A Hemipelvectomy Prosthesis'

Fred Hampton, C.P.[2]

A Hemipelvectomy amputation involves removal of the entire lower extremity and half of the pelvis, separation generally being effected at the sacroiliac and symphysis pubis joints. Whenever possible the gluteus maximus and oblique abdominal muscles are preserved and usually are sutured together along the lower anterior aspect of the abdominal cavity. Because of disease or trauma, it is often necessary to remove the gluteus maximus, in which case the "stump" consists simply of a skin-covered abdominal cavity. The operative procedure is described and pictured in detail in *An Atlas of Amputations* by Dr. Donald B. Slocum (5).

Because there is no longer a skeletal structure on the affected side to assume the forces required during ambulation with a prosthesis, many workers have attempted to design sockets that will transfer weight-bearing loads directly to existing bony structure. Some have tried to use the ischial tuberosity on the unaffected side to support body weight, but with limited success. Others have felt it necessary to extend the socket so that the rib cage can absorb most of the weight-bearing forces, but this arrangement greatly restricts body motion and heat dissipation.

However, it has been found that it is entirely feasible for the "stump" to carry the loads if the socket is designed so that the semisolid abdominal mass of the stump is upward and medially toward the somewhat firmer area of the lower rib cage. Sometimes it is possible to utilize the sacrum for some support but relief for the coccyx must be provided because pressure on this sensitive bone almost always results in pain. Some additional support can often be achieved by utilizing the area of the gluteus maximus on the unaffected side.

Such support may be achieved by means of a piece of 1-in. Dacron webbing anchored to the inner distal area of the socket so that the anchor point is anterior to the ischial tuberosity on the sound side. The Dacron tape is led from its anchor point in the socket, under the gluteus maximus on the sound side, passing just distal to the trochanter and then diagonally across the anterior of the socket to a buckle (Fig. 1). Because the strap passes across the sound side at the level of the trochanter, it acts as a counterforce to the shearing action of the stump slipping in the socket under weight-bearing.

This article describes a method for fitting the hemipelvectomy patient in such a manner that the major loads are carried through the stump. The hemipelvectomy prosthesis incorporates many of the features of the Canadian hip-disarticulation socket, which was fully discussed in the Autumn 1957 issue of *Artificial Limbs.* However, the opening used for donning the prosthesis has been moved from the anterior portion to the lateral side of the socket. Greater stability is achieved by this arrangement since both the anterior and the posterior sections of the socket can contribute more support.

The hip-disarticulation socket utilizes the ischial tuberosity on the amputated side to support the patient in the socket, and the crest of the ilium for suspension of the prosthesis. In the hemipelvectomy case, the skeletal structure is absent and support of the patient in the prosthesis depends upon oblique upward pressure on the stump with an equivalent opposing pressure on the sound

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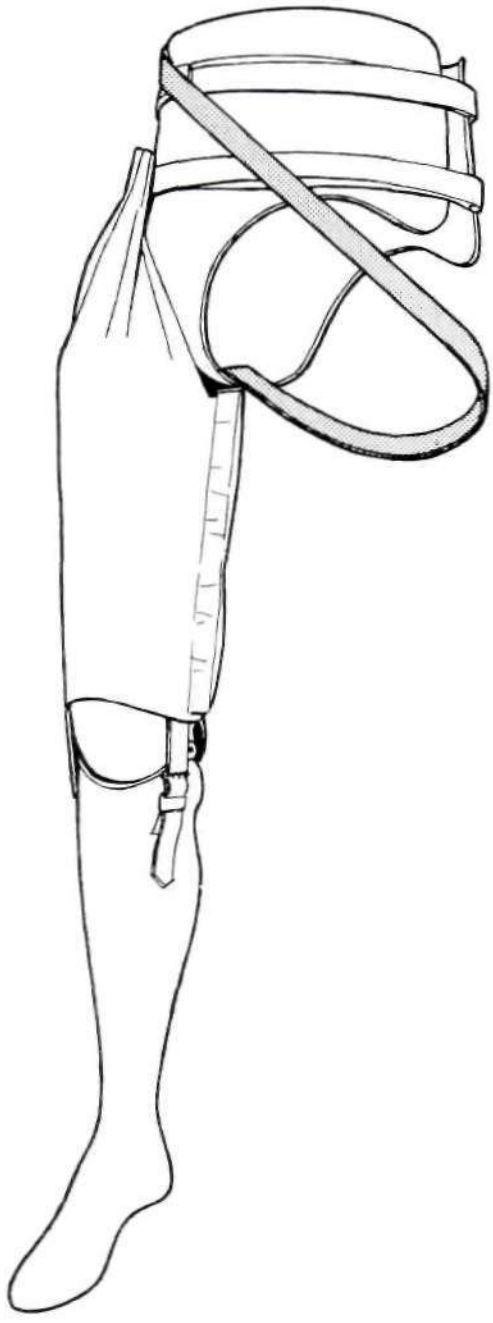


Fig. 1. Sketch shows webbing used as additional support to help to stabilize the amputee in the socket during stance phase.

side, obtained by the shape of the socket *(1)* (Fig. 2).

During casting, hip sticks (Fig. 3) are used to obtain the desired contours of tissues

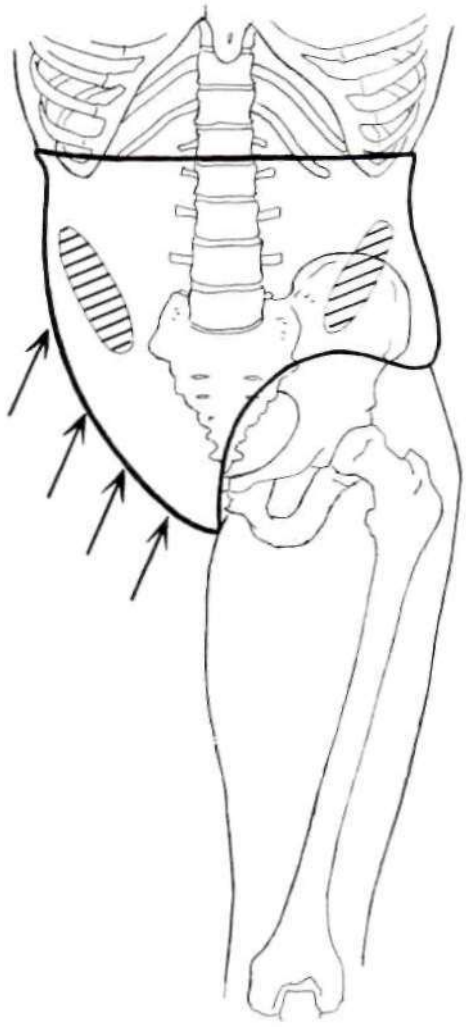


Fig. 2. Hemipelvectomy socket. Arrows indicate pressure applied by the socket to the "stump," upward and medially. Shaded areas indicate bulges produced by the use of hip sticks. The bulges aid in suspension of the prosthesis, in preventing rotation, and serve as guides for correct alignment while donning the prosthesis.

necessary for good suspension of the prosthesis *(2)*. Casting a patient while suspended in a sling is one method of compressing tissues in an upward oblique direction, resulting in a cast of the desired shape.

The hemipelvectomy prosthesis utilizes the principles of alignment of the Canadian-type hip-disarticulation prosthesis. Moreover, the mechanics of the hemipelvectomy prosthesis are essentially the same as those of the hip-disarticulation prosthesis (4).

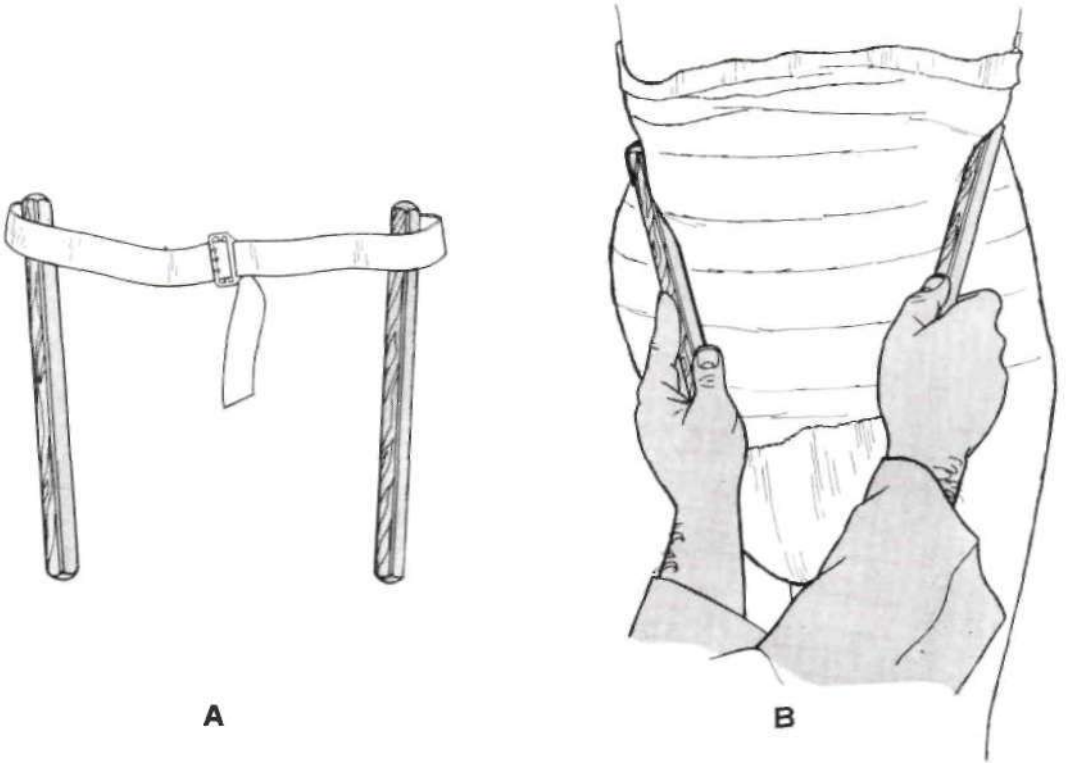


Fig. 3. Hip sticks. *A,* two sticks, approximately 14 in. in length, 1 in. in diameter, joined by a piece of 2-in. webbing, adjustable by means of a buckle. *B,* hip sticks as applied to the "stump" during casting to create relief for the crest of the ilium on the sound side and desired shape of tissues on the amputated side.

