

A Laminated Ultralight Prosthesis

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INTRODUCTION

Weight, like any other component, is a factor in prosthetic design, but it has been only until recently, with the advent of more sophisticated materials, that weight reduction has drawn so much attention. Initially designed for the geriatric amputee, techniques were developed to reduce as much of the weight of a prosthesis as possible.

In 1976, Moss Rehabilitation and Rancho Los Amigos Hospitals developed the below knee ultralight prosthesis. Made of polypropylene, the ultralight was 65 percent higher than a conventional prosthesis. Despite the weight reduction, however, the ultralight was not widely accepted because of its lack of durability and difficult fabrication procedure.

In 1979, Wilson and Haslam introduced the AFP (adaptive fixation prosthesis) endoskeletal system, and in 1980, Roman and Mott developed a hollow laminated prosthesis. These and other ultralight techniques (Leimkuehler, 1982) have and will continue to be developed as the need for lightweight prosthetic systems increase.

The following article presents a hollow lightweight (1½ to two pound) below knee prosthesis that can be used by the geriatric as well as the aggressive amputee. Its fabrication and prescription criteria will be discussed.

FABRICATION

Fabricate a liner on the case in the usual manner. Then laminate a socket using four layers of nyglass (623 T11 Otto Bock) one layer of fiberglass (616G3 Otto Bock) and acrylic resin (617H19 Otto Bock). Use only acrylic resin for this prosthesis.

Select a Pedilan foot (1S19 Otto Bock) of the appropriate size and enlarge the bolt hole using a $25/64$ inch drill, then attach the Pedilan foot to an endoskeletal pylon using a 10mm bolt. The Pedilan foot provides the same function as the SACH foot and weighs less (Figure 1).



Figure 1. The Pedilan foot provides SACH foot action yet weighs considerably less.



Figure 2. Components assembled for dynamic alignment.



Figure 3. Remove the endoskeletal pylon after dynamic alignment is complete.



Figures 4 and 5. Fill the void with rigid polyurethane foam.

With the endoskeletal components and socket held in place, attach the alignment block (5R1 Otto Bock) to the socket using rigid polyurethane foam (617H12 Otto Bock) as shown in Figure 2. (NOTE: Leave the PVA bag on the socket prior to foaming so that the foam can later be removed from the socket).

Reinforce the foam/attachment block junction with fiberglass tape and dynamically align the prosthesis. Caution should be taken at this point to make sure this is accurate because once the prosthesis is finished, it is impossible to make any alignment changes.

After the prosthesis is dynamically aligned, remove the pylon and attachment block (Figure 3). Separate the socket from the attachment block by cutting the foam just proximal to the block, and fill the void between the socket and the foot with rigid polyurethane foam (Figures 4 and 5).

Shape the foam accordingly, taking into account that the circumferential measure-

ments need to be $\frac{1}{2}$ inch smaller than the contralateral measurements to allow for the thickness of the outer lamination (Figure 6).

Hollow out the plantar surface of the keel $\frac{1}{8}$ " and pull a below knee nylon over the foam and socket to make a smooth surface. Apply a PVA bag over the nylon and seal it distally, along the plantar surface of the foot. Then laminate a preliminary socket using, in the following order, one layer of nyglass, one layer of fiberglass, one layer of nyglass, and acrylic resin. Once the lamination is hardened, split the shell down the back using a cast saw (Figure 7). To avoid cutting the socket, it may be necessary to split the shell with a knife in the socket area. Remove the shell from the foam and trim it proximally around the MP area of the foot. (NOTE: There must be a one to two inch overlap of laminated material between the socket and shell).

Once trimmed, place the shell back on the foam and mark its location (Figure 8). These marks must be as accurate as possible, otherwise the alignment will be off. Remove the trimmed shell from the pros-

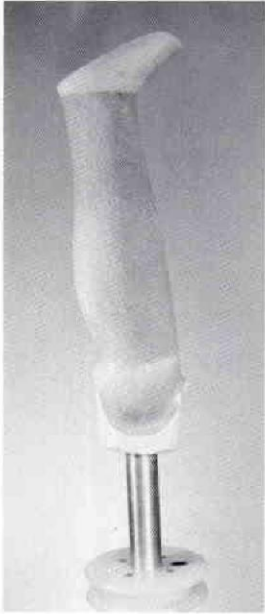


Figure 6. Shape the foam accordingly.

