A Technique for Fitting Converted Proximal Femoral Focal Deficiencies

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Proximal femoral focal deficiency (PFFD) is a congenital limb deficiency affecting the proximal end of the femur and, usually, the iliofemoral joint. The condition is characterized by shortness of the

Fig. 1

affected limb; flexion, abduction, and external rotation of the extremity; inadequate proximal musculature; and unstable proximal joints *(1).* The condition may be unilateral or bilateral, and other anomalies may be present (fig. 1).

Aitken (2) has demonstrated four types of PFFD based on serial X-rays of patients before and after skeletal maturity:

Class A: Adequate acetabulum and femoral head. Short femoral shaft. Femoral head and shaft are joined at maturity.

Class B: Adequate acetabulum and femoral head. Short femoral shaft. Femoral head and shaft are not joined at maturity.

Class C: Severely dysplastic acetabulum. Femoral head never ossifies. Short femur.

Class D: No acetabulum or femoral head. Short, deformed femoral segment.

At the Child Amputee Prosthetics Project (CAPP) in Los Angeles, the preferred treatment for children who have unilateral PFFD and functional upper extremities is conversion of the limb deficiency to an above-knee amputation. The surgical pro-

Fig. 2

cedure consists of a Syme's amputation of the foot in all cases, and fusion of the knee in selected cases to give a single skeletal lever (fig. 2). The children are then fitted

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as above-knee amputees, using a specially designed socket.

Since 1967, the prosthetists at CAPP have used a socket with a flexible inner wall to fit PFFD patients who have had the surgical conversion described above. This paper describes the total fabrication and fitting procedure as it is done at CAPP. Only its application to the patient with PFFD will be considered here, although we have used the same principle with success in fitting other amputees who have a stump with a bulbous end.

THE STUMP

The converted PFFD stump is relatively fleshy in the proximal area. The shape of the proximal portion is related to the patient's classification: In those with class A or B involvement, the shape is normal enough for the usual anatomic landmarks to be seen, and in those with class C or D involvement, the proximal stump is cylindrical.

The shaft is usually narrow and bony, and the distal end is bulbous, with soft tissue padding its inferior surface. There are bony projections in the bulb which may not be seen but which can be located by palpation. These projections are sensitive to pressure.

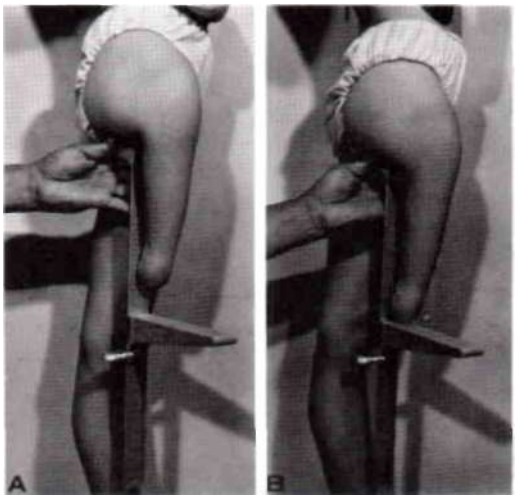


Fig. 3

TELESCOPING

When the structures in the hip region do not provide adequate articulation between the pelvis and the lower-extremity elements, upward pressure under the end of the stump causes upward displacement of the bony elements and apparent shortening of the limb. This motion is called "telescoping," and is frequently seen in patients with PFFD. As much as three inches of telescoping can be demonstrated in some patients.

Telescoping can be a passive or an active motion. In varied cases, some patients can voluntarily retract their limbs and others cannot; they can, however, voluntarily lengthen it beyond the resting position by thrusting down. Traction on the stump also causes lengthening. This apparent shortening and lengthening of the stump in response to pressure and traction has important implications for measuring the stump length, for making the cast, and for weight-bearing (fig. 3) .

THE SOCKET

The socket consists of a rigid outer shell and a three-layered flexible inner wall, with an air space between the flexible layers and the hard socket. The flexible layers extend from the bottom of the socket to at least the level at which the bulbous end can pass through freely, comparable to the placement of the window in a standard Syme prosthesis. This arrangement provides room for expansion of the flexible wall as the bulb is inserted into the socket. Once the stump is fully inserted, the flexible wall closes around it, giving a total-contact fit without using a window and making it possible to use the bulb for suspension.

