be moulded over a plaster of Paris cast, thermoplastics need to be heated. Ideally this is done in an oven, although minor alterations can be carried out with the use of a heat gun. Temperatures required and times of heating vary between 180º and 300º Celsius depending on the plastic used. As in the manufacture of resin AFOs, a more accurate shape is usually obtained if a vacuum is used. Working with thermoplastics requires certain technical skills, which are less common in developing countries than the skills needed to manipulate

a. ALIMCO. GT road. Kanpur 208016, India.

leather, wood or metal. Wenner explains the basics of using thermoplastics.[28, 29] In Nepal and India, a system has been developed to mass-produce AFOs in a number of different sizes.[23] This has the advantage of significant cost savings due to the reduction in materials and time needed to make custom casts.

When thermoplastics are used in large appliances like Knee-Ankle-Foot Orthoses (KAFOs) a combination with a metal (e.g. aluminium) is necessary. This is used to make side steels and knee joints to allow for flexion as appropriate. However, a 100% thermoplastic orthosis has been produced for children.[25]

The main disadvantages of thermoplastic or resin AFOs are their inability to cater for volume fluctuation and also the fact that the materials cannot "breathe". In hot climates in particular, this can be a problem and may result in skin irritation. Drilling holes or cutting out parts which do not affect the strength and integrity of the orthosis can provide a solution to this problem. Regular washing of the limb and the use of stockings can also be of benefit.

Making a Thermoplastic AFO

The thermoplastic AFO is made on a modified plaster model of the lower leg in a similar way to the resin orthosis (Fig. 23-4). If required for insensitive feet, a micro-cellular rubber (MCR) foot-bed can first be applied to the plantar surface of the cast, and the AFO made over this. The cast is held firmly, with its posterior side uppermost, by means of an imbedded pipe or pole. The hot thermoplastic is draped over it and pinched together at the anterior side. This forms a seal and as the plastic starts to cool, it shrinks towards the cast. Accurate shaping of the orthosis is aided by use of vacuum, but it is possible to obtain an adequate contour by wrapping the hot AFO with elastic bandages. As with the resin AFO, when the orthosis is completely cooled, it is cut from the cast, the final shaping carried out and a calf strap applied.

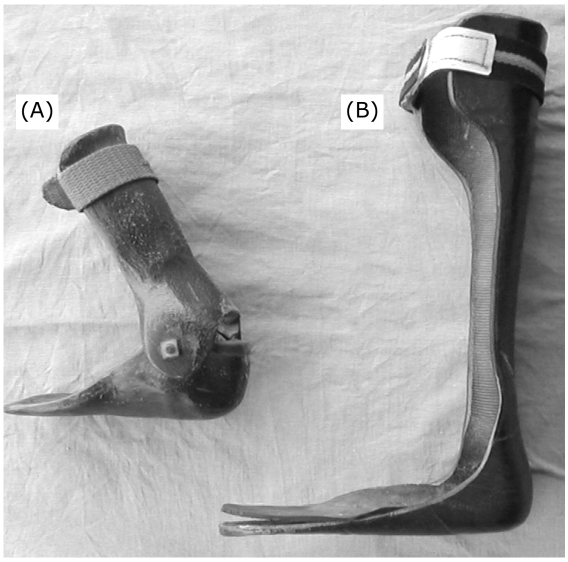


FIGURE 23-4 Two AFOs both made of High Density Polyethylene (Drain pipe). Brace (A) has an ankle joint which allows dorsiflexion.

Alternative Designs of Cosmetic AFO

The main function of an AFO for a client with a foot-drop is preventing plantarflexion during swing phase. Unfortunately the orthosis often also reduces the ability to dorsiflex the foot. This can be a problem especially in cultures where squatting is common for many activities. Solid ankle AFOs are the easiest to make, but they allow no movement of either the ankle or sub-talar joints. There are two designs however, which prevent plantarflexion and allow an appropriate amount of dorsiflexion. These are the Dorsiflexion Assist AFO and the Plantarflexion Stop AFO.

Thermoplastics can be used to make AFOs with different functions. Some differences can be achieved simply by changing the line to which the device is trimmed (the trimline).