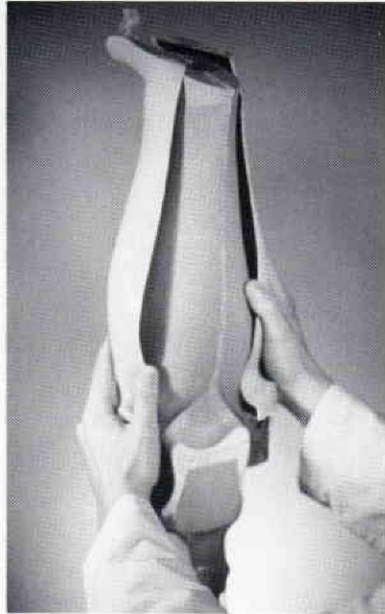


Figure 7. Cut the preliminary shell posteriorly and remove it from the foam mold.

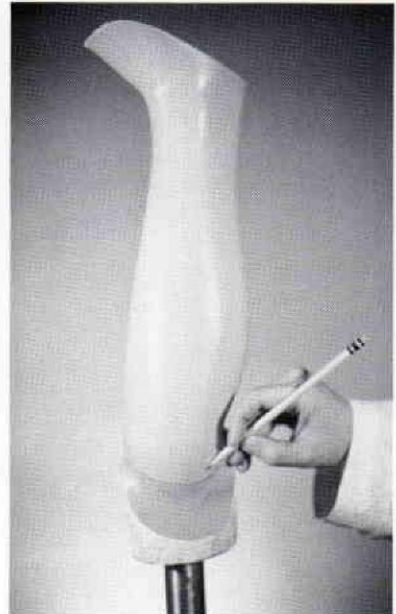


Figure 8. Mark the location of the shell on the socket.



Figure 9. Bond the posterior seam together along the inside.

thesis and bond the posterior seam together along the inside using three layers of one inch wide fiberglass webbing and acrylic resin (Figure 9). If the fiberglass cannot be placed inside the foot section, seal it along the recessed plantar surface. Remove the foam from the socket and glue the preliminary shell to the socket using sealing resin (Otto Bock 617H21) (Figure 10). Be certain that all the location marks match up.

Drill a $\frac{3}{8}$ inch hole in the metatarsal area of the foot. Be careful the drill doesn't grab

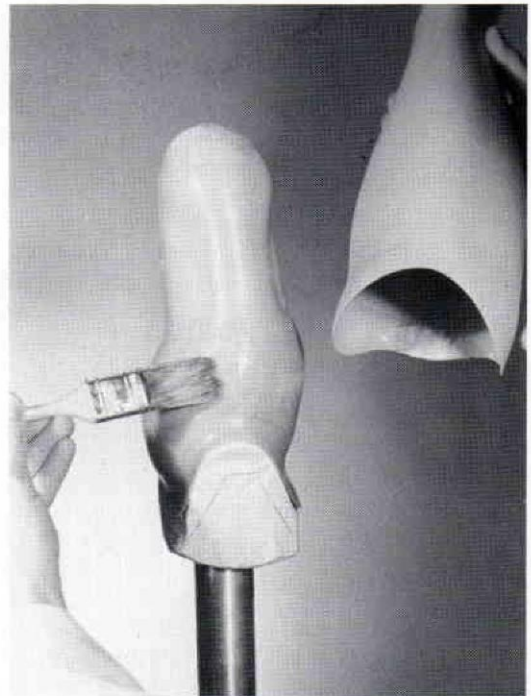


Figure 10. Glue the preliminary shell to the socket.

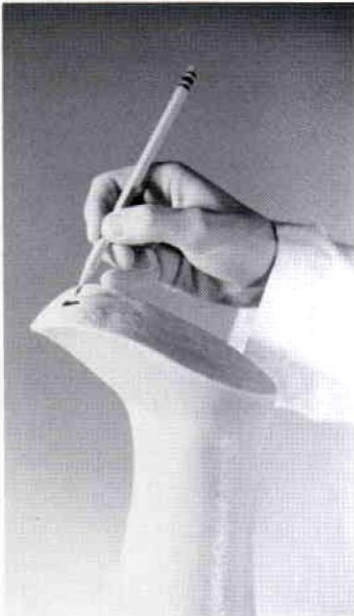


Figure 11. Drill a $\frac{3}{8}$ inch hole in the metatarsal area of the foot.