New features incorporated in the hemipelvectomy prosthesis are: First, silicone foam is used in the socket construction to fill the cavity at the location of the hip joint; silicone foam is nontoxic, easily used, and provides a surface that is not as slippery as the polyester laminates. Second, the attachment for the hip joint is an integral part of the socket. Third, there is an articulated thigh fairing which is lightweight, easily fabricated, allows reduction in the size of the thigh block, and greatly enhances cosmesis in both the sitting and standing positions. Fourth, there is a support strap under the ilium and around the trochanter.

The prosthesis includes the use of a single-axis knee and a SACH foot with a very soft heel wedge. This soft heel wedge increases the stability of the prosthesis at heel strike.

EXAMINATION OF THE AMPUTEE

When an amputee with a hemipelvectomy stump is first seen, a visual examination will reveal scar tissue or other surface conditions that may affect the design of the socket. The location of sensitive areas should be noted so that they may receive special treatment if necessary. All hemipelvectomy amputations are not sectioned at the same level; some surgeons leave behind a small amount of the ilium or a small amount of the pubic bone. Palpation of the stump will usually permit determination of any remaining bony structure, but for definitive evaluation an x-ray of the pelvic area is desirable.

When all the conditions relative to the amputation are known and recorded on the Prosthetic Information Form (Fig. 4), the prosthetist is ready to proceed with the first step of prosthesis fabrication; namely, production of a model of the stump and adjacent areas.

CASTING THE STUMP

It has been found that a minimum of modifications to the positive model is required if

HIP DISARTICULATION AND HEMIPELVECTOMY AMPUTATIONS

Name _____ Date _____

Height _____ Weight _____ Age _____ Sex _____ Race _____

Date of Amputation _____ Type of Amputation _____

Cause _____ Right or Left _____

Previous Prosthesis? Type _____

Prescribed Prosthesis _____

Type Socket _____ Knee Joint _____

Hip Joint _____ Foot and Ankle _____

Tolerance of Ischial Pressure _____

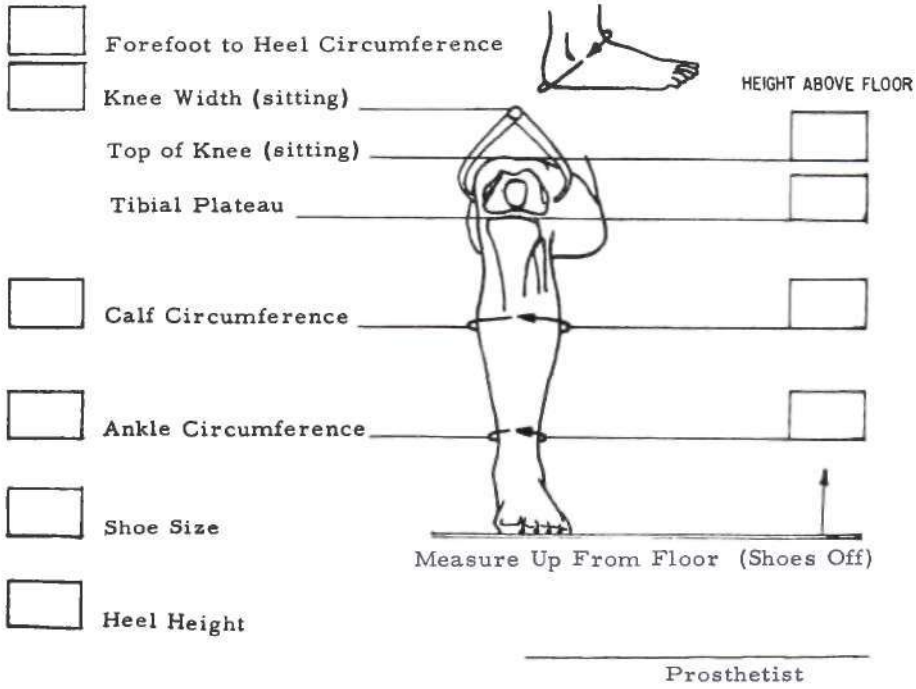
Comments on Special Considerations (Sensitive Areas, Scars, Some Femur Remaining? Any Pelvis Remaining? How Much?) _____

_____

_____

Make Tracing of Normal Limb, Anterior and Medial View, for Cosmesis

Distance from Ischial Tuberosity to Floor (No Shoe) _____



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Prosthetist

Fig. 4. Prosthetic Information Form.

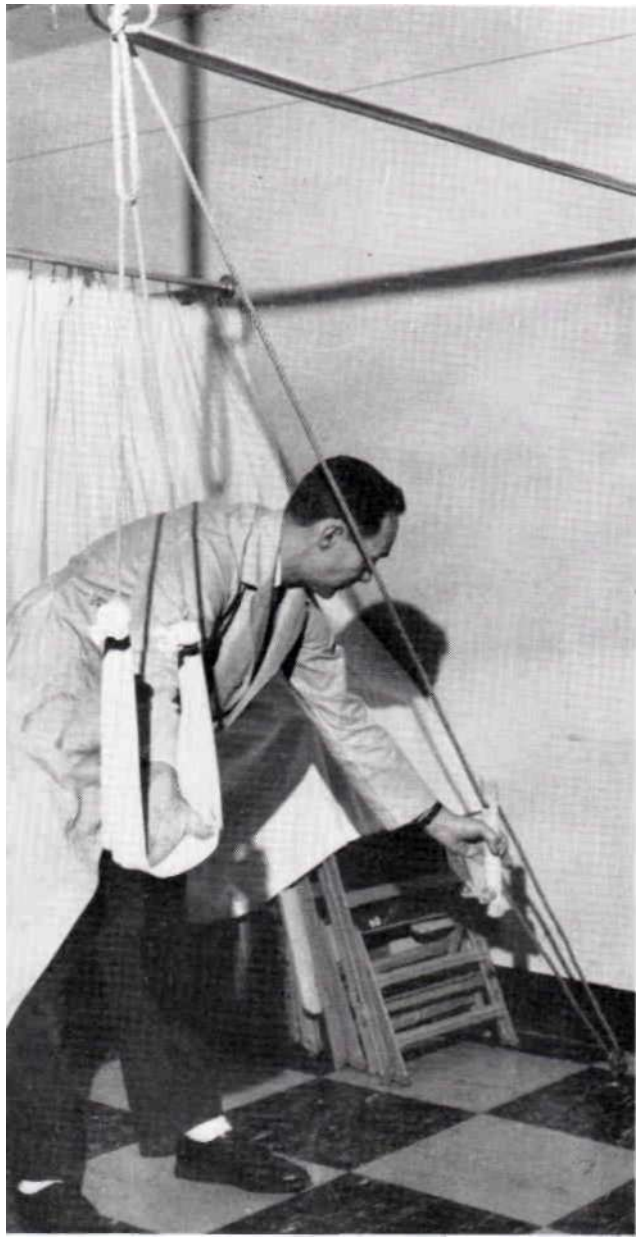

Fig. 5. Adjusting the sling to obtain proper height.

the cast is taken under weight-bearing conditions. To achieve these conditions, a simple adjustable overhead sling is used. The arrangement shown in Figure 5 utilizes existing structure in the laboratory and a tent-rope tension bar to achieve height adjustability, but a number of equally satisfactory designs can be devised.

The seat area of the sling may be made with a piece of 6-in. or 8-in. stockinette tied to the rope at both ends. The stockinette should be long enough to clear the outline of the superior brim of the socket.

In taking the cast, hip sticks are used to assist in locating and providing relief for the anterosuperior spine of the ilium on the

sound side, and to produce a similar impression on the amputated side. This impression assists in suspension of the prosthesis and helps to prevent rotation of the socket on the stump.

Materials required for taking the cast are:

4-in. or 6-in. plaster bandages	Indelible pencil
3-ft. length of 8-in. or 10-in. stockinette	Plumb bob
Two 3-ft. lengths of 1-in webbing	Yardstick
Four harness clamps	Paper
Container with water	

PREPARATION OF THE PATIENT

A 3-ft. length of stockinette (8-in. or 10-in. width as required) is pulled up on the amputee until it is quite snug on the sound thigh. Proximally, it should cover half the thorax. The stockinette is secured with 1-in. webbing over the shoulders and should be pulled tight enough to give some support to the stump mass (Fig. 6).

The distal portion of the rib cage and any areas that need relief are outlined with an indelible pencil. The remaining anterosuperior spine of the ilium is located and outlined. The trochanter on the sound side is located and marked.

An approximate outline of the socket is drawn (Fig. 6). The anterior distal portion of the outline starts at the pubic ramus and arcs upward along the inguinal crease on the sound side with clearance for the sartorius muscle, then passes down to a point just superior to the trochanter. The posterior distal portion of the outline passes from the midline of the body to a point just lateral to the ischial tuberosity, then arcs upward to join the anterior line superior to the trochanter. The proximal outline circumscribes the body at the level of the tenth rib.

Fig. 6. Tentative outline of socket drawn on stockinette.