Solid Ankle AFOs have a trimline anterior to the malleoli. By cutting the AFO back to behind the ankle, a more flexible orthosis is obtained, which can be used to support a flaccid foot-drop. This is known as a Dorsiflexion Assist or Posterior Leaf Spring AFO.

As the Achilles tendon area of this design of orthosis undergoes considerable cyclic stress, only some thermoplastics are durable enough to be used in this way. Another way of achieving passive dorsiflexion (used during the stance phase of gait or for squatting) is to cut several horizontal slots in the Achilles tendon area, which open during dorsiflexion, but close to prevent plantarflexion. Again, this is not easy to do, and poor manufacture or the use of inappropriate material or thickness will result in fracture of the device.

Passive dorsiflexion can also be achieved using a plantarflexion Stop AFO (Fig. 23-4a). This is more difficult to manufacture. The AFO comprises two sections with a joint at the ankle. This can be made from metal (some are available commercially) and moulded into the AFO. Alternatively it can be made using an overlap of the foot and calf sections, with a pivot connection. There is also a thicker plastic section behind the ankle on both sections, which come together to prevent plantarflexion. The use of joints requires attention to detail when modifying the cast to ensure that the medial and lateral joints lie parallel to each other and do not bind when the ankle is moved.

Finally, a few things to remember when supplying AFOs:

- They should have smooth contours and trimlines to ensure no damage to the insensate leg, and also to reduce the likelihood of stress fractures of the device.
- The AFO should be a close fit, but not apply pressure to the vulnerable bony prominences. When the AFO is removed any red marks on the skin should fade within 30 minutes or there will be danger of skin breakdown. Plastics do not "wear in" in the way that leather does, so persistent red marks should be taken seriously and the AFO modified before it is re-applied. This is easily achieved by using a hot air gun to heat the material locally, then reshaping it.
- If a shoe with a moderate heel height is to be used, the AFO should allow for this, and variations in heel height should be avoided.

LOSS OF JOINT STABILITY

A further secondary effect of neuropathy can be loss of joint stability. This can be as a result of muscle imbalance, as referred to above, or neuropathy in the joint itself, leading to small fractures, which in turn can lead to breakdown of the joint. In the foot, this can result in the "rocker-bottom" foot, where the midfoot collapses to the point where it takes the bulk of the forces exerted during walking. Where joint stability is lost, it is possible to support the affected area by an orthosis in some cases. The purpose of this is to reduce the likelihood of worsening of the condition and in most cases, to facilitate mobility. This section outlines three such orthoses.

Backslab

This is essentially an over-sized temporary AFO, which maintains the ankle in a neutral position during a period of healing of an ulcer. It is used in conjunction with appropriate dressings and bed rest, so in this case mobility during its use is not an aim. The dressings are applied to the limb, and the backslab fitted over the top. It is then held in place by bandages or straps. The fitting requirements for this orthosis are not so strict as described above as it is not intended to be used for walking. The orthosis does not need to be custom made, and can be re-used as long as it is decontaminated to prevent cross-infection. It is often made from thermoplastics or resin as described above, however wood has also been used for this purpose.[29]

Fixed Ankle Brace (FAB)

A Fixed Ankle Brace is another name for a solid ankle AFO (Fig. 23-5). It is used for patients with instability of the foot and ankle or to provide immobilisation of the advanced neuropathic foot.[2,9] It is traditionally made from metal and leather set into a boot with a moulded insole, but can also be manufactured using resin or thermoplastics, as detailed above. As complete immobilisation of the foot and ankle is desired, it is important to incorporate into the AFO a "total contact" insole with pressure relief for the vulnerable regions. Walking with a completely rigid foot is very difficult, so progression is aided with a rocker built into the forefoot of the device.

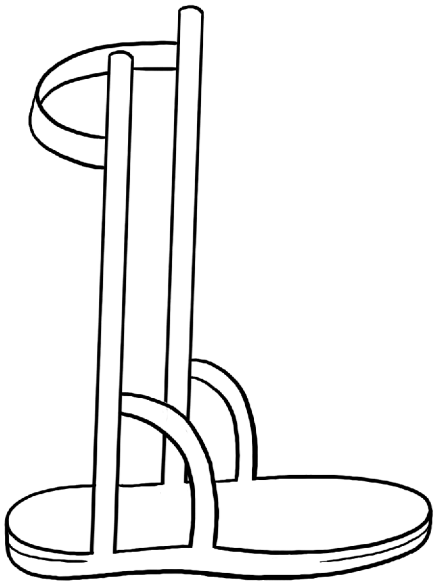


FIGURE 23-5 Fixed Ankle brace (FAB) (from Fritschi[9]).

