Fabrication of the Water-Resistant Recreational B/K Prosthesis

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INTRODUCTION

The Veterans Administration Research Engineering Center (VAREC) has developed a method to provide a water-resistant prosthesis using commercially available components. This method allows a reduction in fabrication time as compared with others, such as the "Ultra Light" or Otto Bock methods. This is made possible by the use of the commercially available Beachcomber foot. The following article describes the fabrication technique for a below knee prosthesis only. However, with the use of the Otto Bock plastic knee set-up and the elimination of the plastic tubes, this method may also be used for above knee prostheses.

CASTING AND FITTING PROCEDURES

Using standard prosthetic procedures, a negative impression is taken, a positive model made and modified, and a socket laminated. The socket's distal end is foamed to form an extension for attachment of an alignment coupling.[1] The proper size foot is selected and standard bench alignment is used to assemble the component parts. The Staros/Gardner alignment fixture is ideal for this set-up. Figure 1 illustrates the prosthesis with the alignment

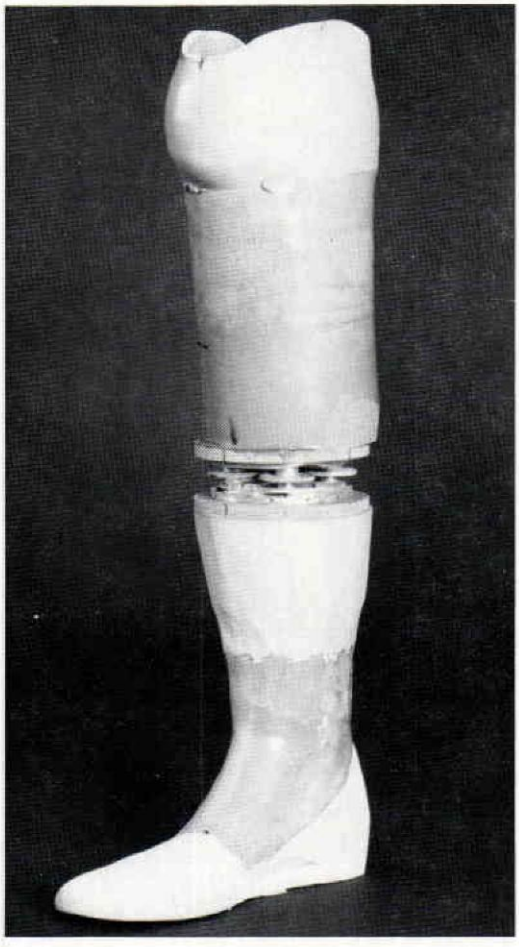

Figure 1. Prosthesis ready for fitting (Old-style foot).

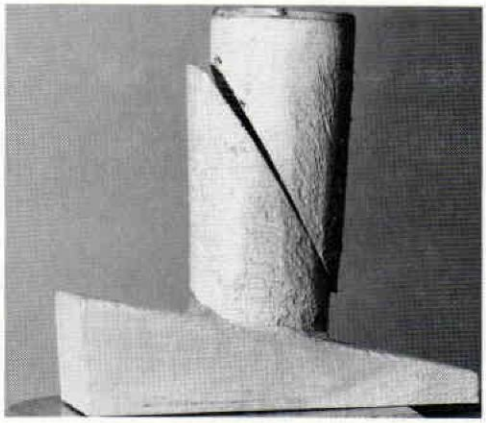

Figure 2. Wooden holding device for transfer fixture.

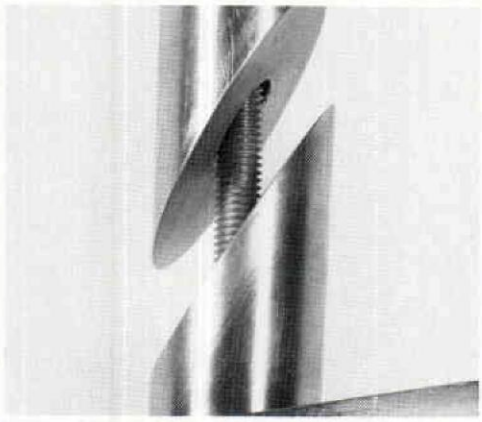

Figure 3. New aluminum holding device.