SLING ORIENTATION

The amputee is seated in the sling after it has been positioned approximately for height. Pressure on the stump should be diagonally upward and toward the opposite shoulder. Therefore, the sling should pass diagonally across the body to the sound side. A piece of 1-in. webbing under the axilla on the sound side will hold the rope away from the neck and face of the amputee.

Fig. 7. Orientation of amputee in sling. Retention strap adjusted just distal to trochanter on sound side.

A slot is cut in the sling posteriorly and just superior to the seat area. Another slot is cut opposite this in the anterior section. A piece of 1-in. webbing is pulled through these slots, around the thigh, and clamped together to prevent the seat from sliding on the stump (Fig. 7).

The amputee is instructed to place more weight on the sling than on the sound leg, and the sling is adjusted for height. It is ascertained that the seat area is contacting the remaining ramus.

The setting of the hip sticks is checked. The length of the webbing should be adjusted to fit the patient so that the groove for relief of the remaining ilium and a corresponding groove on the amputated side will be in the proper position. The fulcrum of the hip sticks should be slightly posterior to the crest of the ilium to obtain leverage necessary to bring adequate pressure against the proximal posterior portion of the plaster wrap.

WRAPPING THE STUMP

The procedure of wrapping the stump usually requires two people. Except for obese cases, the patient is removed from the sling for application of the plaster wrap. This is done to contain the tissues and so prevent lateral distortion of the stump when weight is reapplied in the sling. An obese amputee, however, should not be removed from the sling. The wrap cast should be made to incorporate the stockinette initially, because it is too difficult to wrap the stump and properly orient the patient back into the sling before the plaster starts to set,

The wrap is started at the lateral proximal brim on the sound side and is brought diagonally upwards across the anterior (Fig. 8). Moderate pressure is placed on the wrap, but ridges should be avoided. The stump should be completely wrapped just past the outline previously drawn on the stockinette. Care must be taken to include the trochanter on the sound side. While the wrap is still wet, the amputee is positioned back in the sling, and the ropes are adjusted until he is standing erect, with at least equal weight being borne on the amputated side.

Fig. 8. Beginning diagonal wrap of stump.

The webbing of the hip sticks is placed across the back of the patient and under the stockinette sling, if it is bridging. The sticks should slant diagonally down just medial to the anterosuperior spine of the ilium on the sound side and a corresponding position on the amputated side. The crest of the ilium on the sound side is palpated by hand to ensure that the hip sticks are not impinging on the anterosuperior spine of the ilium. When the hip sticks are in the correct position, they are held with sufficient pressure to ensure adequate relief. At the same time, an oblique upward pressure is exerted to the lateral distal area of the stump and a counterforce is applied on the opposite ilium. This condition is maintained until the plaster is set. The hip sticks are removed, and the cast is reinforced with additional bandages over the sling. The wrap should touch the remaining ramus, and a portion of the gluteus on the sound side should be included.

Fig. 9. Locating trochanter on sound side.

The trochanter is marked (Fig. 9), and the amputee is removed from the sling.

The patient is then placed on a table with the stump toward the near side of the table. The gap between the plaster cast and the patient's abdomen is checked to determine if alteration to the wrap is required to contain the viscera and ensure an intimate fit to the socket (Fig. 10). The plaster wrap is cut from the proximal to the distal rim just medial to the socket section. The gap, if there is one, is eliminated by pushing the cast down to meet the abdomen, care being taken not to squeeze the cast mediolaterally and so disturb the placement of the bulge caused by the hip sticks on the sound side (Fig. 11). One side of the cut is covered with vaseline to a depth of approximately 4 in. to facilitate removal of the cast.

Fig. 10. Checking the gap between the cast and the patient.

A panel of plaster-of-Paris bandages approximately 8 in. wide is formed and laid across the front of the cast, the cast being held in the desired position. Lines to relocate the position of the panel and the cast are drawn, and the cast is secured on the patient by means of a web belt. This will prevent the cast from spreading when the amputee stands and will result in more accurate datum lines.

With the amputee standing, the cast is checked for lit and comfort.

REFERENCE LINES

To provide datum lines for alignment of the prosthesis, vertical reference lines are marked on the cast at this time.

The amputee should stand erect using an adjustable support under the cast. The spine should be straight and the shoulders level and at right angles to the line of progression.

A plumb bob is suspended from the sternum (Fig. 12), and a vertical line is drawn on the cast. A plumb bob is suspended from the spine, and a vertical line is marked on the cast. A plumb bob is suspended from tinder the axilla to bisect the trochanter on the sound side, and the line is drawn on the cast.

The cast is removed from the amputee and, after being cut down to the outline previously drawn on the stockinette, is used as a check socket. It should be checked for support and comfort under weight-bearing

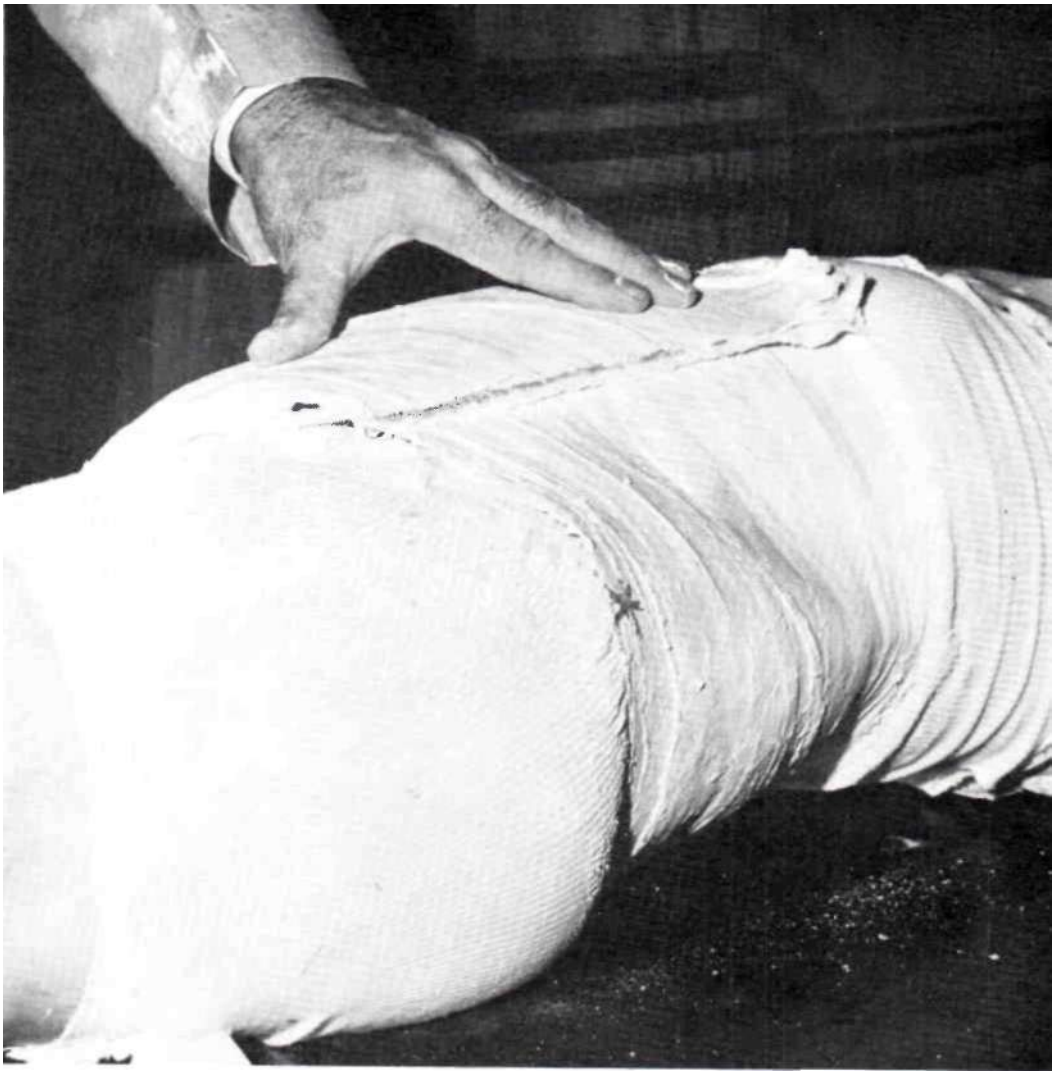

Fig. 11. Closing the gap by downward pressure.

while the amputee is standing, for pressure on the rib cage, and for clearance of the sound leg while the amputee is sitting. The area of the coccyx should be checked, also the area providing relief for the anterosuperior spine of the ilium on the sound side.

POURING THE PLASTER POSITIVE MODEL

The common method of forming the plaster positive model is to pour the negative cast full of a plaster slurry. A mixture of plaster and vermiculite in equal proportions results in a lighter model and one that is quite easy to work. A slush, or hollow model, may be used, but care should be taken to make the model thick enough for it to withstand the pressures involved when lamination is carried out.

The leg opening is closed, and the cast is reinforced with plaster bandages. A separator such as vaseline or silicone spray is applied to the inside of the cast.

The reference lines are reestablished if they were covered by the reinforcement.

A sheet of paper large enough to extend beyond the cast is laid out and divided into four equal parts by means of two perpendicu-

Fig. 12. Use of plumb bob to obtain reference lines on cast.

lar lines. The cast is placed on the paper so that the vertical reference lines on the cast coincide with and are vertical to the lines on the paper. The cast is secured in this position by blocking it up with plaster.

After the plaster has been poured into the cast to form the positive model, a pipe is inserted not only to provide for ease of handling but also to act as a pathway for the air to be drawn out of the laminate by a vacuum pump. A paper cup is installed on the pipe, as shown in Figure 13, to keep plaster from clogging holes that have been drilled in the pipe to allow the passage of air. The pipe is inserted so that it is aligned with the vertical reference lines; thus it can be used as a reference line when the negative mold has been removed.