Patella Tendon Bearing AFO

When foot damage secondary to neuropathy is extensive, it can reach a stage where the plantar surface of the foot is of insufficient area to support the loads applied to it during gait. In this situation the only alternative is to bear weight more proximally. A patella tendon bearing (PTB) AFO offers this alternative. In leprosy and diabetic patients this type of orthosis can be used for ulcer healing.[20]

The principle is the same as the PTB socket in the below knee prosthesis (see below). The body weight is transferred to the calf section of the orthosis via the patella tendon and other pressure tolerant areas of the lower leg, while the foot and ankle are maintained in as neutral a position as possible. As with the AFOs referred to above, the PTB AFO can be made in the conventional style, using metal and leather, or from resins or thermoplastics. The calf section is the most important part of the orthosis, as it must fit well in order to transfer the weight from the limb to the orthosis to relieve the plantar surface of the foot.

There are two main designs of PTB AFO. The first uses an intact proximal section, similar in shape to the PTB socket of a prosthesis, but excluding the distal end. This is held at the required distance above the foot section, so that on standing, the weight is borne through the proximal section. To don the orthosis, the foot must be passed through the proximal section. As the foot is generally not very mobile when such an orthosis is indicated, and is often larger than the proximal section, this design can be very difficult, or even impossible to don and doff.

For this reason, the second design is more common. The calf section is made using posterior and anterior shells, which are separated to don the orthosis, and fastened once the leg is in the desired position.

A design combining these has been developed at Green Pastures Hospital in Pokhara, Nepal. This uses the two-part system, however the anterior and posterior shells are permanently connected medially and laterally by means of a pivot. This allows the proximal opening to be enlarged sufficiently to pass through the foot. It is then closed firmly when the foot is in place, applying the desired forces just distal to the knee (Fig. 23-6).

FIGURE 23-6 Patella Tendon-Bearing brace. The design from Green Pastures Hospital and Rehabilitation Centre in Pokhara (Nepal), shown in its closed and open position.

LOSS OF LIMB

As previously stated, a prosthesis is a device which replaces a missing part of the body. Many amputees manage without prosthetic intervention either through choice or lack of availability of appropriate services. Where improvement of function, mobility and cosmesis can be gained, however, the use of a prosthesis can be beneficial. Although amputations at different sites are common in leprosy, prostheses are frequently only made for the lower limbs.

There are different levels of amputation associated with leprosy, ranging from partial foot through Symes (ankle disarticulation) to trans-tibial. Partial foot amputations (which can be at different levels) have the advantage of being end-bearing. They are normally accommodated by means of a total contact insole together with boots incorporating a rocker sole.[1] A toe-filler, which does not contact the foot at the distal end, is used to maintain the shape of the footwear. An AFO can also be used for partial foot amputees. This can have the advantage of storing energy during early stance and returning it in late stance.

Symes amputation residual limbs can also have the advantage of being end-bearing, and this level of amputation is only advisable when the distal tissue is strong enough to allow this.[9] The other main advantage of a Symes amputation over higher levels of amputation is the fact that less energy is required to mobilise with a longer residual limb.[20] Although Weaver states that Symes amputations are normally preferable to trans-tibial, this is not always possible in leprosy due to previous ulceration of the weight bearing area.[27] Symes residual limbs are however, much harder to fit with a cosmetically pleasing prosthesis due to the bulk at the distal end.

Amputation of part of the lower limb in this disease often follows considerable time of repeated ulceration of the affected part. In an attempt to save as much of the limb as possible, there may be repeated amputations at different more distal levels before a trans-tibial operation is carried out. It is not usually necessary to amputate above this level in leprosy. This is a common level of amputation, and amputees gain considerable benefit from the use of a prosthesis as distal end bearing is not possible. The bulk of this section will major on this type of prosthesis.

Patella Tendon Bearing (PTB) Prostheses

Three parts of the trans-tibial prosthesis can be distinguished: the socket, shin and foot/ankle.