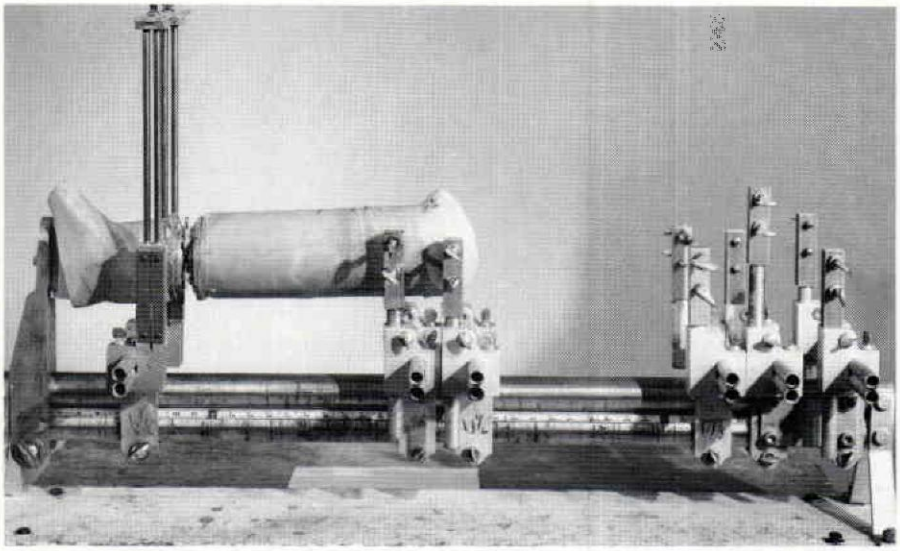

Figure 4. Prosthesis in transfer fixture.

fixture in place, ready for fitting and dynamic alignment, with the rubber sole cemented to the foam ankle block.

With the fitting and dynamic alignment procedures completed, the prosthesis is now ready to be transferred and finished.

TRANSFERRING PROCEDURE

The rubber sole should be removed at this time. A simple holding device is used to hold the foot during the transfer procedures (Figure 2). By tightening the ankle bolt, the top portion within the tube is offset, similar to the way most footrests on wheelchairs are held in place. Figure 3 illustrates the new holding device presently being used. This device may be used in either the horizontal or vertical transfer fixture. We at VAREC prefer to use the horizontal fixture.

The prosthesis is then secured in the transfer fixture with a saw guide in place (Figure 4). Two saw cuts are made through the foam sections, one below the alignment fixture, one above it. The first cut should be through the ankle block as far proximal as

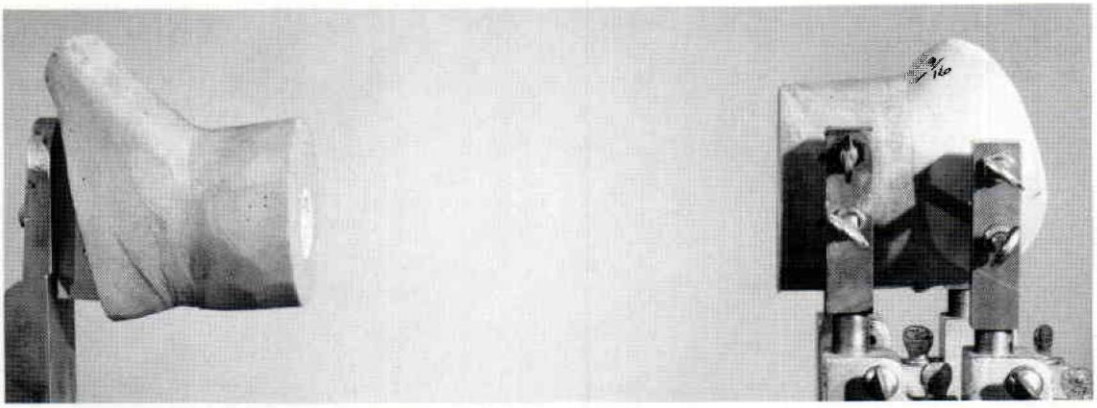

Figure 5. Prosthesis after alignment fixture is removed.

possible. The second cut is made at the very distal end of the socket, and should expose the lamination. Figure 5 illustrates the prosthesis after the two saw cuts have been made and all materials in-between have been removed.