Since the patient has a Syme's amputation, it would seem logical to fit him with an end-bearing socket. However, if this were done, pressure under the end of the stump during the stance phase of gait would cause telescoping and relative shortening of the leg. The patient would then have excessive lateral trunk bending during stance. For this reason, the socket is

designed to be ischial weight-bearing, with the patient taking light contact on the end of the stump. The ischial weight-bearing minimizes the amount of telescoping and therefore decreases the lateral trunk bending. The light contact at the distal end gives him better control over the prosthesis.

MATERIALS AND COMPONENTS

The hard outer socket is formed with 4110 polyester resin.

Considerable thought was given to selecting the materials for the flexible layers. Our clinical experience has shown that, with continued use, RTV develops an odor and the material becomes fuzzy; nor will RTV bond to the rigid shell of the outside socket.

Therefore, flexible polyester resin was selected for the layer closest to the skin. It is durable, is easy to keep clean and free of odor, and has a surface that is relatively friction-free. 384 RTV was used for the center layer because it laminates readily and will stretch and return to the same shape repeatedly. Flexible polyester resin was also used for the layer next to the outer socket, for it bonds to the hard material if the polyester resin is "roughed up" sufficiently. The polyester resin also protects the RTV from impregnation by wax during socket fabrication. In all the cases in our experience, the materials have retained these properties until the child outgrew the prosthesis.

Primary suspension is provided by closure of the flexible layers over the bulbous end of the stump. A Silesian bandage, worn about an inch below the iliac crest, gives lateral support and secondary suspension.

We have used a constant-friction knee and SACH foot for all children fitted with this type of prosthesis. The constant-friction knee is light in weight and has provided good function. All of the children have had adequate strength to lock the knee joint during stance.

SPECIAL MEASUREMENTS

Before describing the fabrication procedure, a brief discussion of the measurements is in order, for much of the success of this method of fitting depends upon having ischial weight-bearing and a total-contact fit.

SOCKET BRIM AND ISCHIAL SEAT

In patients with class A or B involvement, the shape of the proximal thigh is normal enough to enable the prosthetist to make the A-P and M-L measurements as he would for a patient with a standard above-knee amputation. The socket will have a modified quadrilateral shape at the ischial level.

In patients with class C or D involvement, the shape of the proximal stump is cylindrical, and there is no area comparable to the adductor-longus-tendon area of the standard above-knee amputee. In these cases, the M-L dimension is measured with outside calipers at the level of the adductor fold, and the ischial-seat measurement is made on a horizontal line from the ischium to the lateral edge of the stump at the ischial level.

The inside measurements of the socket must be the same as the circumferential

Fig. 4

Fig. 5

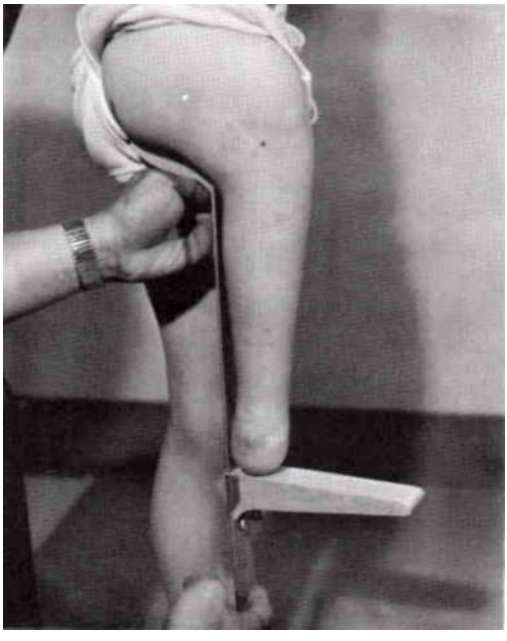


Fig. 6

measurements of the stump. The prosthetist must reproduce the size and shape of the stump in the cast, positive mold, and socket to insure total contact without looseness or constriction.

