

A SIMPLIFIED BELOW-KNEE PROSTHESIS

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INTRODUCTION

Working in an overseas situation without staff trained in prosthetics fabrication, of necessity, has caused us to develop a simple yet practical method for making a below-knee prosthesis. Although developed particularly for leprosy patients, this prosthesis has been used where there has been amputation for other indications as well.

The fabrication technique described in this paper was developed because of a great need. In this country a person must be ambulatory to live as there are no other means of transportation for the average individual. Farming is almost the only occupation and oftentimes farms are miles away from home. The only prosthetic device for amputees in the past was a kneeling peg as nothing more refined was available or even feasible in the economy. This device was highly unsatisfactory with the result that most amputees became beggars.

One factor that contributes to the success of the prosthesis described in this article is that the people really need to walk and are by nature excellent walkers. Ambulating 20 to 30 miles a day is not at all uncommon. Training to walk with the prosthesis has never been very difficult. Even in instances where we have adapted this technic to make an above-knee prosthesis for a high femoral amputation, we have always ultimately obtained satisfactory ambulation. We do not find alignment, exact length, or any

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other measurements at all critical, and have seen patients satisfactorily compensate for gross misalignment and obtain good function.

Other factors contributing to the success of the prosthesis may be related to the disease itself; e.g., anesthesia is often present, but this may be of negative value in that the patient does not recognize early stump trauma. On the other hand, pain in the stump does not deter use. Also, there is often vasomotor loss with consequently little or no sweating of the stump which helps to prevent maceration and socket deterioration. On the other hand, this type of prosthesis has been provided to at least 10 patients who have had amputation for conditions other than leprosy where these factors did not apply, and yet they have been completely successful.

FACILITIES AND STAFF

Adamawa Provincial Leprosarium is the center for treatment of problem cases of leprosy for a large area in which there is a population of roughly one million. There are about 30,000 patients treated in out-patient clinics in the area, extending as far as 200 miles off. There are from 500 to 600 patients treated here annually on a permanent or temporary basis. For those needing hospitalization we have an 88-bed unit with an average census of about 60 patients.

The author is in charge of all aspects of the medical program for this unit, and nominally for out-patient care as well. Mrs. Pfaltzgraft is Nursing Supervisor, and another expatriate in the family cares for the non-medical aspects of the program. The balance of the staff is Nigerian, and almost without exception patient or ex-patient. There are about 20 medical attendants and one Nigerian Registered Nurse. Also, one patient has been trained to make prosthetic shoes and the below-knee prosthesis described herein.

TECHNIC

Since 1961 we have fitted this prosthesis to approximately 42 patients. The prosthesis lasts from 3 to 5 years, and if the fabrication is done correctly and maintenance is performed on the areas where there is friction, it should last practically indefinitely. There are 3 parts that need replacement with wear: 1. the retaining strap (if used), 2. the sole or distal tip, and 3. the socket-brim leather. One prosthesis has lasted just about 6 years. (I believe it was the first one we made for an old rather inactive man.) The patient doesn't give it excessive wear, but it has had almost no repairs at all.

Actually, many of the second prostheses we have made have been simply replacements because of improved technics, especially that related to increasing the level of the socket brim proximally to incorporate the patella and femoral condyles.

The technic used will not be described in detail as in many respects it is simply the adaptation and modification of already well-known technics.

First, the socket is made directly on the stump itself instead of making a positive and then a negative stump cast. For this reason, any alterations of pressure indicated in certain areas on the stump will need to be made by increase or decrease of pressure on the stump itself.

Where reliefs are needed in the socket, pads of cotton or felt of the desired size and thickness are fixed in areas indicated onto the stump (Fig. 1). This leaves an area of relief in the final prosthesis. Most commonly needed areas of relief are the distal end of the anterior tibial ridge and over the head of the fibula.

It is also advisable to increase the pressure in the area most suitable for weight bearing as is commonly done in the PTB prosthesis. This is accomplished by increasing pressure on the *outside* of the socket as it is being formed over the areas of the patella, the patellar tendon, and the tibial condyles. This is done by firmly bandaging a small, shaped, foam rubber pad over this area (see Fig. 5).

The socket is of the soft type with an inner layer of soft foam rubber applied to the stump over a single layer of stockinet (Fig. 2 and 3). The solid socket is developed over this by adding two layers of stockinet which are impregnated with epoxy resin (Fig. 4). This is contoured at its proximal end to cover the patella and the condyles of the femur but leaving adequate room for the hamstring tendons posteriorly on knee flexion.