A piece of 1¼" O.D. Poly Vinyl Chloride (PVC) tubing—available in most hardware stores—is measured and placed in the void between the ankle block and the socket. This tube is then centered on a similar tube already in the ankle block and the very distal end of the socket. Bond it in place (at VAREC we use Devcon 5 minute epoxy for bonding) and let the epoxy harden. Be sure to place paper over the fixture, to protect it from the epoxy. Figure 6 illustrates the tubing bonded in place. Once the epoxy has hardened, the prosthesis may be removed from the transfer fixture.

FINISHING THE PROSTHESIS

A ¼" hole is drilled at the posterior distal end of the socket in the PVC tubing, and a ¼" O.D. PVC flexible tube is installed. This tubing allows the air to escape as water enters the larger tube. Trim the foam from the posterior part of the socket to allow the tube to lay against the socket wall. The PVC tubing should be long enough to reach from the hole to at least 2" above the proximal posterior (center) trim line of the socket. This step is important, and will

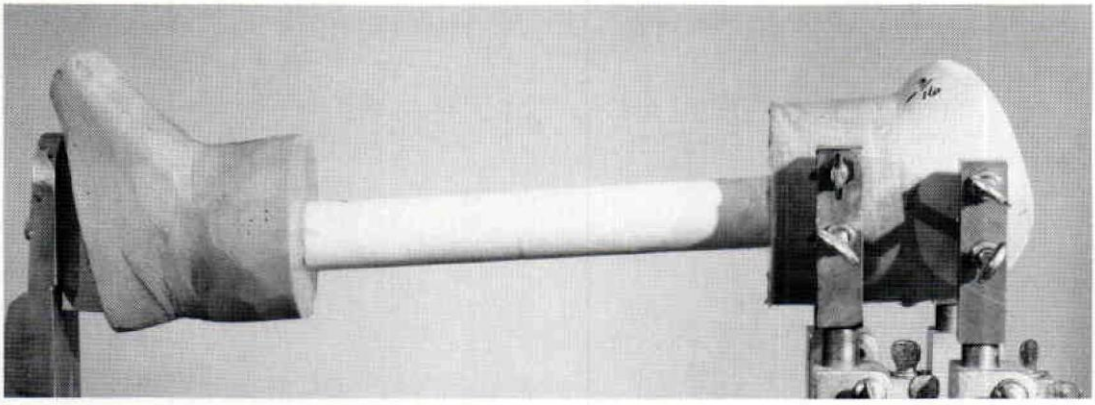

Figure 6. PVC (1¼") tubing bonded in place.

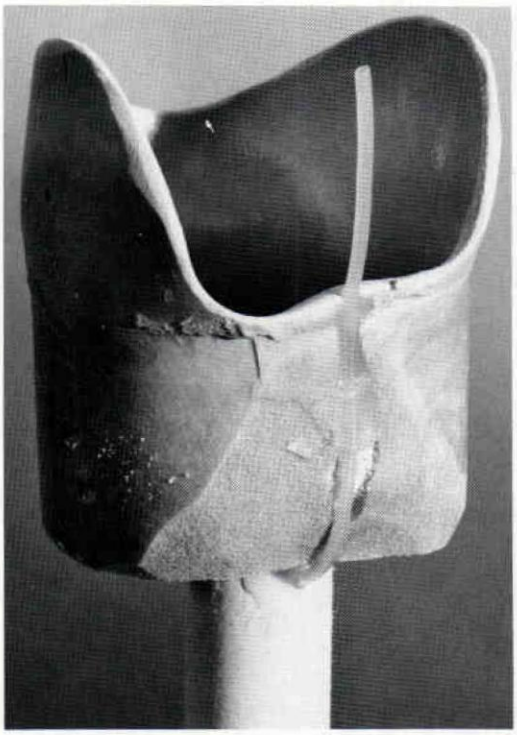

Figure 7. Air tube bonded in place.