The stump length is measured from the ischium to the distal end of the stump with the stump at its greatest stretched length. The importance of measuring the length and taking the wrap with the stump fully elongated cannot be overemphasized, for two reasons: First, it helps ensure that the patient will take most of his weight on the ischium so that telescoping will be minimal; second, the length of the cast can be modified by only 3/8 in. in either direction.

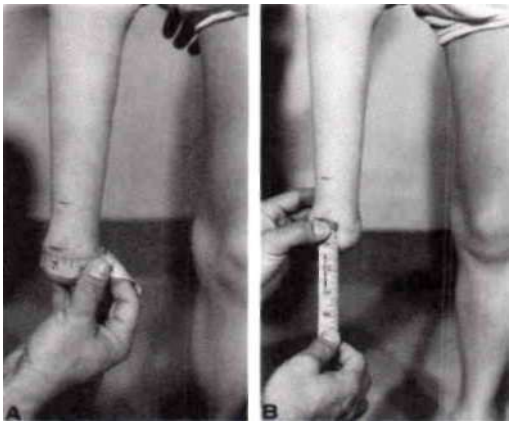


Fig. 7

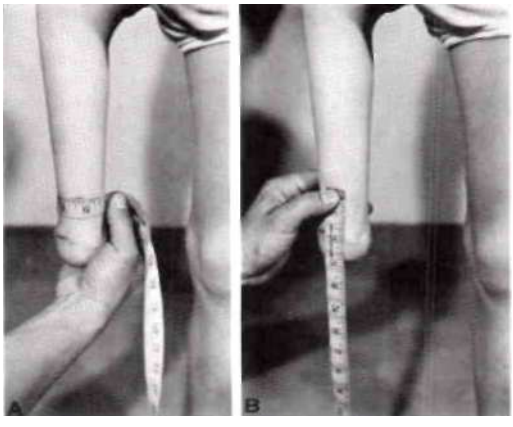


Fig. 8

MEASUREMENTS

BRIM

Mediolateral

In class A and B patients, take the M-L measurement as for a standard above-knee amputee.

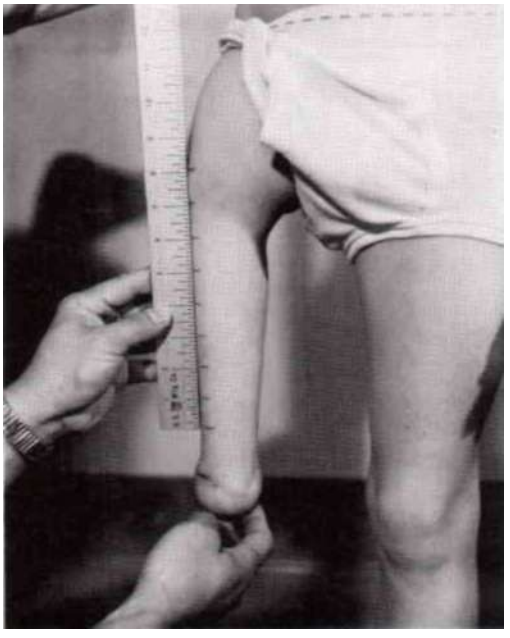


Fig. 9

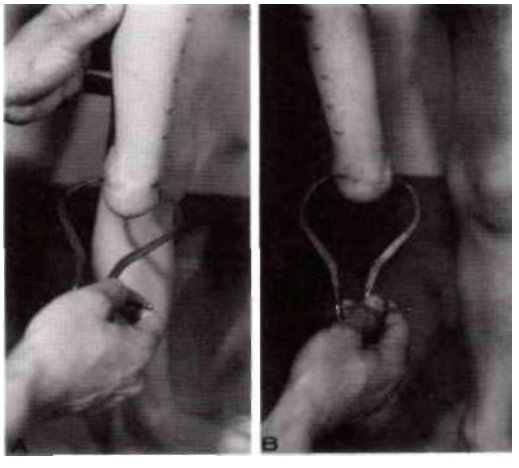


Fig. 10

In class C and D patients, caliper the horizontal distance from the adductor fold to the lateral aspect of the stump (fig. 4).

Anteroposterior

Take standard above-knee A-P measurements for classes A and B.

For classes C and D, to measure the ischial seat, caliper the horizontal distance from the inferior edge of the ischium to the lateral aspect of the stump (fig. 5).