- The socket is the interface between the residual limb and the prosthesis. During stance it transmits the forces generated by gait to the stump, so the shape is very important if skin breakdown is to be avoided. During the swing phase of gait it prevents rotation of the prosthesis on the residual limb and maintains suspension of the prosthesis, either alone or in conjunction with straps or a sleeve.

- The foot is the contact with the walking surface, and provides a smooth roll over from heel strike to toe-off. This is sometimes enhanced by use of an ankle, which provides relative movement between the foot and shin.
- The shin section is the connection between the foot and the socket.

There are two categories of prosthesis: endoskeletal and exoskeletal. In the endoskeletal design the shin section is a tube which is usually attached by means of a series of bolts allowing for angular adjustment. An anatomically shaped foam and cosmetic sheath normally cover this. The exoskeletal prosthesis has an exterior strong shin section, which is shaped to be cosmetically acceptable. This design is harder to align accurately, but is more robust and can tolerate being immersed in water.

Shin pieces and feet are available in prefabricated form in some developing countries.[17] In India, ALIMCO markets a range of components in different sizes, and in Vietnam the INGO Prosthetic Outreach Foundation (POF) supplies the "monolimb" system which is based on a computer design of the socket.[11] This is a PTB socket with shin section attached. The foot is a separate component. The Jaipur foot, developed by Dr. P K. Sethi, is used both in India and further afield.[18,22,28] The foot can be used without shoes and allows the user to squat, which is important in some cultures. The ICRC (International Committee of the Red Cross) has developed a complete prosthetic system, together with a manual explaining its use, which is available in some areas.[8] Some companies in the 'West' are also producing systems with developing countries in mind.

Although the use of prefabricated components in the manufacture of prostheses makes the process quicker, it is possible to produce them from raw materials. In various places there are descriptions of prostheses from aluminium, bamboo and plastics available.[7,8,11,12,13,16, 28, 29]

Socket Design

The PTB socket is commonly used for trans-tibial amputees. The principle of the design is to transfer forces incurred during gait to pressure tolerant areas of the residual limb, whilst protecting those areas which are pressure sensitive. It is therefore essential to have a good understanding of the anatomy of the lower limb to make an effective socket. The socket is custom-made for each amputee to ensure a good fit. To ensure that the correct information is collected for the production process the use of a common measurement form is recommended (Appendix I). The residual limb is loaded on the patella tendon, and this is counterbalanced by pressure in the popliteal area. Additional load is taken on the tibial flares. Soft tissues are also compressed to provide containment, load bearing and aid venous return. Pressure is avoided on the bony prominences of the fibular head, the tibial tubercle and the cut ends of both bones. The anterior distal end of the tibia is also protected, as are the hamstring tendons (Fig. 23-7).

The basic PTB socket covers the residual limb below the knee and extends proximally to the mid-patella anteriorly, to the level of the tibial plateau posteriorly and proximally to this on the medial and lateral sides (Fig. 23-8). Where supracondylar suspension is required from the socket, these sides extend further, and the socket is cupped in above the femoral condyles. The socket is manufactured in a similar way to the AFOs described above. Initially a cast is taken of the residual limb, together