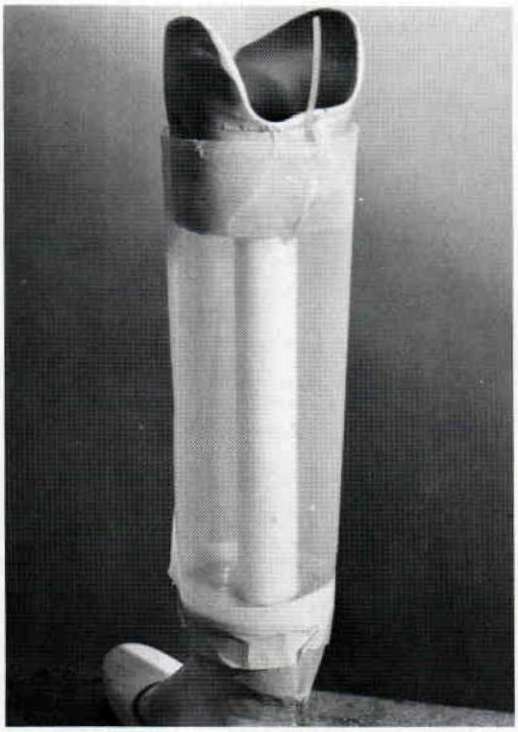

Figure 8. Plastic sleeve taped in place ready for pouring foam to obtain proper shaping.

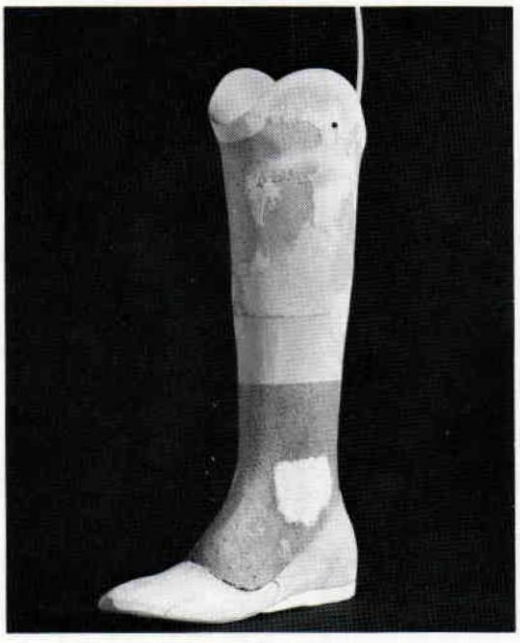

Figure 9. Prosthesis ready for lamination.

prevent resin from blocking the tube during final lamination. Bond the small tube in place with epoxy. Figure 7 shows the small tube in place.

Place a thin piece of polyethylene or X-ray film over the prosthesis, forming a sleeve in which to pour the foam (Figure 8). Tape it in place so the foam may be poured into the sleeve. Mix the necessary amount of foam to fill the cavity. The amount of foam used varies with the size and length of each prosthesis. Pour the mixture and let it harden.

After the foam has hardened, shape the prosthesis as desired to agree with measurements, filling all voids. The foam ankle block must be reduced to accommodate the thickness of the final lamination, thus providing a smooth transition to the rubber sole. The prosthesis is now ready for lamination (Figure 9).

LAMINATING PROCEDURES

The conventional lamination procedure is used. Although vacuum is not necessary however, it does help hold the PVC in place around the ankle. Two layers of nylon stockinette are used for final lamination. The air tube is taped closed and a piece of Kemblo rubber is glued over the PVC tubing at the distal end.

Measure a piece of nylon stockinette, wide enough to fit over the prosthesis, and twice the length of the prosthesis plus three or four inches. Locate the middle of this piece and sew a semi-circular shape at that point. Then pull the stockinette over the prosthesis. Reflect the remainder over the first part of the stockinette (Figure 10). Make sure the proper size of stockinette is used, so that there are no wrinkles left. Tie the stockinette off to the mandrel at the proximal end of the socket.