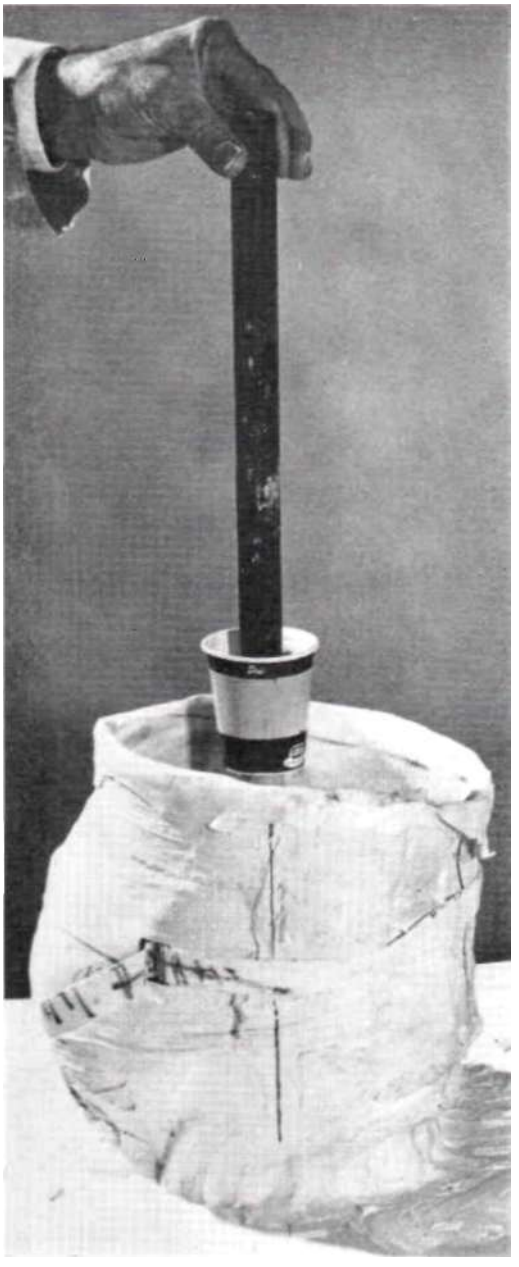

Fig. 13. Setting pipe vertically using vertical lines on cast as reference.

LOCATION of THE HIP JOINT

Before any modifications to the positive model are undertaken, a buildup is made so that the finished socket will contain a flat area suitable for installation of the hip joint. Instructions given here are for the so-called

Fig. 14. Scribing 45-deg. line on cast.

Northwestern hip joint,[3] a unit which provides for alignment adjustment.

The hip joint should be placed laterally to provide adequate clearance in the crotch area, placed well forward to ensure adequate stability during the stance phase of walking, and high enough so that the extension stop does not interfere with sitting.

If the hip joint is placed too far to the rear, the amputee will be insecure, the joint will interfere with sitting, and more energy will be expended in walking. If it is placed too far forward, the prosthetic knee will extend past the normal knee when the patient is seated. This condition can be partially alleviated by shortening the thigh and lengthening the shank. However, a compromise in the location of the joint is essential.

Location of the hip joint in approximately the optimum position may be achieved by the following method:

Before the positive model is removed from the cast, a reference trochanter, the point on the cast directly opposite the trochanter on the sound side, is established. By means of a height gauge, the trochanter mark on the cast is transposed to a point vertical to the layout line on the opposite side. A point on the surface of the cast 1 1/2 in. vertically below this point is marked. Through this last mark, a line is drawn on the cast at an angle of 45 deg. A useful aid for this is a piece of wood approximately 1 in. thick, cut on an angle of 45 deg. (Fig. 14). In scribing the line, the pencil must be held flat on the 45-deg. surface.

All reference lines from the cast are cut through to the positive model by use of an awl. When the cast is removed, the lines are marked on the model with an indelible pencil.

An outline of the socket is drawn on the model. Heretofore, it has been the common practice to cut the anterior portion of the socket to allow entry and exit of the torso. Experiments at the Northwestern University Prosthetics Research Center have shown that more stability between patient and socket can be achieved if the opening is made on the lateral wall.

MODIFICATION OF THE POSITIVE MODEL

To provide additional relief for the antero-superior spine of the ilium on the sound side, a skived piece of leather or a plaster buildup 1/4 in. thick on the positive model should be adequate.

[3] NHJ-100, Hosmer Corp., Santa Clara, Calif.

The anterior section of the model usually has a ridge caused by overlapping during the casting procedure. This ridge should be eliminated by removal of plaster. If there is a large bulge posteriorly in the gluteal area, the bulge should be reduced by removal of plaster. Sometimes the angle of the lateral wall will continue to the ramus. If this is apparent, the distal seat area may be modified and flattened slightly by removal of plaster in order to minimize slipping. Any other ridges should be removed, and the entire model should be smoothed with files, wire screen, or sandpaper. A good finish may be obtained by wet sanding with a piece of Wetordry Fabricut.

Moisture must be contained in a new model to prevent the PVA bag used as a separator from becoming wrinkled. Application of a sealer, such as Ambroid or parting lacquer, will serve to retain moisture.

Leather tongues used at the closure of the socket will deteriorate from sweat. A molded flexible polyester tongue is more durable and sanitary. It should be formed to the model before the flare is added to ensure a smooth transition from the tongue to the socket surface. The tongue is made by laminating four staggered pieces of nylon stockinette across the proposed opening with a flexible mixture of polyester resin (60 per cent Laminac 4134 to 40 per cent Laminac 4110 is an adequate mix). After the tongue has set, it should be trimmed to the desired shape and taped to the model.

The outline of the socket on the model is built up to provide a flare with a radius of approximately 3/4 in. The buildup is accomplished by folding a piece of 4-in. plaster bandage lengthwise approximately seven times, wetting it, and laying it on the outline as a beading. The plaster bandage is formed over the tongue to provide a lateral opening at least 1 in. wide. The beading is formed to the desired flare and smoothed with plaster (Fig. 15). The flare should be coated with Ambroid or parting lacquer.

The model is now inverted and mounted in a vise with the sagittal plane vertical. The mounting pipe should be set at an angle of 45 deg. to the horizontal, with the anterior surface of the model upward (Fig. 16). The 45-deg.

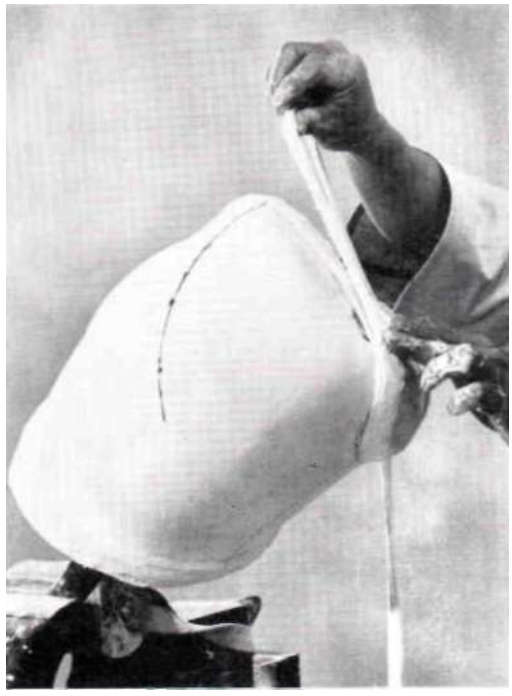

Fig. 15. Construction of flaring.

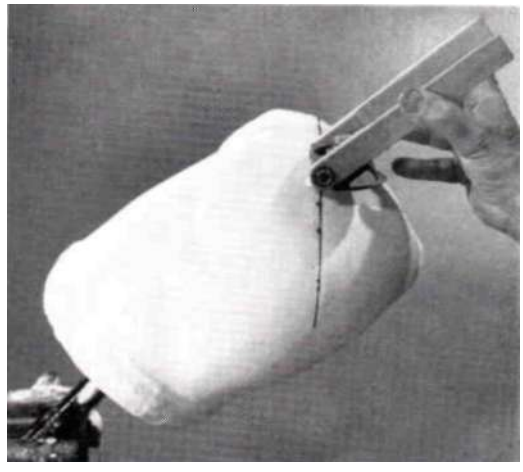

Fig. 16. Positioning joint on positive model using 45-deg. line as reference. (Model is held in vise at 45-deg. angle, so 45-deg. line, previously scribed, is now vertical.)

line on the model should now be vertical, and it should be extended past the flare, both proximally and distally.

The configuration of many hemipelvectomy sockets will not allow sufficient clearance for the joint in the crotch area. To allow the joint to be placed more laterally and to provide a flat area for mounting the joint, it is necessary to build up the positive model with rigid polyurethane foam.

The principal considerations in planning the joint location are: First, the flat area must be large enough to receive the mounting plate (about 2 3/4 in. in diameter). Second, the flat area will be horizontal when the model is mounted at the 45-deg. angle. Third, usually the axial center of the joint is somewhat anterior to the 45-deg. line. (It should be kept as close as possible to the line, but the joint must not be permitted to interfere with the sitting position.) Fourth, in most hemipelvectomy sockets, the joint will project beyond the lateral edge of the socket, but it should not project further from the midline of the body than the corresponding joint of the sound leg.

Fig. 17. Pouring polyurethane foam into cardboard form.

Fig. 18. Anterior view of positive model showing flat area necessary to receive hip joint.