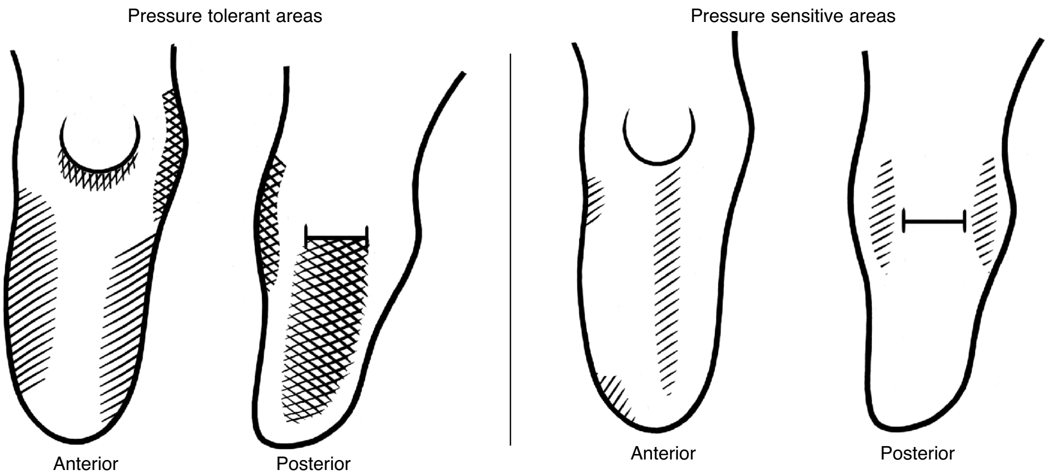


FIGURE 23-7 Pressure sensitive and tolerant areas on the stump (From Deckers[6] with permission).

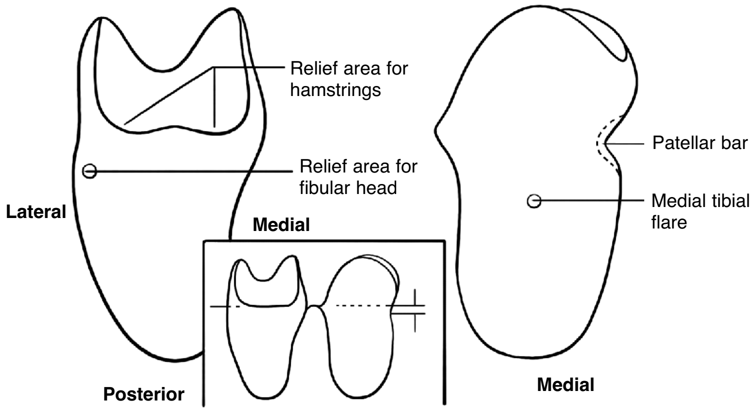


FIGURE 23-8 The trimlines for a PTB socket (from International Committee Red Cross manual, with permission[8]).

with measurements. The positive cast is carefully modified to ensure that the forces of gait are transmitted to the pressure tolerant areas. This model is then used to manufacture the socket.

Some prostheses are made with a hard socket against the limb, however in leprosy an intermediate soft socket is strongly recommended to provide extra protection. The soft interface can be made with resilient foam such as Pelite or Evazote. These can be shaped to the cast using heat. Microcellular rubber can also be used, however this needs to be shaped by cutting and sticking it onto a thin leather liner. The hard socket is then built on top of the soft liner. This can be made from reinforced resin or thermoplastics as described in the AFO section.

Suspension

Choice of suspension for a prosthesis depends on a number of factors, including the shape and length of the residual limb, the dexterity of the amputee's hands and even the climate. The supracondylar socket incorporates suspension in its design. If this is not used, the basic PTB socket is held onto the leg with a strap or elastic sleeve. The strap is tightened above the patella, and has two arms, which attach medially and laterally to the socket. Positioning of the attachments is important to allow for firm location of the socket on the limb as well as the ability to flex the knee in sitting. Sleeve suspension fits over the proximal part of the prosthesis and 10-15 cm above the knee. This type of suspension can be very hot to wear, so may be less suitable for tropical climates.

Feet

Prefabricated feet are available in some areas, however it is also possible to manufacture them from wood and rubber (Fig. 23-9). The simplest design is the Solid Ankle Cushion Heel (SACH) foot. This incorporates a rubber heel wedge into the wooden foot. As the name suggests, there is no ankle movement, but the heel wedge compresses during early stance to simulate plantarflexion. Variation in the hardness of the rubber heel (which can be achieved by alternating rubbers of different densities) can be useful to control the rate of progression from heel-strike to foot-flat during the early part of the stance phase of gait. Pluyter describes the manufacturing process for different types of feet in more detail.[16]

FIGURE 23-9 A wooden foot which can be made locally in the workshop.