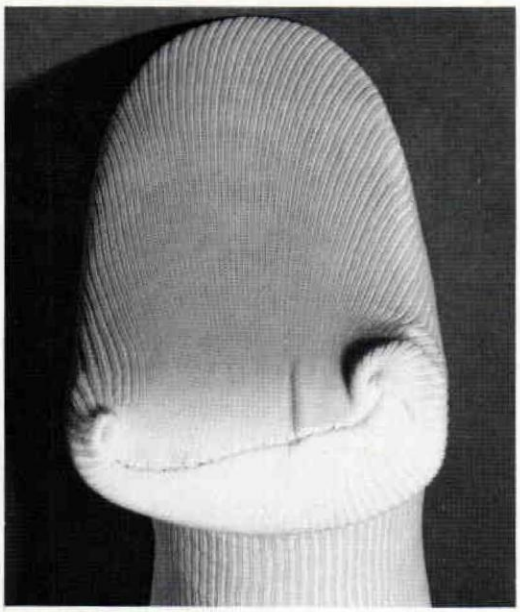

Figure 10. Two layers of stockinette pulled over prosthesis. Seam over keel area.

Pull a snugly fitting PVA sleeve over the entire prosthesis. The sleeve should be pulled over the prosthesis, in order that the small opening ends at the most distal part of the foot (keel area). Tie the PVA sleeve to the mandrel. If vacuum is used, connect it at this time.

Mix the proper amount of resin and the appropriate color for the prosthesis. Pour the mixture into the PVA sleeve. Work the resin into the stockinette. String out the resin, as excess resin adds weight, not strength. Once the resin is in place, pull the small end of the sleeve back and tape it off with pressure sensitive tape. This will give you a smooth line at the keel area. Remove excess resin in the small part of the sleeve. Let the resin cure properly.

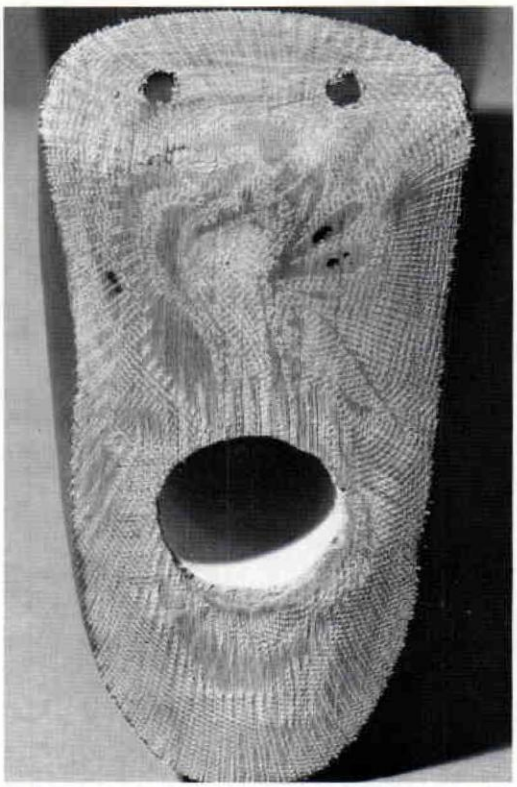

Figure 11. KEEL area sanded and ¼" holes drilled for bonding sole to KEEL.

Trim all areas to finish the prosthesis. Remove the Kemblo patch, exposing the PVC tubing. Trim the air tube at the proximal edge of the posterior wall. Sand the distal part of the keel[2] so the rubber sole may be bonded in place. Drill two ¼" holes in the keel (Figure 11). Tape should be placed around the borders of the keel in order that the cement does not spread.

