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A New Design and Construction For a Swimming Prosthesis

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This article, which concerns an innovation in ambulation for the active amputee, may be read in conjunction with the article by Kenneth P. LaBlanc, B.S., C.P.O., in Orthotics and Prosthetics, *Vol. 37, No. 3, pp. 42-49, "Fabrication of the Water Resistant B/K Prosthesis."*
The Editors

The ability of the lower limb amputee to participate in recreational activities is sometimes necessary in order to improve the quality of his or her life. Swimming, in particular, can be an enjoyable method of exercise for the amputee.

Prosthetic devices for swimming are necessary, not only to improve one's ability to swim, but to provide:

- a safe means for ambulation in and out of water
- protection against trauma to the residual limb
- constancy of residual limb volume during swimming activities
- safety in the shower.

Contemporary prosthetic devices for swimming satisfy the latter objectives, but fall short of providing maximum safety. Especially when ambulating in water, problems have been encountered due to the buoyancy of these devices. A prosthesis that is fully buoyant may be hazardous to the wearer. A great amount of effort must be exerted to keep the prosthesis submerged. A reduction in buoyancy gives the patient a greater degree of control over the prosthesis. He can affect its position with a degree of coordination and muscle power that more closely approximates out-of-water ambulation.

When a body is immersed in a fluid, it is buoyed up with a force equal to the weight of the fluid displaced by the body. Therefore, in order to reduce the buoyancy of a swimming prosthesis, one must reduce the amount of water that it displaces.

It was our goal to design a swimming prosthesis that was practical, cosmetic, safe, and displayed a minimal amount of buoyancy. We have achieved this end by constructing a prosthesis with a large central chamber through which water can enter and exit quickly.

This chamber has a distal opening located in the base of the water repellent foot, and a proximal opening in the posterior shelf of the socket (Figure 1).

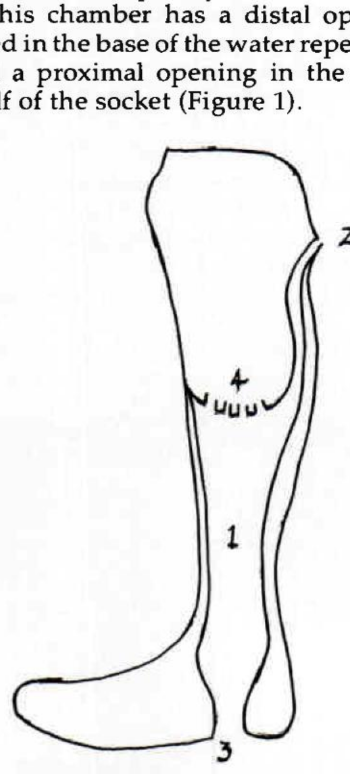

Figure 1. Schematic drawing of swimming prosthesis: (1) central chamber, (2) proximal opening, (3) distal opening, and (4) distal socket drain.

As the amputee enters the water with the prosthesis, water enters the distal opening and begins to fill the chamber. Air is simultaneously expelled through the proximal opening. The water level in the chamber will equilibrate with the water level outside the prosthesis until the prosthesis is completely submerged. As the prosthesis is removed from the water, air enters the proximal opening and forces water out distally. Without this proximal opening, the amputee would feel a downward pull on the prosthesis due to the force of the exiting water.

THE WATER REPELLENT FOOT

The distal opening of the central chamber is a 1.25 inch diameter hole in the base of a specially prepared foot. Experience has demonstrated that water, especially salt water, readily deteriorates the foot portion of a swimming prosthesis as well as its attachment to the shank. Efforts to reduce maintenance and facilitate fabrication, without reducing function, have led to the design of a water repellent foot for swimming prostheses.

The keel of the foot is fabricated from 350 grams of Pedilen foam (three parts hard to one part soft) poured into a neuter blank mold. This blank can be shaped to accommodate all foot sizes, left and right (Figure 2).

Otto Bock Pedilen toe and sole parts are chosen to correspond to the patient's foot size and fitted to a flat rubber swimming sneaker. The keel is shaped to fit these components.

Fiberglass cloth, impregnated with polyester resin, is sandwiched between the base of the keel and the plantar components of the foot. This layer insures a strong keel base and an intimate fit with the sole of the foot.