In some cases it might be appropriate to consider using a rubber bumper at the end of the shin pylon instead of a foot. Although this is cosmetically inferior, ease of walking over uneven terrain may be increased and pressures on the residual limb may be reduced. The foot is often the component which requires the most maintenance, so where this is a problem, dispensing with the foot is a possibility. The idea of having no foot is, however, an anathema to many people. The use of a small rocker can be a compromise (Fig. 23-10).[16]

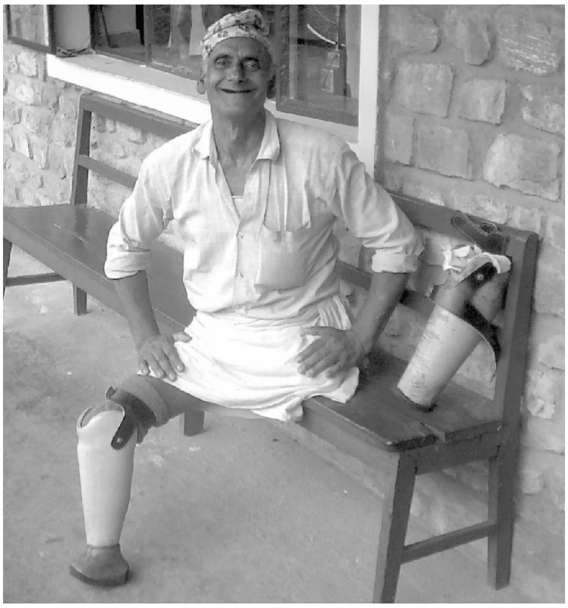


FIGURE 23-10 A man using a small prosthetic foot rocker, useful in uneven terrain.

Symes Prostheses

Symes amputations have the advantage that the residual limb is long and can be end-bearing, so ambulation without the aid of a prosthesis or other walking aid is possible. This level of amputation does, however present some problems:

- Symes residual limbs are often bulbous at the distal end, as the malleoli are wider than the shafts of the tibia and fibula. The shape of the residual limb is difficult to fit with a cosmetically pleasing prosthesis, as the ankle will almost always appear disproportionately large.
- The length of the limb is advantageous in terms of the energy needed to walk, however there is limited space for a prosthetic foot.

Ideally, weight can be borne through the end of the limb, although sometimes the fat pad moves away from the distal part of the tibia, making it unstable. The socket is made to accommodate end-bearing or take some of the forces more proximally, depending on the characteristics of the residual limb.

Older designs of prosthesis for Symes amputees were essentially boots made from leather, with a moulded insole and lace fastening. Toe fillers could be added to the sole and the whole thing inserted into an outer boot to give a more cosmetic finish. Nowadays it is more common to use a hard socket with a cosmetic foot. The socket must be sufficiently close-fitting to prevent rotation of the residual limb within the prosthesis.

Due to the shape of the residual limb, special consideration needs to be made in manufacture to allow the bulbous end to pass through the narrower section of the prosthesis. If a liner is used (and this is recommended in leprosy) a split down its length will make this possible. The outside of the liner is then built up to allow it to pass into the prosthesis if an intact shell is used as a socket. There are also other designs of sockets. Some designs are more open, whilst others, like the 'Obturator Design', have a window and shutter/panel (Fig. 23-11).

The foot for a Symes prosthesis is attached directly to the socket. If there is sufficient space, a low wooden SACH design can be used. Otherwise a robust rubber sole can be attached to the socket and a toe filler used anteriorly. It is important that the foot does not impede progression from heel strike to toe–off. A softer rubber heel can provide some shock absorption.

Pointers in Fitting and Alignment

It is important when supplying a prosthesis that it is a good fit and well aligned.

- If a socket is a poor fit there is a danger that damage will be caused to the residual limb or the prosthesis may not be firmly attached to the body. It is common for a residual limb to change in shape and volume over the first months or even