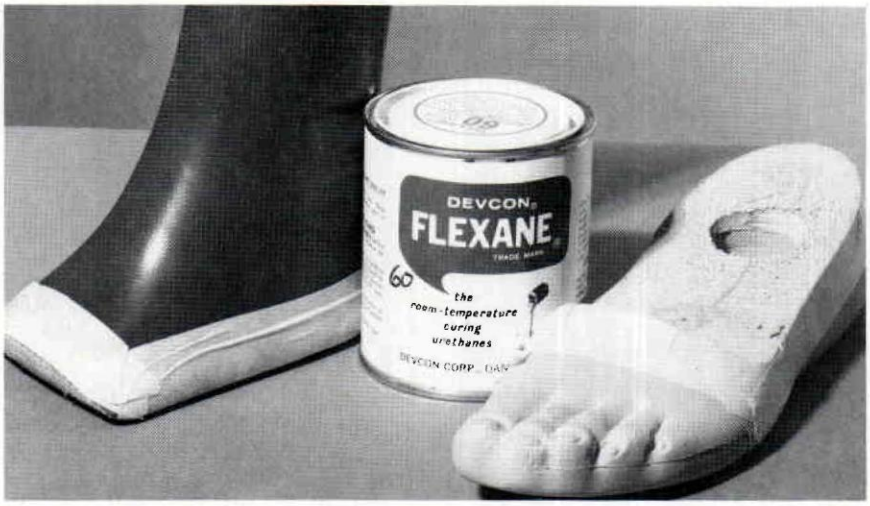

Figure 12. Tape placed around edge of KEEL and rubber sole.

Tape should be placed around the rubber sole edges for the same reason (Figure 12).

To cement the rubber sole in place, use Devcon Flexane Putty #60 or #80 (#60 is more flexible). Mix an amount according to directions provided with the cement. Bond the sole in place, matching the hole in the rubber sole to the PVC tubing opening. Pressure-sensitive tape may be used to hold the sole in place until the cement cures. It should cure for twenty-four hours before the prosthesis is worn. Be sure that the flexane is placed into the two ¼" holes drilled in the keel. The cement line may be painted with the proper color to provide a better appearance (Figure 13).

To allow water to drain out of the socket area, three or four holes ⅛" to 3/16" are drilled at the distal end of the socket. Their location must be within the PVC tubing. If a liner is used, a hole should be drilled in the same area. The first prosthesis fabricated at VAREC had plugs with holes (Figure 14); however, it was found that drilling a few holes worked better.

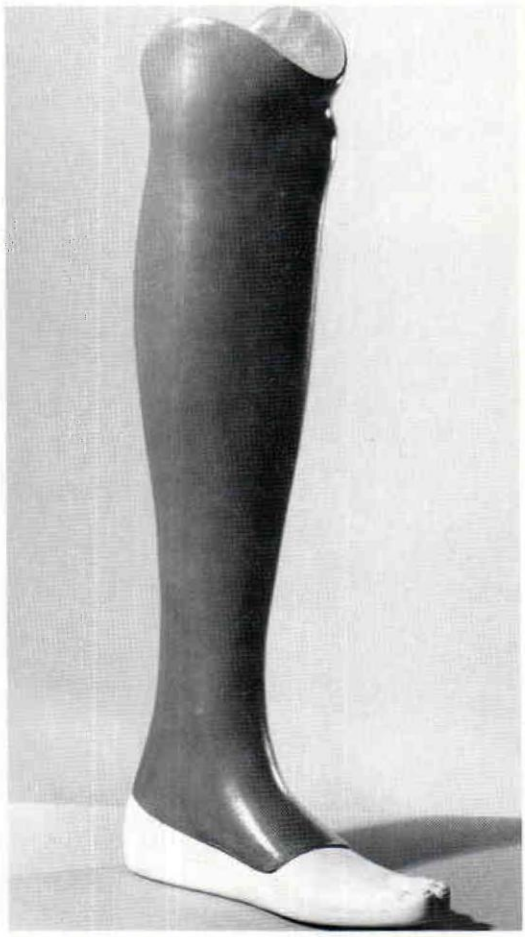

Figure 13. Rubber sole bonded to prosthesis.

DELIVERY

With a PTB design, add a suspension strap, fabricated from waterproof materials; the prosthesis is now ready for delivery. Figure 15 illustrates a posterior view of the air hole. Figure 16 illustrates the com-

