RECENT DEVELOPMENTS IN THE FITTING AND FABRICATION OF THE SYMES PROSTHESIS

By FRED HAMPTON

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The identifying components of the Canadian Symes prosthesis are the posterior opening laminated plastic socket and the laminated cellular rubber foot with an internal support or keel. There have been many variations, including the use of a prefabricated SACH foot, nylon reinforcing, medial openings, and proximal bearing sockets.

Recently a course in Special Prostheses was presented at Northwestern University Prosthetic Education School for prosthetists. In general, the material offered was founded on the experience of the author of this report who was intimately associated with the development since its conception at Sunnybrook Hospital in Toronto, and who has gathered further experience since joining the Northwestern University Prosthetic Research Center two years ago. The highlights of the course were the method of taking the cast, a glass epoxy method of socket fabrication, and a method of cutting down and attaching a standard SACH foot in a manner that allows adjustment in aligning when fitting. The method of taking the cast and the ease with which foot alignment can be adjusted makes it possible for an inexperienced prosthetist to obtain satisfactory results.

A good fit begins with a good impression of the stump. Instead of plaster, alginate is used because it is flexible enough to allow removal of the stump without splitting the cast. It is also very fast and clean and does not require any vaseline or separator on the stump, although soap may be used. Unfortunately, the alginate (produced for dental impressions) is expensive, about $5 worth being used for a typical Symes cast. Alginate comes in a powder form and when mixed with water forms a jelly-like solid. In taking a cast of a bulbous stump it is necessary to line the container with a light canvas bag. When the alginate has gelled the can is slipped off so that the gel can distort inside the bag as the stump is withdrawn. The bag with the impression is then put back in the container and the plaster positive is poured. Since the alginate dries out and shrinks very quickly it is important that the plaster positive be poured without delay. Very little modification to the cast is necessary, but the folds or creases in the distal area should be filled. It is desirable to flatten off the posterior area so that the back panel will fit snugly over the gastrox and prevent rotation of the prosthesis on the stump.

Glass has many disadvantages as a reinforcing material. It isn't as easy to lay up as stockinette; it dulls tools and the fine fibres from sanding or cutting can cause irritation. However, because it offers superior strength, especially when used with epoxy resins, and since structural strength is particularly important in Symes prostheses, it should be considered. Two types of glass are used: woven cloth and roving. The roving is a yarn made of many monofilament strands and is used where great strength concentration is required. In the Symes, this occurs at the radius of the cut-out where the edge is heavily loaded in tension when weight is applied on the ball of the foot. Although glass roving has a tensile value of 400,000 psi, only about 75,000 to 100,000 psi are realised in the actual laminate due to uneven loading and because the resin itself is rather weak in tension. However, it is still as strong as most steels likely to be used; it also offers ease of fabrication and is shock and corrosion resistant. One of the difficulties in laminating with roving is keeping it in place. This is largely overcome by draping it over small nails driven into the cast along the line forming the posterior opening.

The position of this line is important since the posterior opening must be large enough to allow stump entry but not so large that the main structure is unnecessarily weakened. A reasonable compromise is to draw a vertical line down each side of the socket at the widest point to where the ball reaches its maximum diameter and then horizontally to the posterior. To avoid stress concentration at the corner a radius of at least ½" should be used.

Concern over toxicity of epoxy resin has often been a deterrent to its use in limb shops, but when used with the dry lay-up method there is little cause for apprehension if good housekeeping habits are maintained. A barrier cream can be used on the hands as added precaution. The amine hardener—not the resin—is the toxic agent, and if it is found that a workman does develop dermatitis from using epoxies, it is important that he avoid further contact

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FRED HAMPTON

Mr. Hampton, a native of Canada, was employed by the DeHaviland Aircraft at Toronto from 1945-1947, where he did considerable work with plexiglas. In 1946 he first began to work in plastics and metals. He then served two years in the Royal Canadian Air Force, where he had considerable experience with metal fabrication in aircraft components and developed plastic crash helmets and rescue sleds.

Mr. Hampton's introduction to prosthetics as such began in 1949, when he joined the Prosthetics Research Laboratory of Sunnybrook Hospital at Toronto. There he began working with plastics in the field of prosthetics. Mr. Hampton made and fitted the first Canadian Symes and Canadian type Hip Disarticulation Prosthesis during these years. He was engaged in the production of all types of metal limbs.