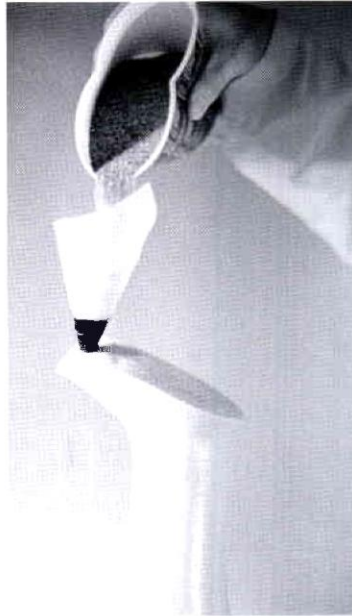


Figure 12. Fill the entire prosthesis with sand.

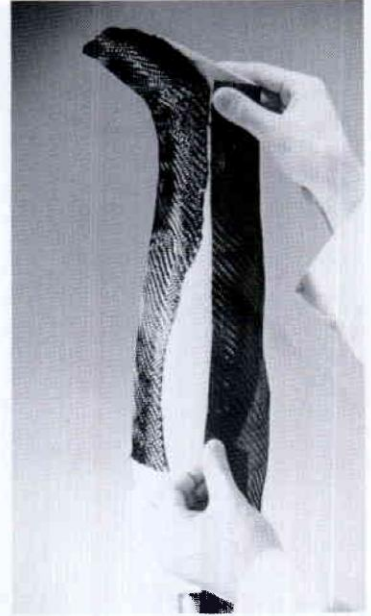


Figure 13. Reinforce the prosthesis with several layers of carbon fiber.

and go through the dorsum of the foot (Figure 11). Fill the prosthesis with sand and seal the hole with masking tape (Figure 12). The sand will keep the shell from collapsing during the second lamination.

Sand the prosthesis to insure a good bond between the outer laminations, and smooth down all ridges between the socket and preliminary shell. Then laminate the secondary socket using, in the following order, two layers of carbon fiber (Otto Bock 616G12), one layer of fiberglass, and two layers of nyglass and acrylic resin. Carbon fiber is a high strength, low modulus (stiff) material that produces a strong and lightweight prosthesis.

The carbon is put down first because its black color has a tendency to bleed through if left on the top. Cover with several layers of fabric. Lay the carbon around the foot, ankle and proximal brim, and anterior and posterior section of the calf (Figure 13). To do this, first determine the shape or size of the carbon needed and run a piece of dou-

ble-faced tape (3M #950) along the cutting edge. Cut down the middle of the tape, remove the paper backing, and stick the piece of carbon in place. This technique keeps the edges from unraveling and keeps the fabric in place during lamination. Do not run the carbon into the ears of the supracondylar socket because it makes them too rigid; and don't run the carbon around the edge of the prosthesis because it makes trimming difficult.

The amount of vacuum used during the final lamination should be kept to a minimum. Even with the sand, if too much vacuum is applied during the final lamination, the outer shell will collapse. Once the final lamination is complete, redrill the hole in the bottom of the foot and drain out the sand.

Sand the plantar aspect of the prosthesis and attach the foot using sealing resin. Fill the crack between the foot and the prosthesis with flesh/light brown latex caulk or a mixture of sealing resin and solkafloc.

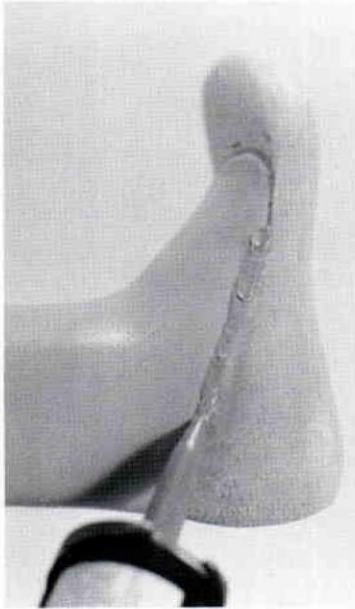


Figure 14. Fill the crack between the foot and shell with latex caulk or sealing resin.