THE BELOW KNEE SOCKET

All below the knee swimming prostheses fabricated in our laboratory utilize PTB sockets with Supracondylar or Supracondylar/Suprapatellar suspension systems. These have proven to be the suspension types of choice. Auxiliary suspensions should be avoided whenever possible, because immersion in water increases their rate of deterioration and thus affects safety and frequency of repair.

As previously stated, the water emission rate from the central chamber can be increased by providing a proximal opening in the posterior brim of the socket (Figure 3). This opening is created during the socket lamination. A 1.5 inch wide, slightly tapered, piece of .125 inch thick polyethylene is inserted between the layers of stockinette prior to lamination. The polyethylene wedge extends to the distal end of the socket but is easily removed by heating the posterior aspect of the socket. When the tapered wedge is removed, it will leave a channel that will ultimately drain into the central chamber of the shank.

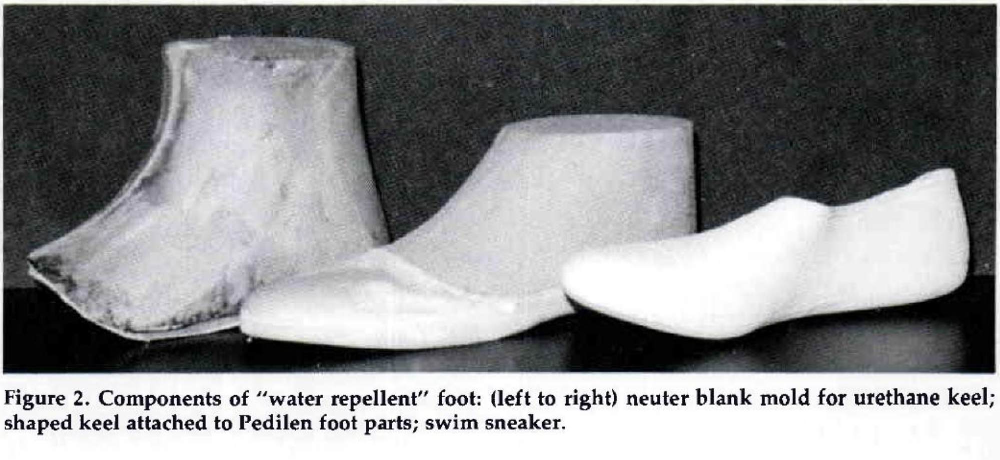

Figure 2. Components of "water repellent" foot: (left to right) neuter blank mold for urethane keel; shaped keel attached to Pedilen foot parts; swim sneaker.

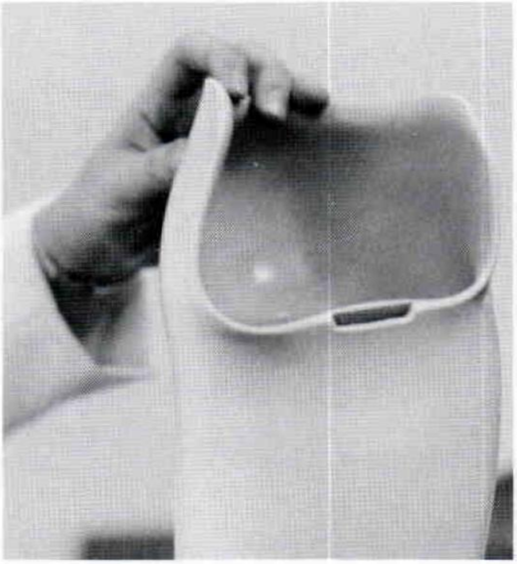

Figure 3. Posterior socket channel in proximal brim—air passes through this opening to facilitate equilibration of water level.

Figure 4. Distal socket drain leads to the central chamber of the shank and allows water to enter the socket.

Additional openings to the chamber are produced by drilling .125 inch diameter holes through the distal end of the socket (Figure 4). The final result is a socket in which the posterior channel and distal openings empty into the central chamber of the shank. Air pressure through these openings increases the rate of water flow in and out of the prosthesis.

ALIGNMENT AND FITTINGS

The socket is embedded in urethane foam and is attached to an adjustable pylon. The foot is attached to the pylon using a wooden block as a base for the foot plug (Figure 5). All alignment procedures are performed according to established techniques.