In 1957 he came to the States to serve as Laboratory Supervisor at Northwestern University Prosthetic Research Center. He is also an instructor in the Prosthetics Education Program at Northwestern. With his associate, Mr. McLaurin, he appeared on the program of the National Assembly at Dallas in October 1959, presenting seminars on the Canadian Hip Disarticulation and the Canadian Symes Prosthesis.

Alignment

The functional characteristics of the prosthesis depend upon the character of the foot and alignment. In an end bearing Symes it is more comfortable to bear weight on the heel than on the toe since pressure at the forefoot induces a bending moment which must be resisted by pressure at the anterior of the socket. Since a soft heel quickly transfers weight to the forefoot and allows too much drop at the early part of the stance phase, a firm heel should be used. A smooth transition from heel to forefoot is easily controlled by the long stump.

In a normal individual the foot is in dorsiflexion during nearly all the stance phase, and the Symes foot should be similarly aligned. If the foot is not set in dorsiflexion the amputee will feel that he is climbing over an obstacle. This dorsiflexion gives an asymmetrical appearance when standing, but this is more than offset by the advantages in walking. Some of this discrepancy between standing and walking can be offset by setting the socket well forward on the foot. This also reduces the anterior pressure induced when the weight is on the forefoot.

Experience also indicates that the socket should be set medial to the foot. As a general rule the socket should be set as far forward and as far medial (with respect to the foot) as good appearance will allow.

The actual amount of dorsiflexion and toe-out is fairly critical for a good comfortable gait, hence it is desirable that some adjustment be possible after the amputee has worn the prosthesis for a short time in the fitting room. For this purpose a ball joint can be used in attaching the socket to the foot. This joint can be made of metal or from plastic as shown later in the article.

Although it is not necessary to use a SACH type foot on a Symes prosthesis the SACH is more easily faired into the socket and very often there is not enough room for a standard ankle. In many cases the amputation is so low that a Symes SACH cannot be fitted without modification, and the usual alternative is for the prosthetist to build up a foot. This can be time consuming, and unless the prosthetist has had considerable experience the result may be less than satisfactory from the standpoint of appearance, function or durability.

Accordingly, at Northwestern University Prosthetic Research Center a method was developed by which a standard SACH foot can be cut down and reconstructed so that it may be attached, using the adjustable ball joint, to any plastic socket. The system can also be adapted to Chopart amputations, but such a description is beyond the scope of this paper.

The step by step procedures used are described in the following section under the following headings: Impressions, Ball Joint, Socket Fabrication, and Foot Reconstruction.

I. Taking the Impression

The materials used in a typical case are a tapered can with open top—about 6¼″ diameter at the top, 5½″ diameter at the bottom, and 20″ high; a canvas liner for the can about 23″ long; 4 pounds of alginate powder; a polyethylene pail for mixing; and water as needed.

1. Checking the alginate setting time.

A small sample of alginate is mixed according to manufacturer's instructions (1 cup). The time available for pouring and the time required to gel should be noted. It may be necessary to use a leaner mix (less alginate) than specified. If fast setting Coe alginate* is used typical proportions are: 3 parts

* Source of Supply for Coe alginate: Coe Laboratories, 6033 S. Wentworth, Chicago, Illinois.

of powder to 4 parts water (cold, from tap) by volume. This allows about 75 seconds for mixing and pouring and the cast is satisfactorily gelled in six minutes.

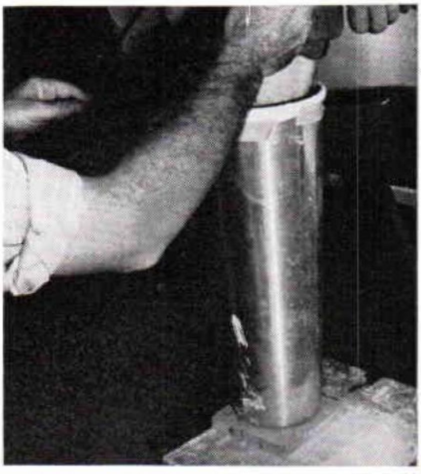
2. Checking can for size and distance from floor. (Fig. 1)

With the patient standing the stump is placed in the can and blocks are placed under the can until the stump bears one half of patient's weight with the pelvis level. With this done, the patient may be seated and the stump be withdrawn from can.