Cardboard is formed on the positive model to form the buildup for the joint location and to allow for contours that will blend well with the socket. Polyurethane foam (Pelron 4-lb. density No. 9664[4]) is mixed and poured into the cardboard form (Fig. 17). As the foam is being shaped, care should be taken to shape the area immediately medial to the joint to permit full adjustment of the joint. Figure 18 shows the completed buildup on the positive model for the location of the hip joint.

SOCKET FABRICATION

Although it is not necessary to use any specific laminating procedure, the vacuum technique described in this article is presented as one that has produced consistently good results in the Northwestern University Prosthetics Research Center *(3)*.

Radial suction grooves are cut with a sharp knife from the crest of the flare on the positive model to the cup, or approximately eight 1/8-in. holes are drilled through the model into the cup, the holes being so situated as to ensure the evacuation of air from undercuts.

[4] Pelron Corp., Lyons, Ill.

A thin smear of vaseline or motor oil is applied over the sealed surfaces of the model and the polyurethane foam buildup. (Caution: Ambroid should not be applied to the polyurethane foam; the thinner in the Ambroid will soften the foam.) A light plaster slurry is used to blend the edges of the foam into the contours of the socket. A light plaster wash is then applied to the foam and allowed to dry. Ambroid, then vaseline or oil, may be applied to facilitate pulling the PVA separator over the model.

A tailored PVA bag is pulled down over the positive model. One end is gathered and tied over the area of the sound leg. The other end is taped tightly around the pipe. Three or four holes are punched in the bag near the cup.

Fabric is applied as follows:

1 layer 1/2-oz. Dacron felt.
1 layer nylon stockinette.
7 layers of glass cloth over the joint and seat areas The pieces of cloth should be of varying size to produce a gradual transition in rigidity.
1 layer Dacron felt over all.
5 layers of nylon stockinette pulled on tight and tied to the pipe.
A PVA bag is pulled down over the layup and taped tightly to the pipe.

Resin, in an appropriate amount, should be prepared in the proportion of 80 per cent rigid Laminac 4110 to 20 per cent flexible Laminac 4134. ATC catalyst—2 per cent of the weight of the resin mixture—is added and spatulated thoroughly. Appropriate pigment, amounting to about 2 per cent of the weight of the resin mixture, should be added: 12 drops of Naugatuck # 3 promoter results in approximately 20 min. working time. This will vary according to temperature and humidity.

One method of impregnating the fabric with the resin is to pour the resin into the top of the outer PVA bag and "string" the resin downward, working it into the layup, especially into the reinforced seat area, to obtain complete saturation. After the resin has been "strung" into the layup, the vacuum is applied and a head of resin is maintained at the top to prevent air from being sucked into the laminate. Insofar as possible, air is excluded from the top of the PVA bag, and the bag is tied off tightly at the top.

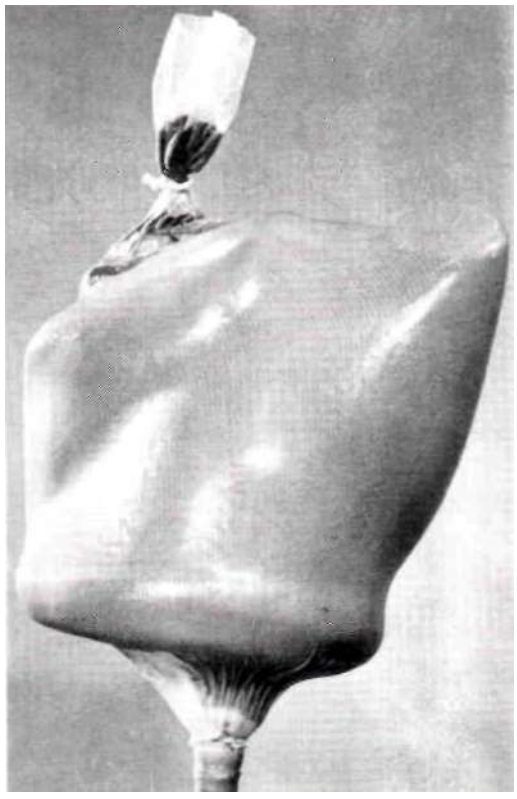

Fig. 19. View of laminate of socket using vacuum technique.

Another method is to apply vacuum prior to "stringing" the resin into the layup. In this procedure, the resin is poured into the top of the PVA bag, which is then tied off and vacuum is applied. The resin is then "strung" down into the layup.

In both procedures, the hands must be used to force the resin from undercuts, considerable "stringing" downward must be done to remove bubbles, and "stringing" upward to remove excess resin.

Low negative pressure should be maintained until the plastic has set (Fig. 19). Excessive vacuum will pull the resin from the laminate, causing "starving."[5]

[5] At sea level, the atmosphere will support a column of mercury 30 in. high. Most vacuum gauges, therefore, are calibrated in inches of mercury (in. Hg.), reading from 0 to 30. 10 in. Hg. negative pressure means 10 in. of mercury below atmospheric pressure.

REMOVAL OF SOCKET FROM POSITIVE MODEL AND REPLACEMENT OF POLYURETHANE FOAM BUILDUP WITH SILICONE FOAM

With the flare as a guide, a Stryker cast cutter is used to cut through the laminate along the outline of the socket. If a molded tongue has been attached to the positive model, care should be taken when making the cut on the lateral side. It is prudent to leave a little extra laminate for subsequent trimming.

The polyurethane buildup for the location of the hip joint is removed from the positive model. The positive model is smoothed in this area, and a thin smear of vaseline is applied. A piece of lightweight stockinette is stretched over this part of the model and stapled in place.

Using the back plate as a template, three 1/4-in. holes are drilled. The center hole is drilled with a 1/2-in. drill. The back plate is mounted in the socket with two bolts and nuts. The bolts should not be cut.

The socket is replaced on the stump model and secured tightly with a web belt or friction tape (Fig. 20). It is in position for the injection of silicone rubber through the 1/2-in. center hole in order to provide support for the amputee over the area of the hip joint.

In choosing the silicone rubber to be used, it should be remembered that Silastic 386 Foam Elastomer is relatively soft and may not be capable of supporting the weight of the amputee, while Silastic 385 Elastomer forms a solid rubber which will, if used by itself, add considerable weight to the prosthesis. Accordingly, a mixture of 70 per cent by weight of 386 with 30 per cent by weight of 385 is recommended. This is poured into a caulking gun. The 386 catalyst—6 per cent by weight of the mixture—is added, and the mixture is spatulated for 25 seconds. Because of the small amount of catalyst, the viscosity of the Silastic, and the shape of the chamber of the caulking gun, it is very difficult to get a homogeneous mix if spatulated by hand. A mixing rod should be formed that can be used in conjunction with a 1/4-in. electric drill. A rotary up and down movement should be used, mixing for 25 seconds. It is then injected through the center hole of the spherical plate to fill the

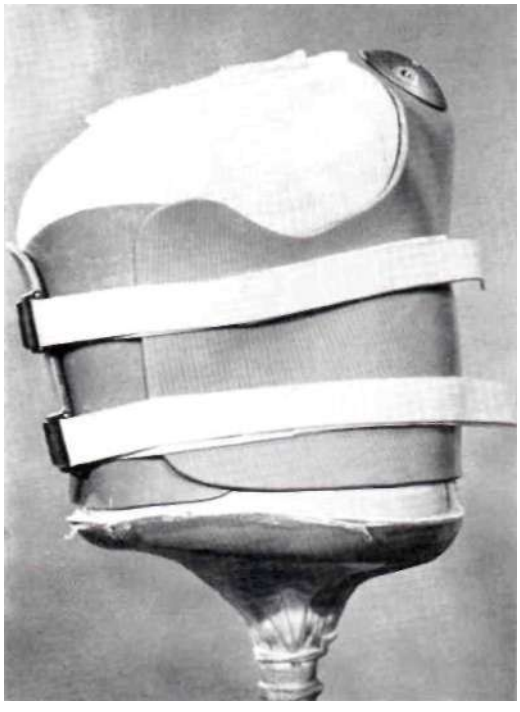

Fig. 20. Socket replaced on stockinette-covered cast preparatory to injection of foam.

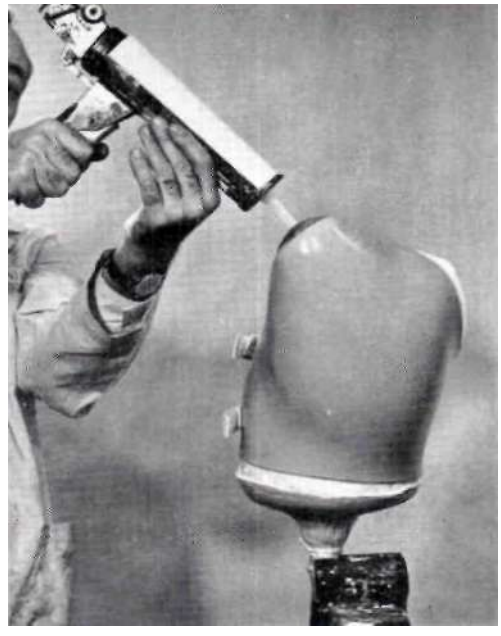

Fig. 21. Injection of silicone foam through center hole of spherical plate.

socket cavity (Fig. 21). The mixture will expand approximately four times its volume during foaming. If necessary, more of the same mixture is added until the cavity is filled.

The socket is removed from the cast. The silicone pad is removed and the nuts are removed from the two bolts. The spherical plate is attached to the socket with three 1/4-in. flat head bolts. The bolts should be locked tight with a locking compound. The bolts are threaded into the spherical plate with a screwdriver, but they should be tightened with vise grip pliers applied to the protruding threaded portion of the bolt. If this spherical plate is not tightened sufficiently, movement and noise will result. The bolts should then be cut and ground to maintain the spherical contour (Fig. 22).