Since the swimming foot has no compressible SACH component, the patient may experience increased flexion at heel strike. It may be necessary to bevel the posterior aspect of the heel, to a 45 degree angle, to help reduce this moment. The patient will adjust to this slight increase in flexion at heel strike while walking on solid ground. When ambulating on sand, or

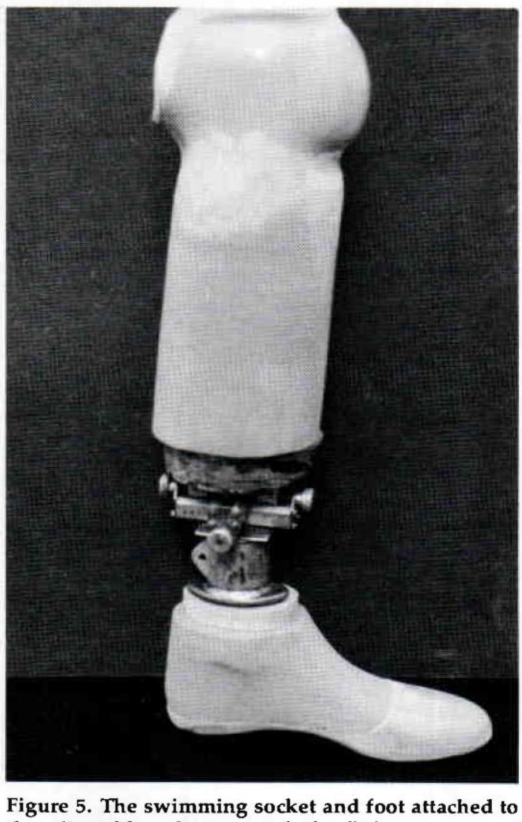

Figure 5. The swimming socket and foot attached to the adjustable pylon are ready for fitting.

other soft terrain, the compression of the sand will provide an even smoother gait pattern.

Alignment duplication is performed using urethane foam as a shank filler. Subsequent to a second dynamic alignment, the prosthesis is shaped and prepared for the finishing process.

FINISHING PROCESS (BELOW KNEE)

After cosmetic shaping, the toe and sole parts are removed and the prosthesis is laminated with polyester resin in two layers of fiberglass stockinette. The prosthesis is then reference marked and cut in a transverse plane at the shank. All the urethane foam within the shank is removed, thus creating the central chamber. The two hollowed sections are glued together and smoothed for final lamination. The final lamination consists of three layers of nylon stockinette saturated with polyester resin and the appropriate pigment.

After final trimming, the Pedilen foot parts are adhered to the base of the keel with epoxy and covered with a swim sneaker. The sneaker is glued to the keel and a 1.25 inch diameter hole is drilled through the sneaker and foot parts (Figure 6). It is this hole that becomes the distal opening of the central chamber. The finished prosthesis is shown in Figure 7.

ABOVE KNEE PROSTHESES

The aforementioned techniques can be incorporated into the fabrication of above knee prostheses.

The knee unit of choice is the Otto Bock 3K5 unit. It is plastic, lightweight, and ideal for immersion in water when the metal extension spring is removed. The openings in the knee eliminate the need for a posterior socket channel.

The foamed socket, knee, and water repellent foot are set in bench alignment and glued. The prosthesis is then fit according to established practice; however, the patient must ambulate with the knee locked.

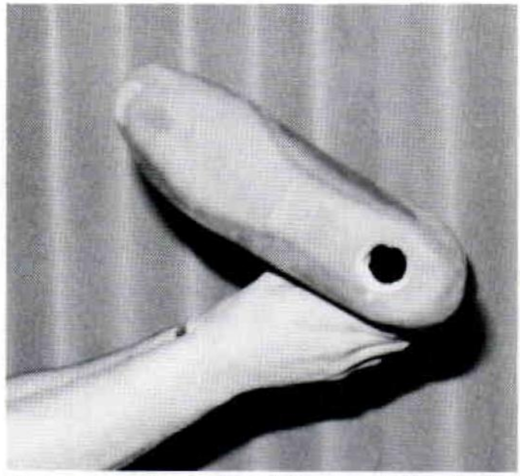

Figure 6. Distal opening of the central chamber located in the base of the foot, allows free flow of water in and out of the chamber.