3. Placing liner in can.

The canvas liner is placed in the can. Excess length is folded over the top edge of can and any large wrinkles inside the can are smoothed especially at the bottom. A split ring is placed on the inside of the canvas bag to hold the bottom taut.

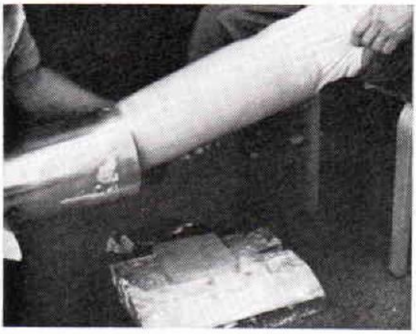
1. The correct level is obtained by using blocks.



2. The stump is centered in a can of alginate.

4. Mixing alginate and taking impression.

The correct quantities of alginate and water are measured and mixed quickly by hand. A slightly lumpy mix will cause no loss in effectiveness. The mix is now poured into the can and then the stump is placed in the can, making sure it is centered. (Fig. 2) This whole operation must be done in about one minute or the mix will begin to gel.



3. The can is removed from the alginate and stump.

4. The stump is removed from the alginate impression.

5. When the alginate is set (about 6 minutes) the amputee is seated and grasps firmly the canvas liner while the can is removed by the prosthetist. (Fig. 3) The top of the mold is held by the prosthetist while the stump is eased out of the mold by the amputee. (Fig. 4)

6. Pouring the plaster positive.

The alginate and liner are placed back in the can. A sufficient batch of orthopedic plaster to fill the mold is mixed and poured into the alginate impression. A length of pipe is placed in the centre of the plaster, the pipe being supported until the plaster has set.

7. Removing the plaster positive.

The canvas bag is peeled off, the alginate slit with a knife from end to end and is peeled back, (Fig. 5) and the plaster cast is lifted out. (Fig. 6)

5. The alginate is slit open.

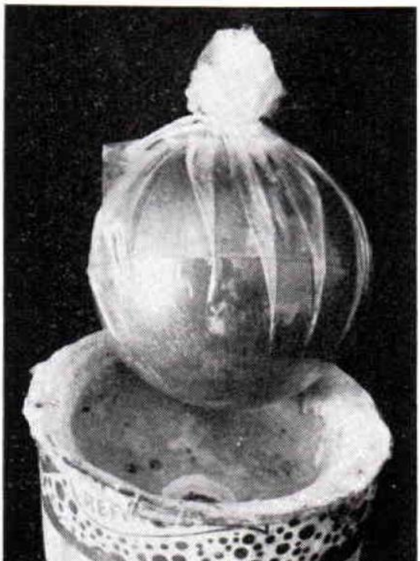
6. The plaster positive is removed from the alginate.

II. Making a Plastic Ball Joint for the Symes Prosthesis

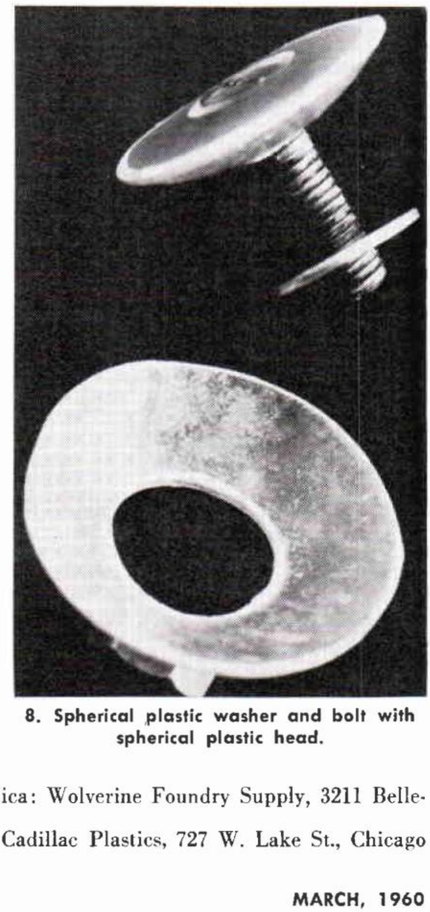
A concave spherical mold is made by taking an impression of a rubber ball in plaster. The depth should not be more than one third the diameter. A suitable mold release is then applied to the plaster and ball (paste floor wax dusted with water ground mica* is satisfactory). (Fig. 7)