FIGURE 1. Cotton pads fixed with pre-vulcanized latex over areas where relief is indicated.

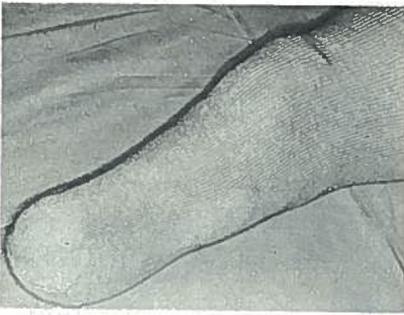


FIGURE 2. Inner layer of stockinet applied next to the skin.

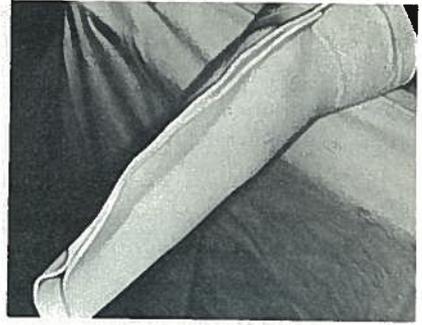


FIGURE 3. Layer of $\frac{1}{8}$ -in. soft foam rubber glued to stockinet.

The socket is removed from the patient and set up in a jig using a small truncated cone of wood for the distal end of the prosthesis (Fig. 6). In this technic, the cone becomes the weight-bearing end of the prosthesis as a foot is not practical in this situation; however, a foot could easily be added as shown in Figure 16 where a SACH foot has been attached. After the socket has been fixed at one end of the jig and the peg-like prosthesis at the other end, the two are joined together with a flexible corrugated cardboard. This is then covered by two layers of stockinet which are impregnated with epoxy resin by direct application (Fig. 7). The prosthesis, which is now sturdy, can be removed from the supporting jig and fixed vertically with the socket opening downward. At this stage, two or three more layers of stockinet are added. A polyvinyl alcohol cone is now made to enclose the prosthesis, and epoxy resin is poured into the open top of the cone as in the conventional prosthetic technic (Fig. 8).

The brim of the socket is then trimmed to fit the stump allowing for the hamstring tendons posteriorly (Fig. 9), and a narrow leather cuff is cut and fixed to the brim of the socket to prevent undue wear (Fig. 10).

In many instances, especially if the stump is long, a simple friction fitting is adequate to retain the stump in the socket. No stump socks are worn. This is not, however, a true suction socket as the inner surface which is

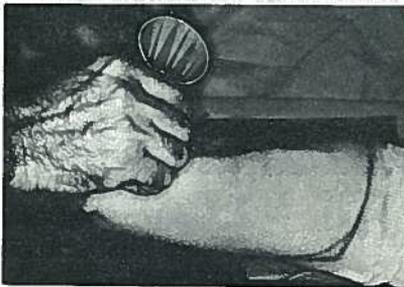


FIGURE 4. Application of epoxy resin on two layers of stockinet.

made up of the ribbed surface of stockinet is not smooth. We have found that amputation should preserve as much length as possible. A well-planned amputation just proximal to the malleoli is much simpler to fit than a Syme's amputation and, in fact, is the type of stump most easily fitted with this type of prosthesis.



FIGURE 5. Snug bandaging of impregnated stockinet incorporating prepatellar pressure pad.

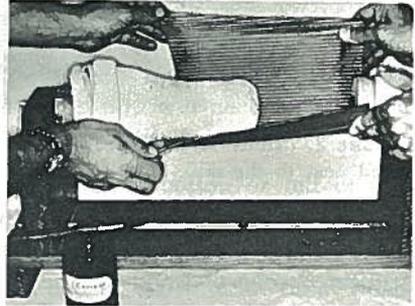


FIGURE 6. Socket and distal wood cone set up in jig.

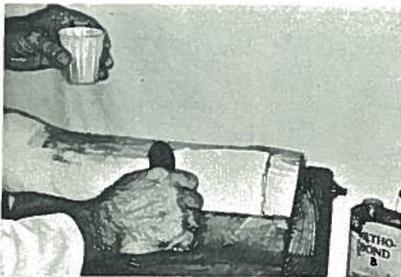


FIGURE 7. Application of epoxy to outer shell.