SOCKET LENGTH

With the stump at its greatest length and vertical to the floor, measure from the ischium to the end of the stump (fig. 6).

CIRCUMFERENCE

1. Measure the circumference of the largest part of the bulb, and from this point to the distal end of the stump (figs. 7a and 7b).

2. Measure the circumference of the narrowest part of the shaft, and from this point to the distal end of the stump (fig.8)

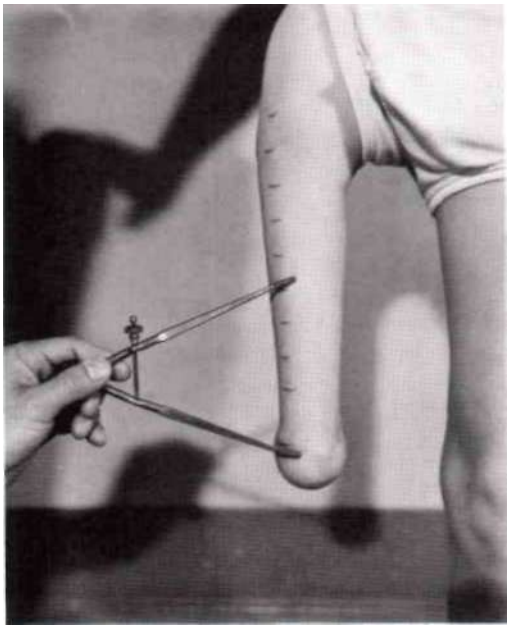


Fig. 11

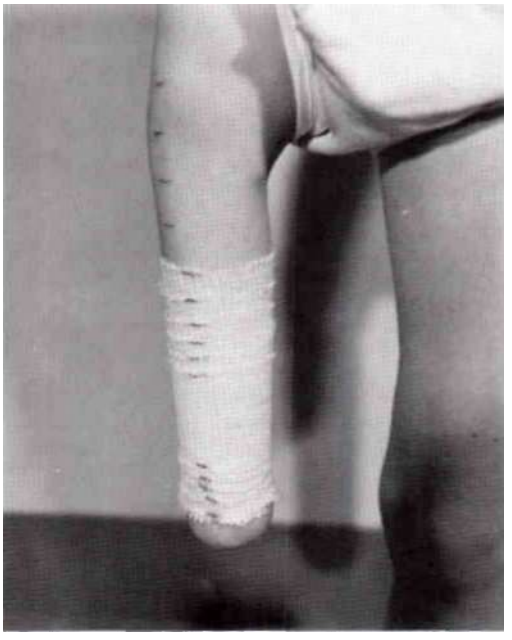


Fig. 12

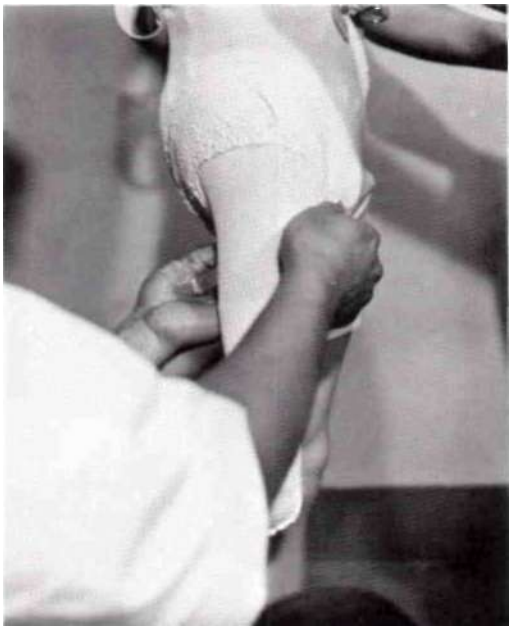


Fig. 13

3. Beginning at the narrowest part of the shaft, measure the circumference at one-inch intervals to the adductor fold (fig. 9).

BULB

1. Caliper the A-P and M-L dimensions at the largest part of the bulb (figs. 10a and 10b).

2. Palpate the bulb to locate the bony prominences and mark them with indelible pen.

OVERALL LENGTH

Measure the sound side as for a standard above-knee amputee.