A spherical washer is then formed by laying about 8 layers of glass cloth* in the cavity saturating with resin and placing the ball with a light weight on it. The laminated washer is then trimmed and a 1" hole bored in the centre. (Fig. 8)

To form a spherical head to the bolt a hole is drilled in the centre of the plaster mold to hold the bolt with the head protruding about $\frac{7}{16}$". About 10 discs of glass cloth with a $\frac{3}{8}$" hole in the centre are placed under the head of the bolt. The threads are then greased and the bolt is placed in the hole. Resin is then added to just cover the top of the bolt. The top may be sanded flat after curing. A metal spherical washer and bolt head may be used in place of plastic. (Fig. 22)



7. Ball and plaster mold for making the spherical washer and bolt.



8. Spherical plastic washer and bolt with spherical plastic head.

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* Source of Supply for Water Ground Mica: Wolverine Foundry Supply, 3211 Bellevue, Detroit, Michigan.

* Source of Supply for Fibreglas cloth: Cadillac Plastics, 727 W. Lake St., Chicago 6, Illinois.

III. Socket Fabrication

Preliminary to the lay-up, minor cast modifications are made. As mentioned in the introduction, any folds and creases in the distal end are filled, the gastrox flattened slightly, and sharp radii relieved as necessary. A strip of light horsehide scived about an inch wide is cemented with Barge over the tibial crest. This prepares the cast for the lay-up procedure. (Fig. 9)

A piece of ½″ thick neoprene* is scived to the distal end to serve as a weight-bearing pad; it is held on by a PVA cover. (Fig. 10) The back panel parting line is determined as described earlier and drawn on the cast. Two coats of paste floor wax with reasonable drying between coats are applied; then the cast is dusted with water ground mica to complete the laminating resin separator. A row of small brads spaced about ½″ is set following the parting line around the distal end and down 2″ below the ball, with a few more near the lateral and medial proximal ends.

Next, the plastic spherical washer made earlier is set on the distal end with beeswax, bearing in mind that its position will locate the vertical axis of the foot. (Fig. 11) Refer to the introduction for the suggested position. The exposed face is cleaned to obtain a good resin bond later.

The lay-up procedure features dry placement of all laminating plies with resin added after the PVA bag is pulled over the lay-up. An optional underlayer of dacron felt* may be used to start the lay-up; if used, it should be pressed on, exposing the brads. Four plies of 181-8 shaft satin fibreglas* tailored over the distal end and lapped about 1½″ over the lateral and medial parting line are then set, with 8 passes of glass roving* run over each layer of cloth on the socket side of the parting line guided by the brads. (Fig. 12) By keeping the roving close at the radius of the cut-out maximum strength is obtained where the greatest stresses will occur in the socket.

The bulbous end is further reinforced with two wide strips of cloth laid at right angles over the end down to the narrow section. Eight narrow strips crossing each other over the distal end, covering the mold on all sides, and tied snugly below the cast complete the dry lay-up. (Fig. 13) If desired, an optional nylon, dacron or cotton stockinette may be pulled over.

After driving in any prominent brads an open ended PVA bag is pulled over. (Fig. 14) About four 6 ounce cups of epoxy resin* are then mixed with colour (if desired) and hardener. The resin can be pre-heated at 125°F before the hardener is added to lower the viscosity. The resin is then poured into the open top of the bag and worked down through the lay-up. When the resin has reached the proximal end, the bag is snugged down on the mold and tied below it. The lay-up is strung and resin added until complete saturation of all plies is assured. (Fig. 15) Bridging of the laminate in the narrow region will not occur if tape or PVA strips are wrapped about the bag to hold it in. The top of the bag is tied off after being drawn upward, so that on release it keeps the distal end snug.