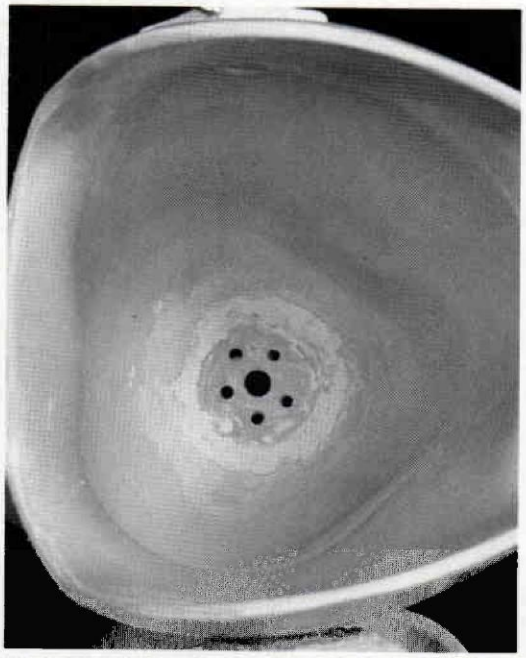

Figure 14. Distal end of socket (interim) with holes to allow water to drain from socket.

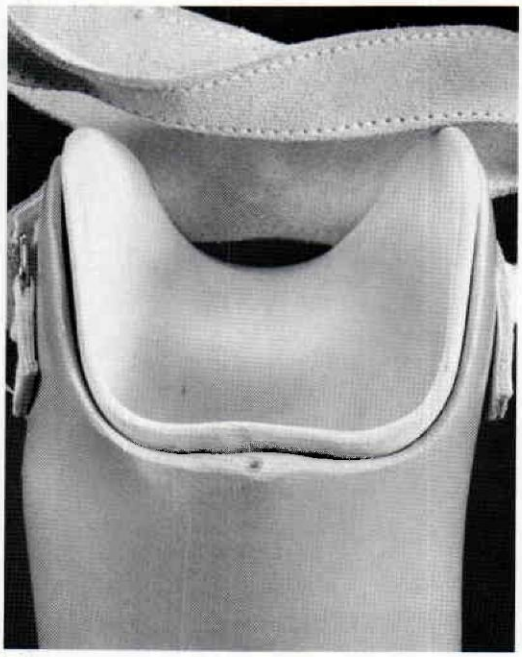

Figure 15. Posterior view showing air vent.

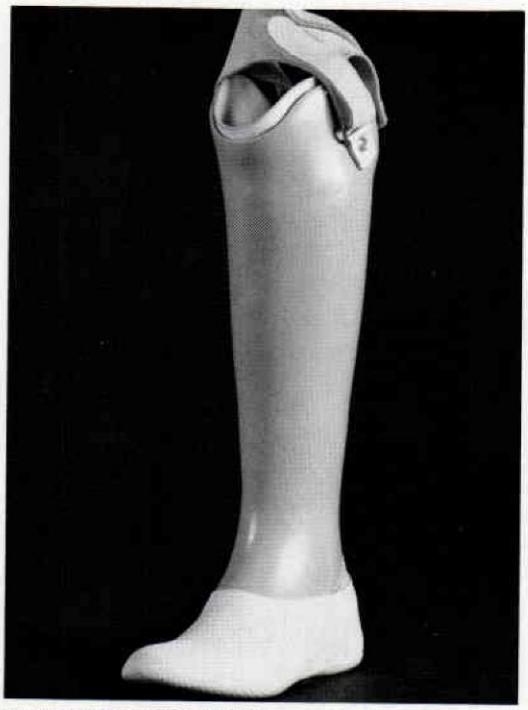

Figure 16. Completed P.T.B. prosthesis.

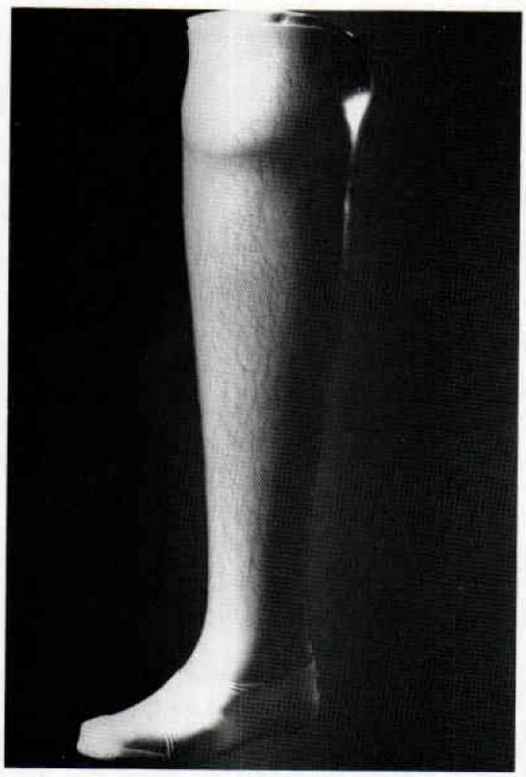

Figure 17. Completed P.T.S. with a cosmetic touch.