The edges of the socket are sanded and buffed to provide a smooth radius.

For fitting purposes, the foam pad is secured in the socket by means of friction tape. It can be glued to the socket when the prosthesis is being completed. The edges of cloth reinforcement on the foam should be trimmed, and the surface coated with a skin of Medical Silastic S—5391 Elastomer (Fig. 23).

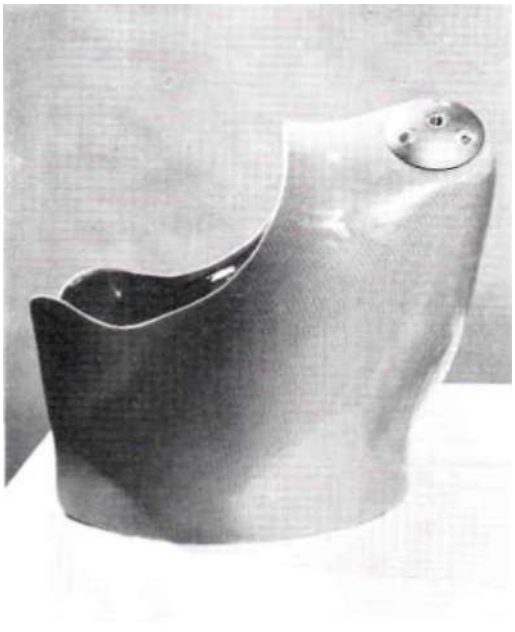

Fig. 22. Socket with spherical plate attached.

Fig. 23. View of silicone foam pad with stockinette reinforcement.

LAYOUT OF THIGH BLOCK

One method of determining the configuration of the thigh block is as follows:

1. On a large piece of paper, line A is drawn to represent the length of the foot (Fig. 24). The distance from the end of the heel to the center of the ankle bolt is measured and marked on line A.

2. Line B is drawn perpendicular lo line A from the point representing the foot attachment bolt. The length of this line is the distance from the ischial tuberosity to the floor.

3. On line B a point is located equal to the height of the medial tibial plateau (MTP) plus 1 1/4 in. for adults. The location of the hip joint often causes the prosthetic knee lo protrude beyond the sound knee when the patient is in the sitting position unless the thigh is shortened and the shin is lengthened. Therefore, 1 1/4 in. is added to the dimension between the floor and the MTP.

4. Two inches above this point a 6-in. line is drawn to represent the attachment plate of an adjustable leg. This line is drawn 3 1/2 in. anterior of and 2 1/2 in. posterior of line B.

5. A line is drawn at right angles to line B at its topmost point. This line, D, represents the height of the level of the seat of the ischium from the floor.

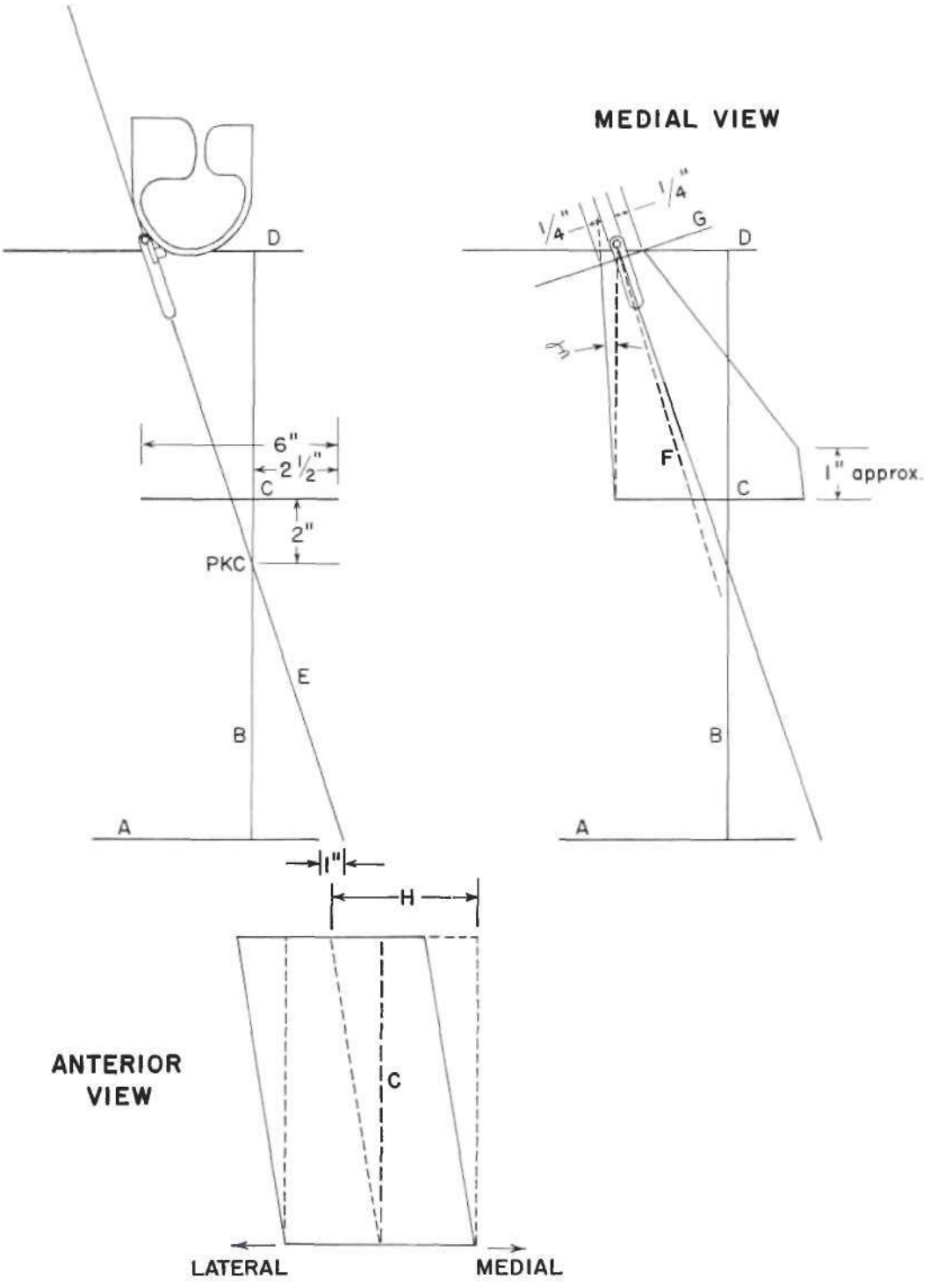

Fig. 24. Schematic drawing (not to scale) for layout of thigh block.

6. From a point 1 in. behind the heel, line E is drawn to intersect the prosthetic knee center (PKC) and the horizontal line D.

7. The socket is superimposed on the layout, with the joint attached and in a neutral position. The inner edge of the socket must fall on line D and the hip joint center must pass through line E.

8. The hip joint is adjusted so that the angle of the straps with line D is 73 deg. in order to maintain the 45 deg. originally planned for the placement of the hip joint.

9. The position of the side straps is marked and outlined, line F, and also the offset for the shoulder of the straps, line G.

10. There should be 1/4 in. of wood anterior to the hip joint. Therefore, from a point 1/4 in. anterior to the shoulder of the side strap outline, a line should be drawn connecting with the anterior end of the socket attachment plate line. (Angle *a* in Fig. 24 is the flexion angle.)

11. From a point 1/4 in. posterior to the shoulder of the side strap outline, a line is drawn to form the posterior outline of the thigh block. Often, this is not a direct connection with the posterior end of the socket attachment plate line, as this would not provide sufficient thickness of wood for screws at the attachment plate of the adjustable leg.

12 An anterior view is drawn of the thigh section in which the proximal center point is offset the equivalent of the distance from the center of the artificial hip joint to the vertical support line on the prosthesis, less 1 in. (distance H in lower part of Fig. 24). This establishes the approximate angle of adduction needed in the thigh block. The objective is to place the artificial foot in the approximate amount of adduction.

13. The thigh block, of correct length, is positioned with the lateral side up and angle *a,* obtained from step 10 above, is inscribed upon it.

14. The thigh block is positioned with the posterior side up. A goniometer is placed with one arm parallel to the lateral side of the posterior wall; the other arm, set in the angle required, should lie across the posterior wall and connect with the flexion angle previously established. If the adduction required is excessive, it is sometimes necessary to bend the side straps. A bend of approximately 8 deg. is usually sufficient. Care must be taken not to produce nicks and notches in the side straps which may cause premature fracture.

15. The table of the saw is set at the adduction angle and a cut is made along the flexion line.

16. The hip joint is centered on the thigh block, and the width of the straps is marked. The outline of the straps should be left showing after the excess wood has been cut away. Enough wood must be left for the socket attachment plate. Care must be taken that the distance between joints is accurately reproduced on the thigh block, otherwise binding will result when the joint is assembled and shimming will become necessary.

17. The joint is clamped to the thigh block. After the two indicated 1/4-in. holes have been drilled, the joint is bolted to the thigh block.

BENCH ALIGNMENT OF PROSTHESIS

Two general rules to be followed in the bench alignment of the prosthesis are: First, the socket should be the correct height above the floor, with the transposed point of the ischium directly over the center of the foot. Second, the knee should be set in slight hyperextension so that a straight line drawn through the hip joint intersects the floor about 1 to 1 1/2 in. behind the heel.