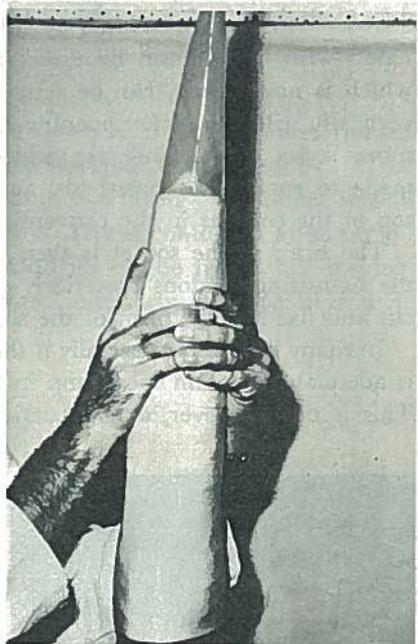


FIGURE 8. P.V.A. cone providing outer finish to prosthesis.



FIGURE 9. Trimming socket brim.

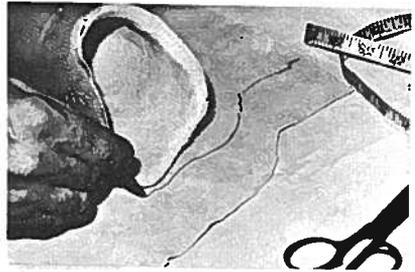


FIGURE 10. Cutting leather cuff for socket brim.

If friction between the stump and socket will not retain the prosthesis, a supporting strap must be affixed. This is done by inserting sheet metal screws with rather large heads into the prosthesis about $1\frac{1}{2}$ in. distal to the brim and parallel to the lines of the hamstring tendons (Fig. 11). An elastic rubber band (Fig. 12) is attached to these two screws (we have been using discarded inner tubes to make the rubber strap). This strap passes from the medial screw across the popliteal space laterally and superiorly, crossing proximal to the patella, and then passes inferiorly and laterally and is attached with slight tension to the lateral screw head (Fig. 13).

The distal end of the prosthesis is completed by cutting to the correct length and affixing a piece of car tire rubber to it with rubber cement and a few nails (Fig. 14 and 15).

Figure 16 shows a cross section of the completed prosthesis.

When it is necessary to alter the socket due to stump shrinkage, it is accomplished by filling in the void with a mixture of prevulcanized latex and cork dust or with a silicone rubber. A length of stockinet is pulled over the stump and the filler is poured into the socket, the stump is inserted, and the patient walks on the prosthesis until the filling material sets. This new layer of stockinet is thus incorporated into the prosthesis, and a new leather cuff must be fitted on the brim.

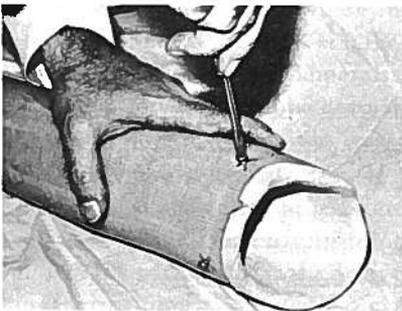


FIGURE 11. Inserting screws for supporting strap.

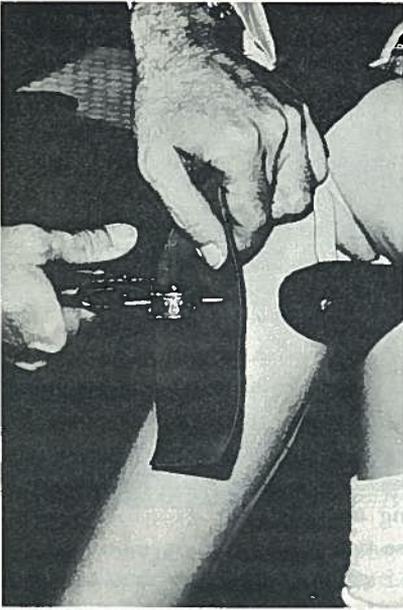


FIGURE 12. Attachment of supporting strap.

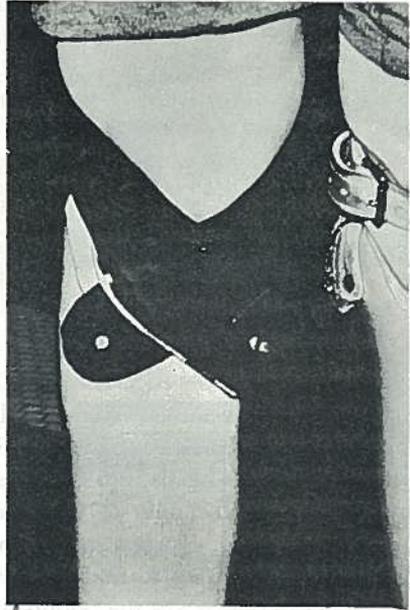


FIGURE 13. Posterior view showing detail of supporting strap.