The lay-up is then allowed to set overnight, and cured 1-3 hours at about 160° F. After cooling to room temperature the back panel cut-out line is marked on the laminate. A Stryker cast cutter is used to make the cut, after

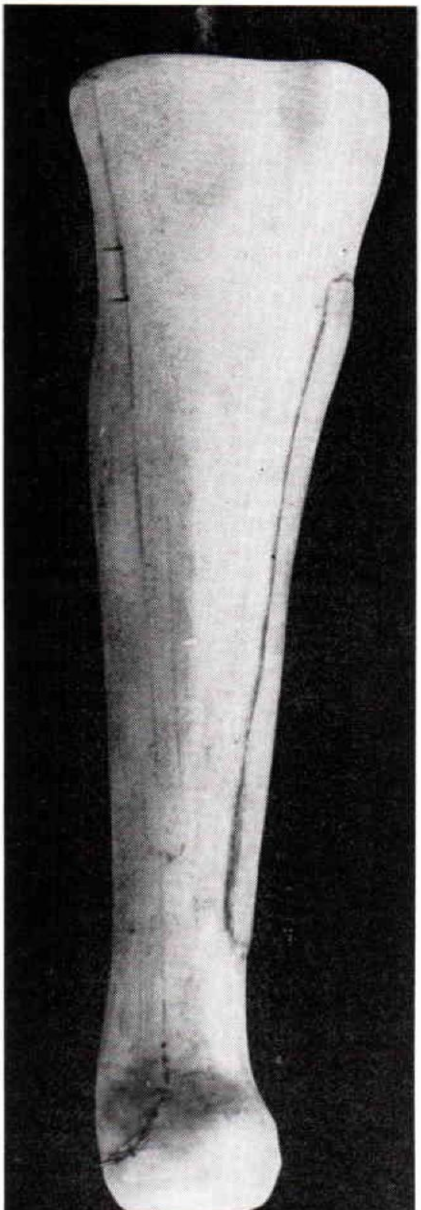
* Source of Supply for Neoprene: Leveton Co., 711 W. Roosevelt Road, Chicago 7, Illinois.

* Source of Supply for Dacron Felt: Troy Blanket Mills, 200 Madison Avenue, New York, New York.

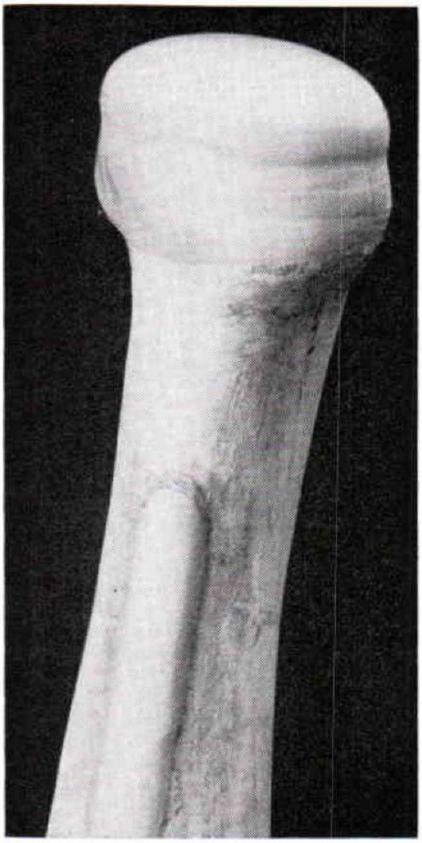
* Source of Supply for Fibreglas Roving: Cadillac Plastics, 727 W. Lake St., Chicago 6, Illinois.

* Source of Supply for: Epoxy Resin: Ciba Products, Plastics Division, Kimberton, Pennsylvania.

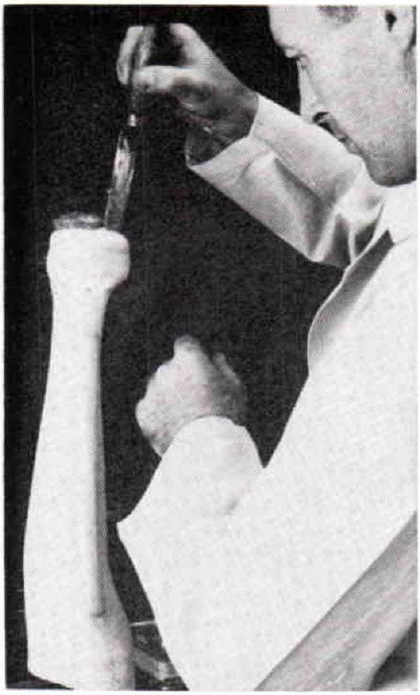
which the back panel and the socket are removed from the plaster. A drill is used at the radius. (Fig. 16) The neoprene distal pad is removed from the cast. The socket and back panel are trimmed along the cutting line, and the beeswax removed from the socket base. The hinge and straps are affixed, completing the socket fabrication.