STUMP SOCK

Make a tracing of the stump to accompany the measurements for ordering stump socks.

CAST FABRICATION

MATERIALS

Fast-setting Johnson and Johnson plaster bandage
Elastic plaster bandage (Johnson and Johnson Orthoflex)
Cast sock
Stockinette
1-in. elastic webbing
A-P caliper
Yates clamp

FITTING THE CAST SOCK

1. Mark the shaft at the level where the A-P or M-L dimension is slightly larger than the A-P or M-L dimension of the bulb.

2. Measure the distance between the two points selected and cut one piece of stockinette that length (fig. 11).

3. Cut five more pieces of stockinette, each 1/2 in. shorter than the last, and place them on the stump to fill in the narrow part. Place the shortest piece on the stump first, then the longer ones over it, *in reverse of what is shown in figure 12.* This facilitates removal of the cast.

MAKING THE CAST

The patient should stand with his stump vertical to the floor.

1. Using the same technique as for a standard above-knee amputee, make the brim with the 4-in. elastic bandage, beginning at the lateral side of the stump at the level of the iliac crest (fig. 13).

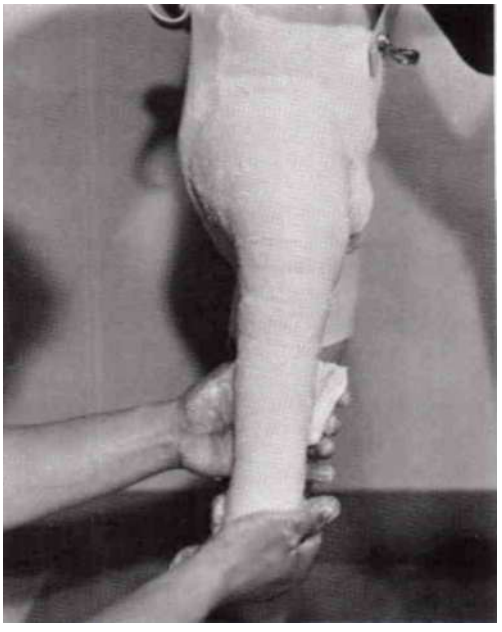


Fig. 14

Fig. 16

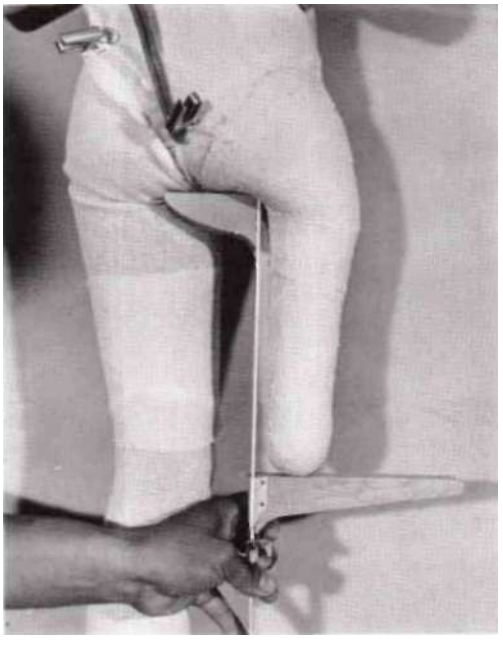


Fig. 15

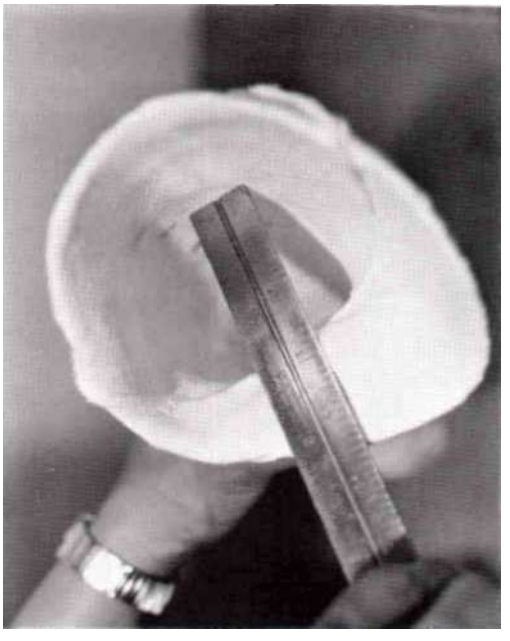


Fig. 17

2. Complete the wrap with the 3-in. regular plaster bandage (fig. 14).

3. Form the ischial seat while the bandage is still wet. With the A-P caliper set to the length measurement of the stump plus 3/16 in., place the short end under the ischium and line up the long end under the end of the stump. Then apply pressure

under the ischium and have the patient thrust down until the stump end touches the caliper (fig. 15).