FIGURE 14. Attaching tire sole to distal end.

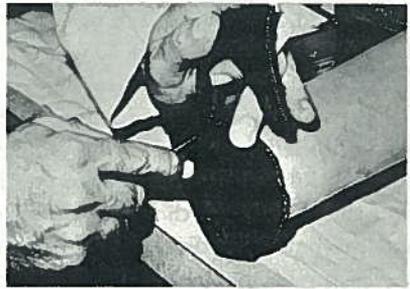


FIGURE 15. Trimming sole rubber.

DISADVANTAGES

The following are some of the problems that arise with the preparation and use of this prosthesis:

1. The development of ulceration from overuse at the beginning. Since many stumps are anesthetic, there is a tendency to misuse or overuse the prosthesis. This causes early breakdown of critical areas such as over the head of the fibula, areas around the brim of the socket, and the tip of the stump. Further tissue breakdown may occur because of stump shrinkage.

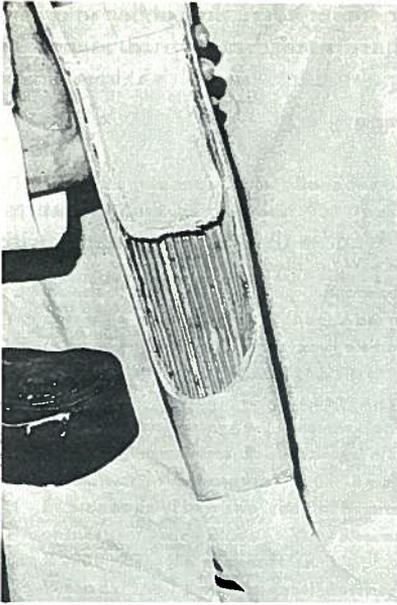


FIGURE 16. Cross section of completed prosthesis.

2. The danger of misuse of epoxy resins in following this technic, especially when making the socket on the stump. The socket must be made snug without producing a break in the skin, the heat of the epoxy catalyization must not burn the stump, and an accurate fit must be obtained.

3. The expense of epoxy resins. A much cheaper prosthesis could be made with polyester resins; however, we have not been able to utilize polyesters due to their instability in a tropical climate.

4. There is the potential danger that with the easy availability of a simple prosthesis, amputation is resorted to too readily. In leprosy, amputation should only be a last resort and there are many conservative measures which are indicated, both surgical and nonsurgical, before amputation should be elected.

ADVANTAGES

The merits of this prosthetic technic are:

1. It is inexpensive. The prosthesis can be manufactured from materials costing approximately \$5.00 to \$10.00 depending upon the source of supply.

2. The simplicity of production (Fig. 17).

a. The technic is simple and easily learned. We have been able to successfully teach this technic to an African who knows no English but is quite clever with his hands.

b. It requires no expensive tools or equipment.

c. A prosthesis can be completed in 5 to 7 hours total working time.

3. Durability. Except for the leather socket edge, the rubber sole, and the supporting strap, many prostheses have needed no repairs after 4 or more years of hard use. The three repairs listed can all be done by an entirely untrained person.

4. It is completely practical.

- a. It is lightweight, averaging 3 to 4 lb.
- b. The training period has been usually negligible. In some instances, patients have donned the prosthesis and walked off immediately with a relatively good gait, and no other support, even though they had never previously worn a prosthesis (Fig. 18 and 19).
- c. A rapid, yet accurate and simple method has been devised to make alterations to the socket when stump shrinkage occurs. It should be noted that alterations to care for increase in stump size are much more difficult, and except for minor alterations it becomes simpler to make a completely new prosthesis.



FIGURE 17. Patient showing mid-calf amputation and prosthesis.



FIGURE 18. Prosthesis donned by patient.



FIGURE 19. Photo shows sandal with microcellular rubber insole provided for all patients with anesthetic feet.

SUMMARY

A simple, economic below-knee prosthesis is described that is practical for use where professional prosthetic facilities are not available. The technic for making this prosthesis is outlined briefly and relative disadvantages and advantages are covered. It is shown that the chief problems encountered are the result of overuse and misuse of the prosthesis, because many stumps are anesthetic, and improper use of epoxy resins. Some of the advantages of this prosthesis are its low cost and simplicity to produce, its light weight, and its durability.