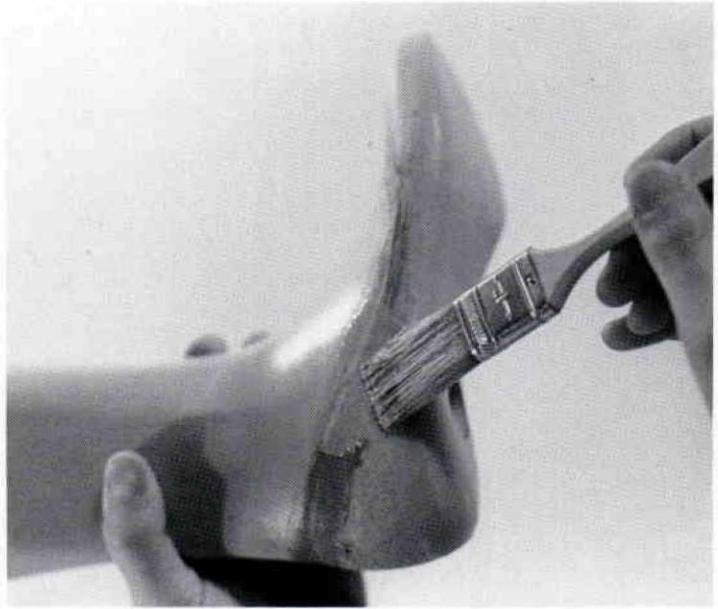


Figure 15. Paint the foot with ultra dip.

Once dry (30 minutes), paint the foot with Ultra-Dip (ATCO) and let dry for 30 minutes (Figures 14, 15, and 16).

DISCUSSION

There are indications and contraindications for any prosthesis and this ultralight unit is no exception. Several factors need to be considered before prescribing and/or fabricating this device.

The question of weight versus durability needs to be addressed. It is hard to design a prosthesis that is lightweight without compromising durability because as durability increases, weight also increases. What is desired is high strength and low weight. The question of just how strong a prosthesis needs to be so that the materials can satisfy this requirement while keeping the weight to a minimum remains to be seen, because the strength requirement depends so much on the level of activity of the particular patient.

While this prosthesis is designed to be durable enough for the geriatric amputee, it can also be modified for the more active

amputee by adding several layers of carbon and fiberglass around the ankle and calf section (e.g. for a construction worker, use six layers of carbon). This ability to vary the strength of the prosthesis is very important because it allows the prosthetist to customize the device depending on the patient's level of activity.

One drawback of any ultralight system is that it is more time consuming to fabricate. Unlike other systems, this technique doesn't require any new equipment or fabrication skills because it uses conventional laminating procedures. This technique doesn't require hollowing out like other techniques, and has minimal amount of weight distally, which decreases the pendulum moment of the prosthesis.

This prosthesis is not recommended for the newer amputee, however, because it lacks adjustment capabilities. While minor modifications are possible through limited grinding and/or heating of the socket, it is not possible to change the alignment once the prosthesis is complete; therefore, more time needs to be spent evaluating and dynamically aligning this prosthesis.

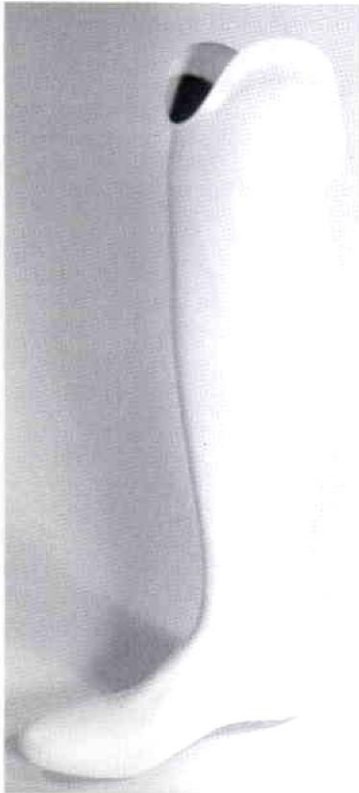


Figure 16. The finished prosthesis weighs between 1½ and 2 pounds.

CONCLUSION

There has been much interest recently in weight reduction as the need for and the ability to make lighter weight prosthetic systems is increased. This article has presented one such ultralight fabrication technique and has discussed its critical factors of design such as durability, weight and fabrication. It is hoped that others will continue to improve ultralight fabrication

techniques because the need for these systems is increasing.

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