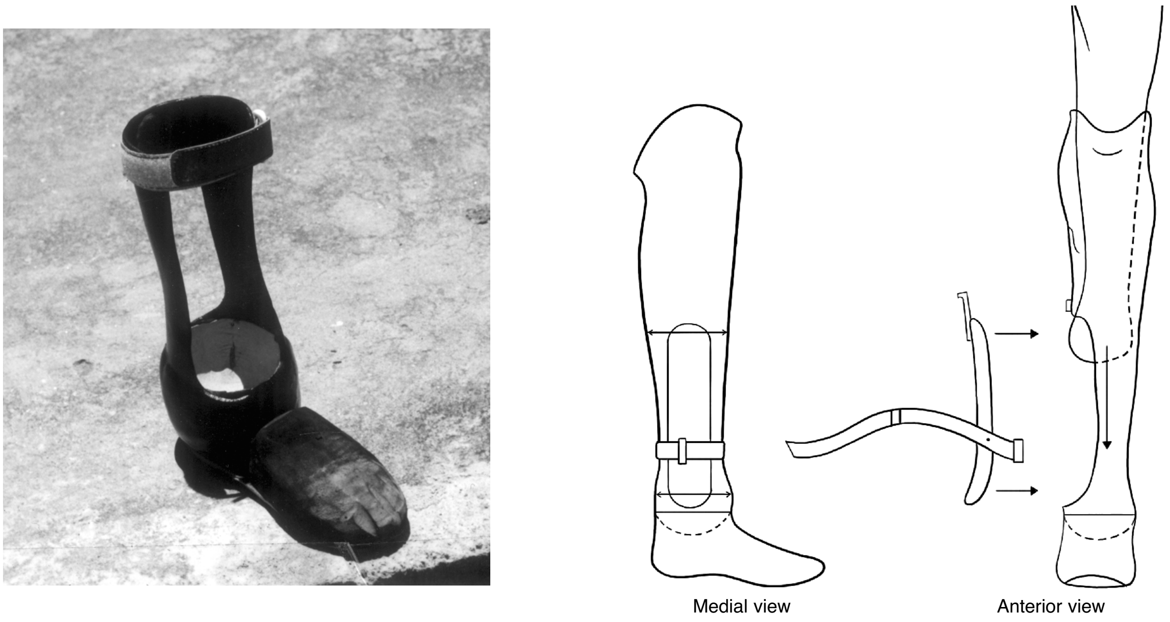


FIGURE 23-11 Two Symes prosthesis designs, one with an open socket and the other using the window and panel principle.[81]

years after amputation. Normally the prosthesis is worn with one or more socks between the residual limb and the soft socket. The initial swelling may reduce and the socket become loose. For small changes, the addition of a sock may be sufficient to make up for the reduction in volume. A thin leather lining added to the soft socket will also make the socket more snug. Eventually, however it is recommended that a new socket be made for the prosthesis. Several socks or liners will only compensate for overall volume reduction, whereas the reduction tends to take place more in the pressure tolerant areas, so the overall shape required is different.

- Approximate trimlines are determined at the casting stage of the prosthesis, as the need for a particular type of suspension or additional medio-lateral stability is taken into account. However, the trimlines of the socket are finalised when the amputee is wearing the prosthesis. It is important to ensure that the socket is comfortable in sitting as well as during gait.
- The position of the socket with respect to the foot is also very important in maximising function. This is known as the "alignment" of the prosthesis. This alignment takes place in all three planes. In the sagittal plane, flexion/extension of the socket and dorsiflexion/ plantarflexion of the foot is considered, together with the anterior/posterior shift of the socket over the foot. In the coronal plane, abduction/adduction of the socket and inversion/eversion of the foot, together with mediolateral shift of the socket over the foot. In the transverse plane, the rotation or toe-out of the foot with respect to the socket is determined. The length of the prosthesis is, of course, also important. There are standard bench settings for the relative positions of the socket and foot, but the optimum setting is best achieved on an individual basis with the patient giving feedback. It may also need alterations once the patient has gained confidence and has established a walking pattern. Alignment can also be a compromise between the perfect gait sought by the prosthetist and the comfort and security desired by the patient.
- When the prosthesis is being fitted, it is important to ensure that no undue pressures are placed on the residual limb. After a period of walking the prosthesis is removed and the limb examined. Impressions from the socks will remain on the skin, and show whether pressure is being borne on the sensitive or tolerant areas. If adjustments are not made at this stage, it is possible that there will be damage to the limb in the longer term. Alterations can be made to the soft socket by adding additional pads on the outside to increase pressure locally, or thinning the socket to decrease it. The hard socket is adjusted by heating it in the desired area and re-contouring it when soft.

CONCLUSION

The purpose of this chapter is to outline some of the issues related to prosthetics and orthotics as related to leprosy. Manufacturing and supplying quality custom-made orthopaedic appliances is a continuous challenge. It is not something to undertaken lightly or by untrained personnel. Good results can only be achieved by a combination of knowledge, understanding, skills and co-operation. Co-operation with other (para)-medical disciplines is desirable, but if a truly beneficial outcome is to be achieved, then co-operation with the client is essential.

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