It is recommended that a SACH foot with a soft heel wedge be used. A knee extension aid is important; it is provided by a piece of 1-in. elastic which also functions as a stride length control. This is adapted for temporary use on the adjustable leg by mounting a piece of leather on the socket approximately 2 in. behind the hip joint in such a way that the elastic strap can pass through the attachment. For a woman, the extension aid is built into the knee mechanism and the socket bias strap is secured to the distal thigh block. One end of the elastic is screwed to the shin 2 in. down from the PKC, and the other end of the elastic is secured by a buckle mounted in the corresponding position on the other side of the shin. A keeper of 1/2-in. Dacron webbing, with a buckle, is positioned about 1 1/2 in. proximal to the knee bolt. This keeper should be adjusted so that it holds the bias strap anterior to the knee bolt center when the patient is standing and walking but allows it to pass posterior to the knee bolt center when the patient is sitting.

Velcro offers a convenient method of closure for the lateral opening of the socket (Fig. 25).

When the prosthesis is assembled, the axes of the hip joint and of the knee joint should be essentially parallel to the floor and at right angles to the line of progression.

STATIC AND DYNAMIC ALIGNMENT

Satisfactory suspension of the prosthesis often depends upon the proper application of

Fig. 25. Arrangement of closure straps using Velcro.

the socket (Fig. 26). The stump should be forced as far laterally as possible and the closure straps should be tightened alternately until the amputee is well supported. The ischial support strap should be secured last. The relief provided by the socket for the anterosuperior spine of the ilium on the sound side is a useful guide in orienting the socket to the patient. The socket should then be checked for fit and comfort under weight bearing in the areas of the ramus, the coccyx, and the rib cage. Lateral stability of the socket should be evaluated by supporting the prosthesis against a chair and asking the patient to raise his good leg without leaning over the prosthesis.

The alignment line from hip center through PKC to a point behind the heel should be verified for stability. It should be ascertained that the height of the prosthesis is correct; that the extension bias strap is forward of the PKC; that there is no friction in the knee joint; and that the bumper and stop are in contact. The patient should not be in a forced position of lordosis, and the socket should not exert pressure proximally in the back. If either of these conditions exists, the bumper is contacting the stop too soon and the socket should be tilted backward by means of the adjustable hip joint. If the bumper is not in contact with the stop, correction should be made by adjustment of the hip joint.

The amputee should then sit upright in a hard chair, and the anterior distal portion of the socket should be inspected for clearance of the thigh. If the amputee tends to lean to the amputated side, the exterior gluteal area of the socket should be built up with foam for support and to improve cosmesis. It should be ascertained that there is no pressure between the proximal edge of the socket and the rib cage; that the thigh block clears the chair; that the shank is vertical; that the prosthetic knee axis does not protrude excessively beyond the normal knee center; that toe-out is approximately correct; and that the extension bias strap is holding the shank in flexion.

In training the amputee to walk, he should be impressed with the importance of standing upright by holding his hands parallel to or slightly posterior to the long axis of his body. If he leans forward to watch his feet, the hip bumper will not contact the stop, making it impossible to propel the leg forward. He should alternately bear his weight on the prosthesis and then lift it clear of the floor. To initiate flexion of the knee, the amputee should be

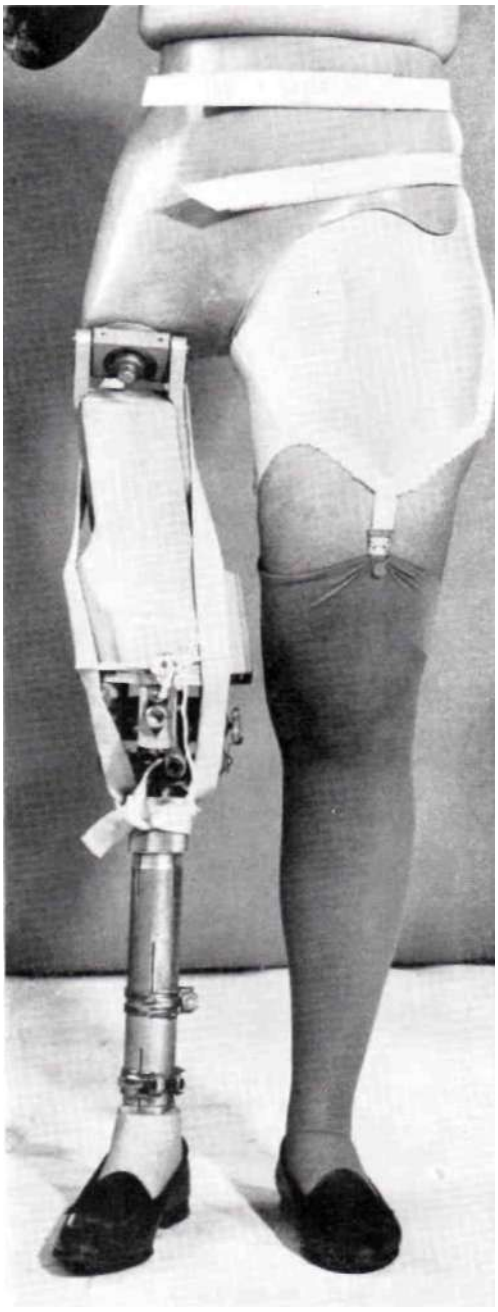

Fig. 26. Socket mounted on adjustable leg preparatory to dynamic alignment.

instructed to "scoop" his stump and pelvis forward and flex his spine. This should be jepeated a few times and the bias strap adrusted to obtain the proper stride length.

The amputee should be instructed to take a few steps. If the knee appears unstable just after heel contact, the durometer of the heel wedge should be checked, and it should be determined whether the shank is reaching full extension; whether the knee is in some hyperextension; whether the hip joint is contacting the stop before the foot is flat on the floor; and whether the alignment line runs correctly from the center of the hip joint through the center of the knee joint to 1 1/2 in. behind the heel of the shoe. To eliminate medial or lateral whip, rotational adjustments are necessary at the knee or hip axis.

Many amputees wear a stump sock, which decreases the friction between the patient and the socket during the stance phase and loses some of the socket's support. To increase the friction, it is sometimes advantageous to line the lateral aspect of the socket with a rubber material or with horsehide.

If toe clearance is still a problem, the length of the prosthesis should be reduced. The

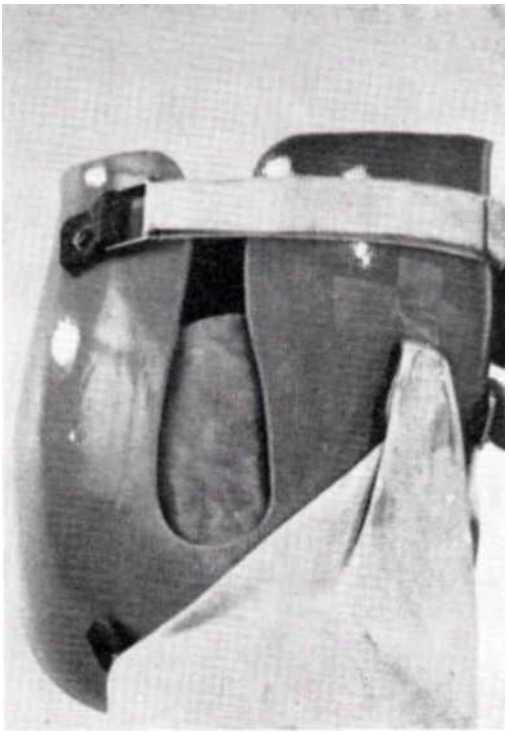

Fig. 27. Teardrop opening in socket on amputated side.

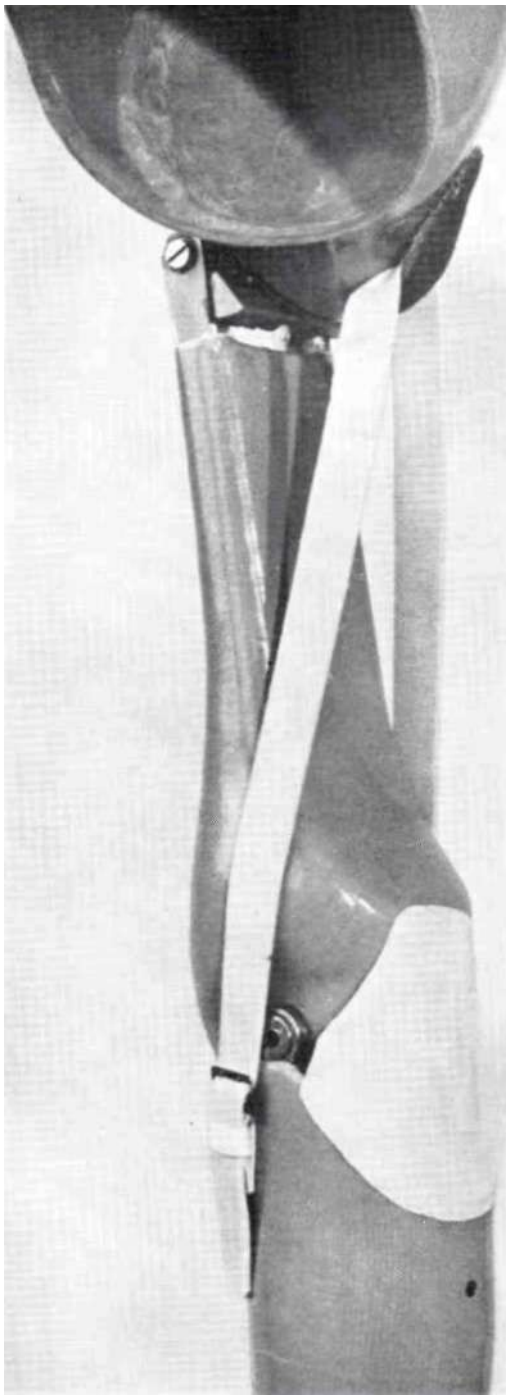

Fig. 28. Finished thigh block in reassembled prosthesis.