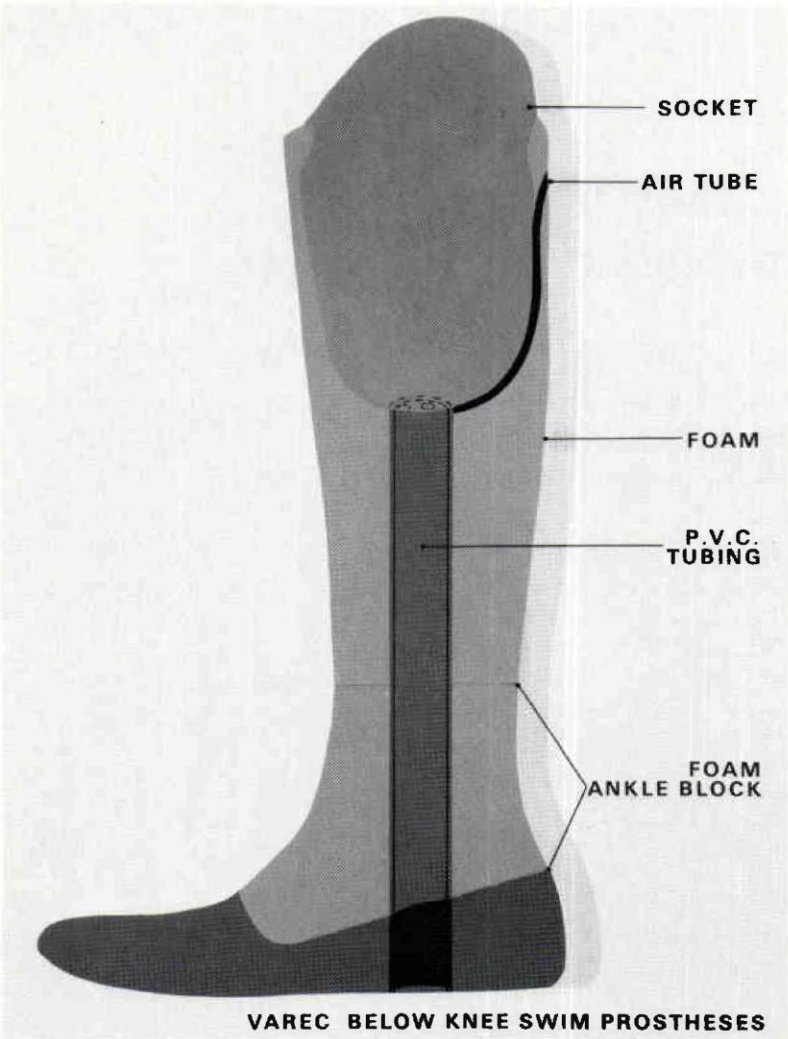

Figure 18. Diagram identifying various components of VAREC's swim prosthesis.

pleted prosthesis, anterior view. Figure 17 illustrates a completed P.T.S. with a cosmetic finish. Figure 18 illustrates a cutaway of the entire prosthesis and identifies the different components.

The PVC tubing allows water to enter the prosthesis as the amputee walks into the water, making it less buoyant. The air escapes via the air tube. As the amputee exits the water, it drains out at the bottom of the foot. Swim sneakers may be used, but holes should be made in the sole to allow water to enter and exit the tube.

CONCLUSION

This paper has outlined the fabrication techniques for a waterproof recreational Below-Knee prosthesis. By the use of tubing and air outlet lines, buoyancy may be controlled.

NOTES

[1]Otto Bock foam is used at VAREC for this procedure.

[2]Note that the center portion of the distal part of the heel will be slightly higher. This must be sanded flush to the edges of the keel. Do not expose the foam beneath.

AUTHOR

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