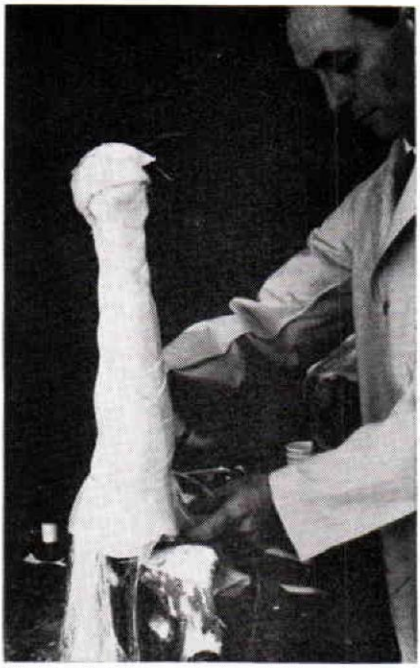
9. The plaster positive modified for the lay-up showing the cut out lines, brads and tibial build-up.



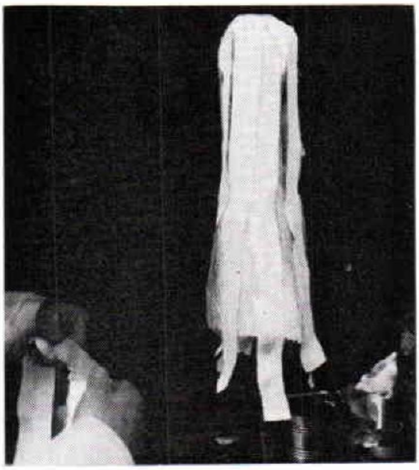
10. The neoprene distal pad is attached with tape.



11. The positioning of the spherical washer with wax.



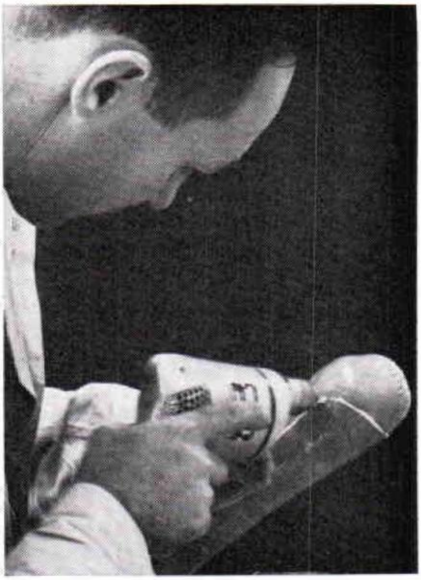
12. The first layer of glass cloth and roving.



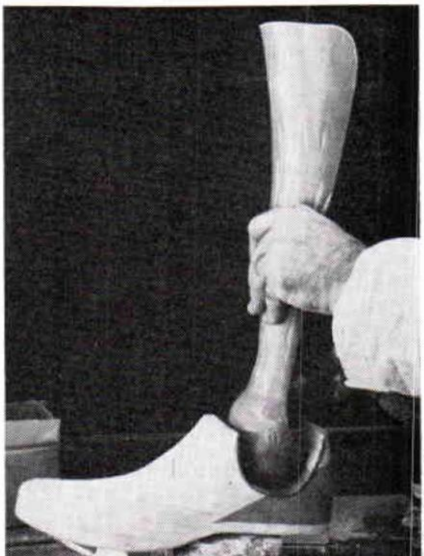
13. The final strips of glass cloth.

14. The complete lay-up with the PVA bag.

15. Pouring the resin.



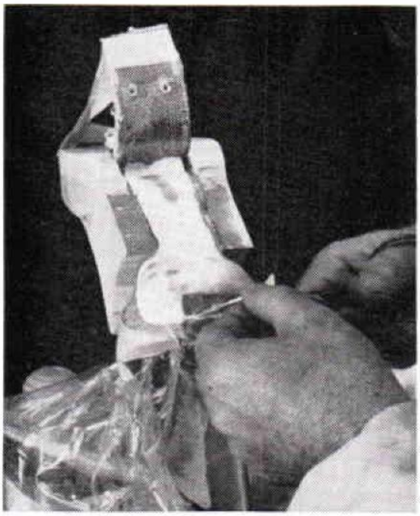
16. A small drill is used for cutting the radius.