Fig 29. Cardboard used as template for metal portion of thigh fairing.

hemipelvectomy amputee will tend to vault on the sound foot to increase the clearance of the prosthesis. This tendency should be minimized as much as possible, but it must

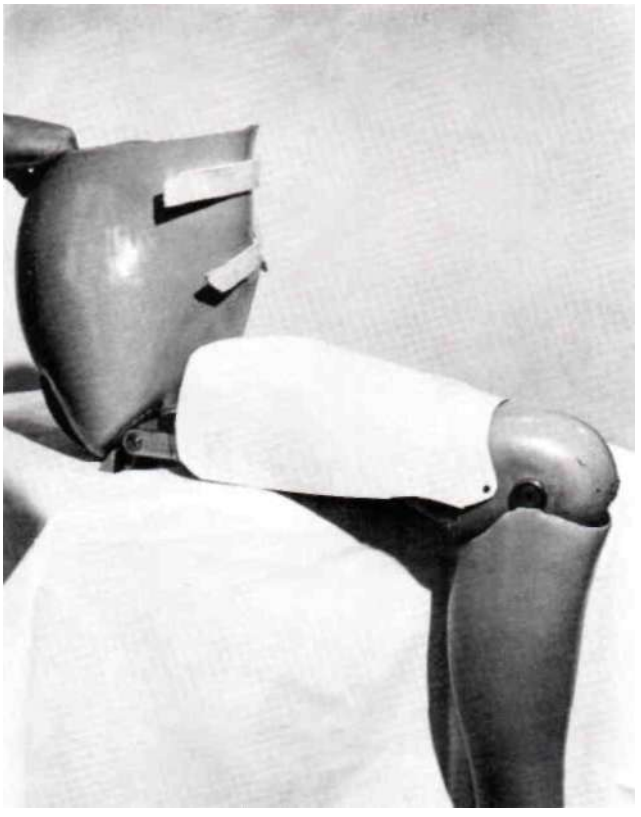

Fig. 30. Template shown on prosthesis in sitting position.

be remembered that the patient cannot "hike" his pelvis on the amputated side since there is no remaining skeletal structure. Where obesity is a problem, it is sometimes necessary to use a shoulder strap to aid suspension.

If the patient experiences rotational instability in the socket, a "teardrop" cutout on the lateral aspect of the socket will help to alleviate the problem and to aid suspension. The cutout should be approximately 2 in. wide at the lateral proximal edge of the socket and extend three-quarters of the length of the socket (Fig. 27). The foam insert in the socket should be removed before the panel is cut out. The edges of the panel should be sanded smooth to prevent cracking. A strap and buckle or Velcro should be attached proximally for closure of the cutout. When the prosthesis is donned, this strap should be loose and should be tightened last.

DUPLICATING AND FINISHING

For duplicating and finishing, the socket is removed and the duplicating jig is used; excess wood is removed from the thigh block and the block is faired into the knee; the knee, thigh, and shin sections are laminated; the keeper for the extension bias strap and all straps and buckles are riveted; and the prosthesis is reassembled (Fig. 28).

THIGH FAIRING

The chief purpose of the thigh fairing is to compensate for the differences in circumference between the thigh block and the sound leg, both in standing and in sitting. This must be done without impairing the function of the prosthesis.

A light, articulated fairing has been developed at the Northwestern University Prosthetics Research Center. It utilizes a piece of

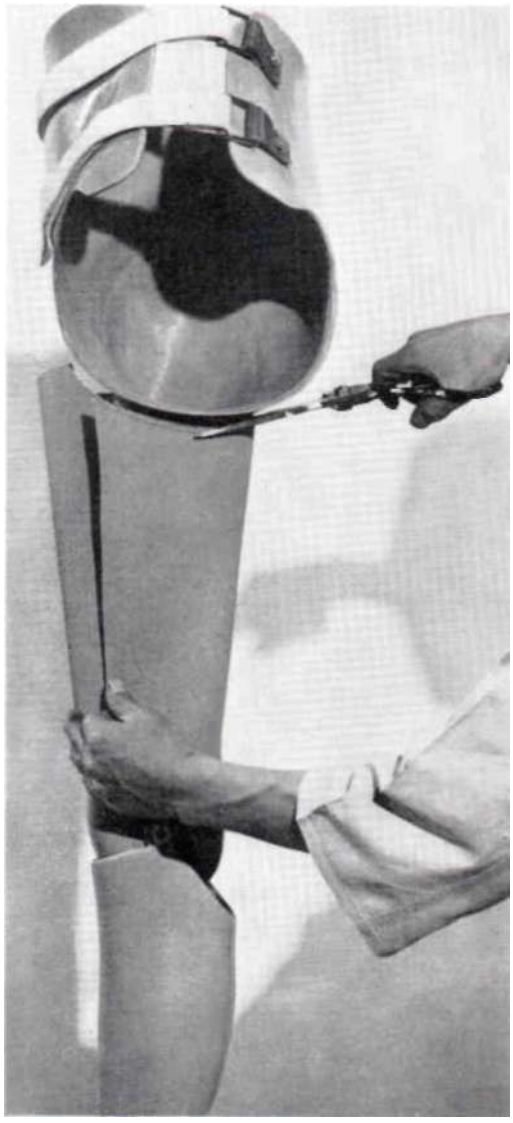

Fig. 31. Contouring rubber portion of thigh fairing.

1/32-in. light aluminum alloy, 1/8-in. Kemblo rubber, and lightweight horsehide, with Velcro for closing. It is pivoted distally by two screws just superior to the knee bolt and fastened proximally by a snap fastener to the anterior wall of the socket.

A piece of cardboard is used to make a pattern for the aluminum (Fig. 29). Distally, it should be wide enough to receive the pivot screws approximately 11/2 in. superior to and vertical to the knee bolt center. Anteriorly, it forms an upward arc. To allow the pivot action, the posterior section is open and the anterior proximal section is cut away so that the socket can be fully flexed without touching the cardboard. The posterior medial and lateral edges govern the amount of anterior displacement of the fairing in the sitting position and the fullness of the thigh in the standing position. In the sitting position, both edges should be in full contact with the seat of the chair (Fig. 30). The cardboard pattern should fit close to the anterior thigh block in the standing position and should be cut and formed to allow the medial and lateral contours of the Kemblo rubber fairing to blend in with the contours of the socket (Fig. 31).

Fig. 32. Open view of completed thigh fairing.

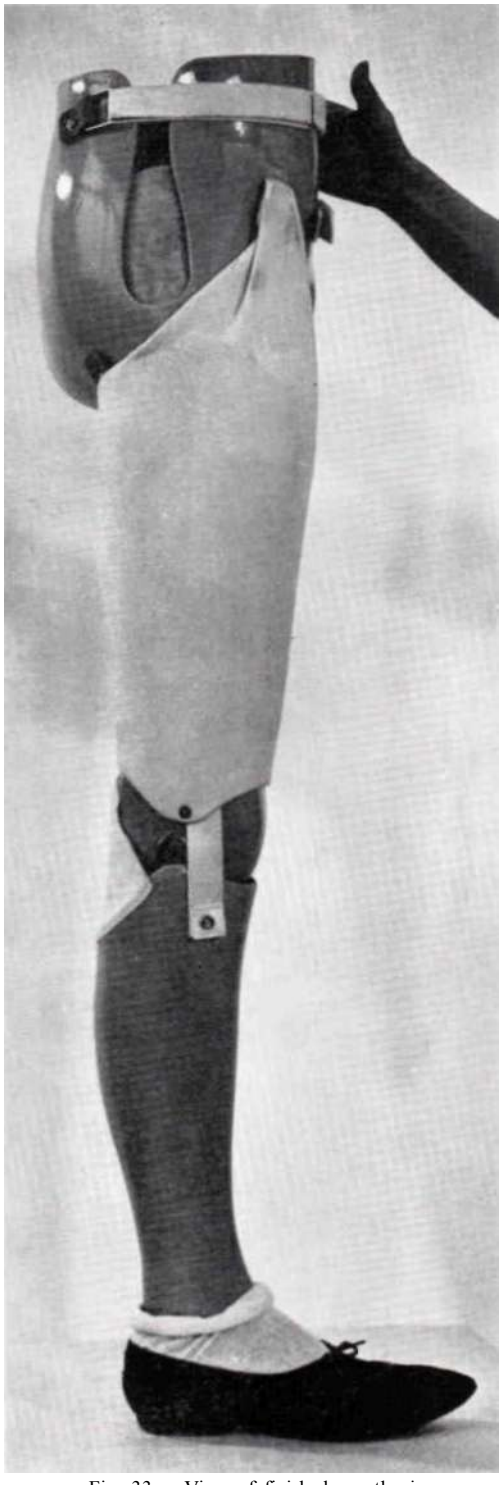

Fig. 33. View of finished prosthesis.

After the aluminum has been cut out, it is formed to the desired shape and attached with a screw to the knee. A sheet of 1/8-in. Kemblo rubber is wrapped around the metal to obtain the desired fullness (Fig. 32). The Kemblo should be long enough to start at the distal end of the aluminum and fair in proximally to the contours of the socket. The distal edge is skived to blend in with the metal form. The anterior proximal edge of the Kemblo should come up to meet the socket in the sitting position. The posterior proximal edge should meet the socket during the stance phase. The Kemblo is glued to the aluminum form.

The Kemblo rubber is covered with lightweight horsehide, and the leather is rolled over the edges of the rubber.

The fairing is attached to the socket anteriorly by means of a snap fastener. The leather continues from the medial and lateral sides to produce a triangle anteriorly with enough slack to allow displacement of the fairing in the sitting position. In the standing position, the attachment should return the fairing and eliminate any slack in the attachment area.

ACKNOWLEDGMENTS

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