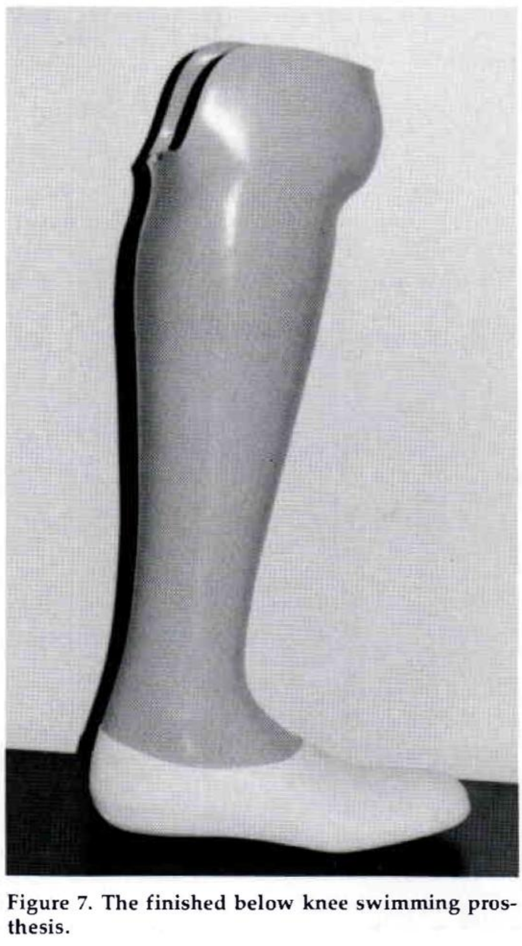

Figure 7. The finished below knee swimming prosthesis.

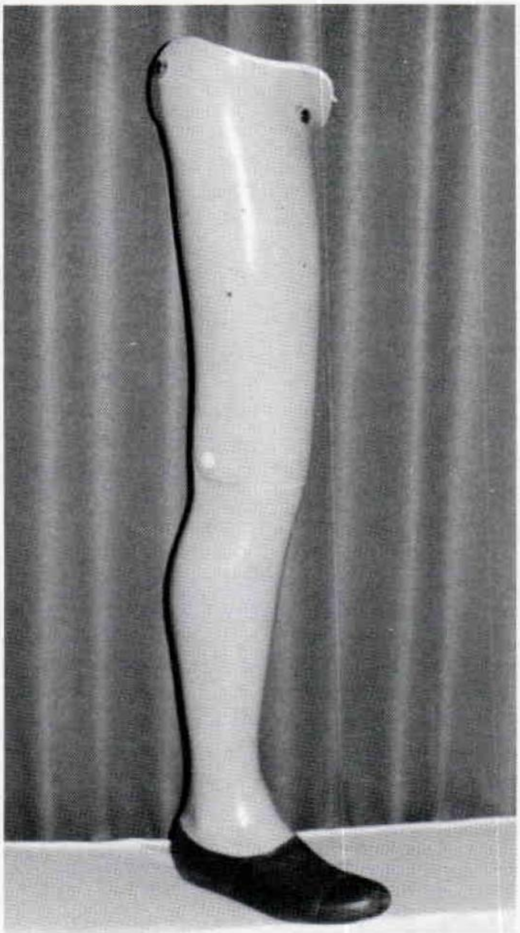

Figure 8. The finished above knee swimming prosthesis.

FINISHING PROCESS (ABOVE KNEE)

After the fitting, the prosthesis is shaped and disassembled. The shank portion is treated as described under the below knee finishing process. It is laminated, cut, hollowed, and relaminated with pigment. The thigh section is hollowed to the distal end of the socket.

Water enters the thigh via the openings in the upper portion of the knee. The openings in the lower portion of the knee are the proximal entry to the distal chamber that is created in the shank.

The foot parts are attached as in the below knee. The swim sneaker is glued to the foot and the distal hole is drilled through the sneaker and foot parts (Figure 8).

DISCUSSION

We have used the techniques outlined for more than twelve years. To date, we have followed the progress of 34 patients wearing swimming prostheses fabricated as described. All the patients were able to achieve their functional goals, from participating in water sports to taking daily showers. The only routine service is an annual check up to insure the integrity of the components.

The patients experience no significant limitations other than a slight decrease in simulated plantar-flexion, but they easily accommodate to it. Above knee patients are limited to walking with the knee locked. Long above knee residual limbs present a cosmetic problem due to the dimensions of the 3K5 unit and the resultant protrusion of the knee.

There are great limitations on the types of components that can be incorporated into a swimming prosthesis. Development of a variety of components, specifically for recreational prostheses, is necessary if we are to help in the rehabilitation of our patients.

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