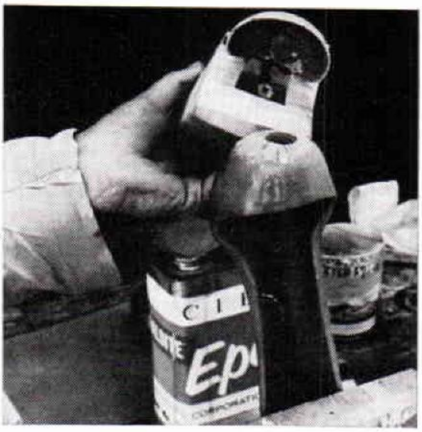
17. The SACH foot cut out for positioning the socket.

IV. Foot Reconstruction

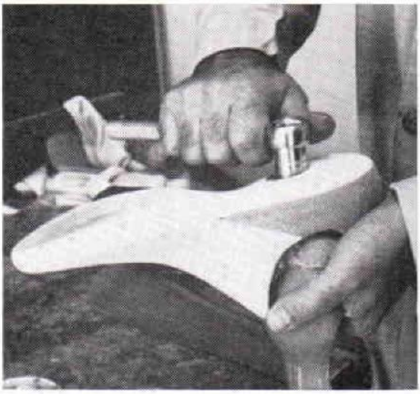
When the stump-to-floor distance is too small for a standard SACH foot the socket is used as a guide for marking the cut-out. The cut is then made with a bandsaw and the socket positioned in the cut-out and fastened with a screw into the keel. (Fig. 17)



18. Laying out the keel extension.



19. The keel extension showing how it fits on the socket.



20. Attaching the foot for trial walking.

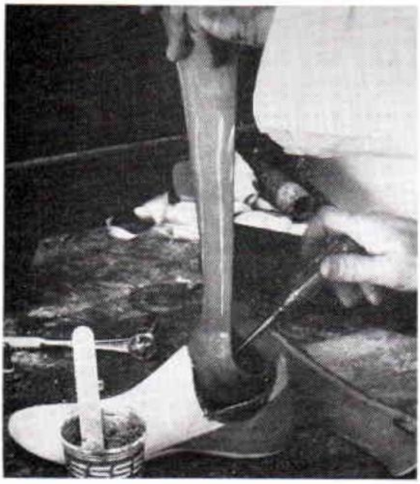
Since part of the keel has been cut away, an extension of fibreglas and epoxy is added to the bottom of the keel. The heel wedge is cut off, exposing the balata belting. The wood screws holding the belting are removed and the belting peeled back exposing the keel.

The socket is held in a vise and a small PVA sheet is pulled over the ball. Nine layers of cloth are tailored to cover the ball and extend up the keel. (Fig. 18) A small wedge of wood may be necessary to build up the keel to the socket. The layers of cloth are laid in place, each ply being saturated with epoxy resin. The balata belting is pulled down over the lastply and the screws replaced. The resin should be partially cured at room temperature before the final oven cure.

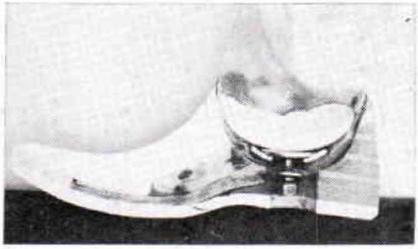
A 3/8″ hole is drilled through the cup-shaped extension and the bottom of the socket. The foot is removed and the hole in the socket enlarged to a 1″ diameter. (Fig. 19)

A corresponding hole, 1¼″ diameter for socket wrench clearance is made in the heel wedge. The heel wedge is then contoured to the thicker keel and cemented to the forefoot and keel with Barge* or similar adhesive.

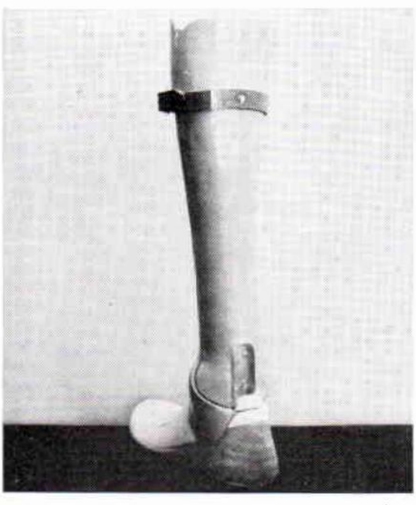
The reconstructed foot is then attached to the socket with the 3/8″ spherical head bolt, washer and nut and is ready for trial walking. (Fig. 20)

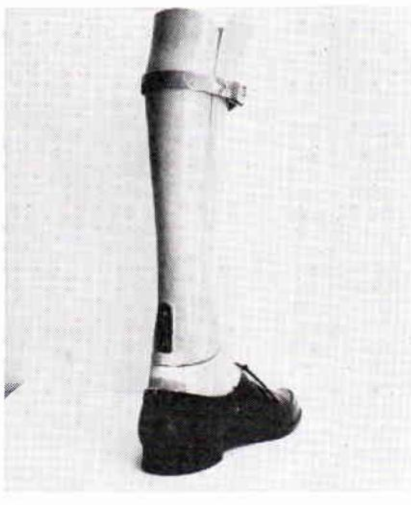


21. The socket is attached to the foot with a wood screw into the keel and a mixture of resin and sawdust is used as a filler.



22. A cross section of the complete prosthesis showing a metal washer.





23-24—The Finished Prosthesis (rear view)

When all necessary adjustments have been made the socket and foot are bonded with epoxy resin and the space around the union is filled with a mixture of epoxy and sawdust. (Fig. 21). After oven curing, this filler is ground or sanded to provide a suitable contour.

Figures 23-26 show the finished prosthesis.

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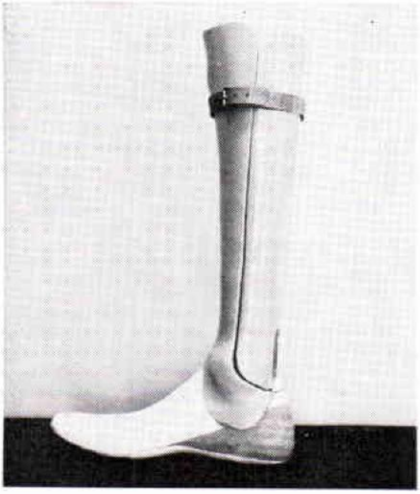
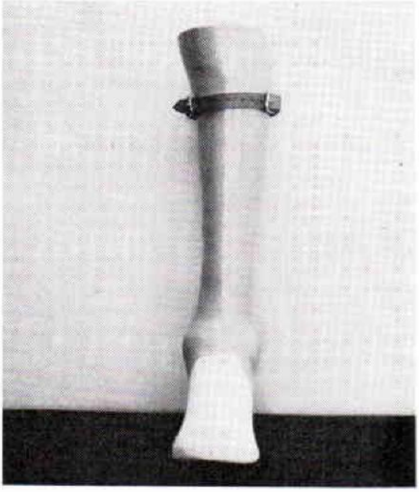
* Source of Supply for Barge Cement: Barge Cement Mfg. Co., 100 Jacksonville Rd., Towaco, New Jersey.





25-26—The Finished Prosthesis (side and front view)

Editor's Note: The preceding article was read in manuscript form by Mr. Howard V. Mooney, C.P., of Boston, a member of the Journal Committee. We think his comments will be of interest:

"I have read the article 'Recent Developments in the Fitting and Fabrication of the Symes Prosthesis' by Fred Hampton. It is written clearly and is excellent.

The information in this article supplemented a discussion of this type of Symes Prosthesis at a lecture during the Below-Knee course at New York University which I attended in January 1960. Of particular interest is the method used in casting the stump. I would agree that by comparison with plaster, alginate is expensive. However, if more accurate impression is obtained, I think that the expense would more than be justified.

"We, in the New England area, have had no experience with a Symes prosthesis fabricated in accordance with Mr. Hampton's article. I, therefore, am in no position to comment on its advantages or disadvantages as compared with what is used in our area. However, at New York University the instructors commented very favorably on it and I have every confidence in their judgment.

"Our most recent experience at the Boston Artificial Limb Company, has been with the Canadian type Symes prosthesis fabricated in accordance with the instructions written by Mr. Foort in a book dated December 1956. We found out early, however, that the glass cloth used with polyester resins did not provide the intended strength. We, therefore, eliminated the glass cloth and used 100% nylon stockinette, and did our reinforcing of the lay-up with 2" Dacron type. This method has worked quite well although some breakage has been experienced. In the most recent Symes prostheses we have made, we have used a medial opening instead of a posterior one.

"At the present time there has been no breakage of these."