4. At the same time, apply three-fingers' firm pressure to the proximal anterior medial aspect of the cast (fig. 16). This prevents the socket from rotating internally on the stump.

5. The patient must remain in this position and the pressures must be maintained until the plaster sets.

6. Remove the cast.

CHECKING THE CAST

1. Check the M-L and ischial-seat measurements of the cast against those of the patient. Be sure that the ischial seat has a large enough surface for the patient to sit firmly upon it. If necessary, build up the seat with plaster before filling the cast (fig. 17).

2. Check the length of the cast against the patient's stump length. They should be the same. If the cast is longer than the stump, pressure was not applied directly under the ischium. If the cast is shorter than the stump, the patient was not thrusting down to maximal stretch. If the difference does not exceed 3/8 in., the mold can be modified. If there is a greater than 3/8-in. difference, a new cast should be made.

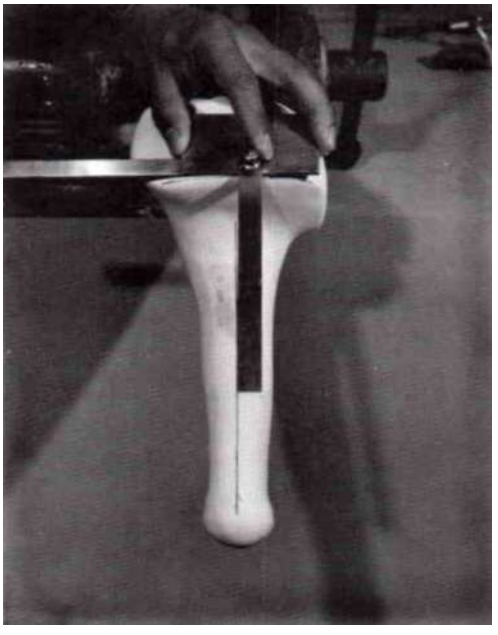


Fig. 18

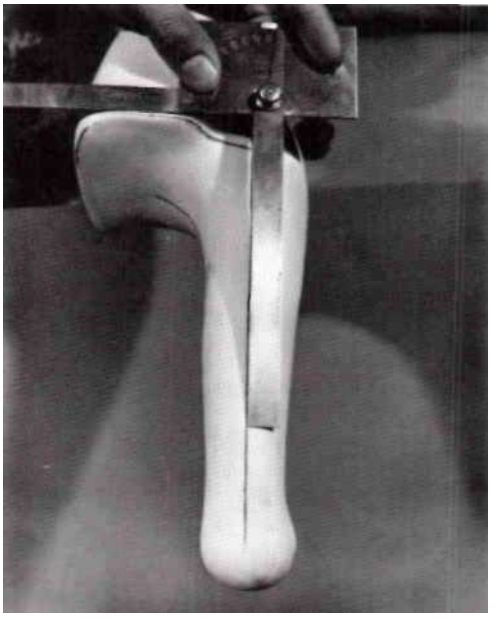


Fig. 19

MODIFYING THE MOLD

To correct the length measurement:

1. Measure from the ischial seat to the end of the mold.

2. Remove or add enough plaster (but no more than 3/8 in.) to the ischial seat to correct the length.

To correct the flexion or extension angle (fig. 18):

1. Draw a line down the medial aspect of the mold, bisecting it into medial and posterior halves.

2. Set the goniometer at 90 deg.; hold one arm on the line described and the other arm at the level of the ischium. Draw a line at right angles to the line on the medial aspect of the mold.

3. Shape the surface of the seat along this line. The shaft should be at 0 deg. of flexion and extension.

To correct the abduction or adduction angle (fig. 19):

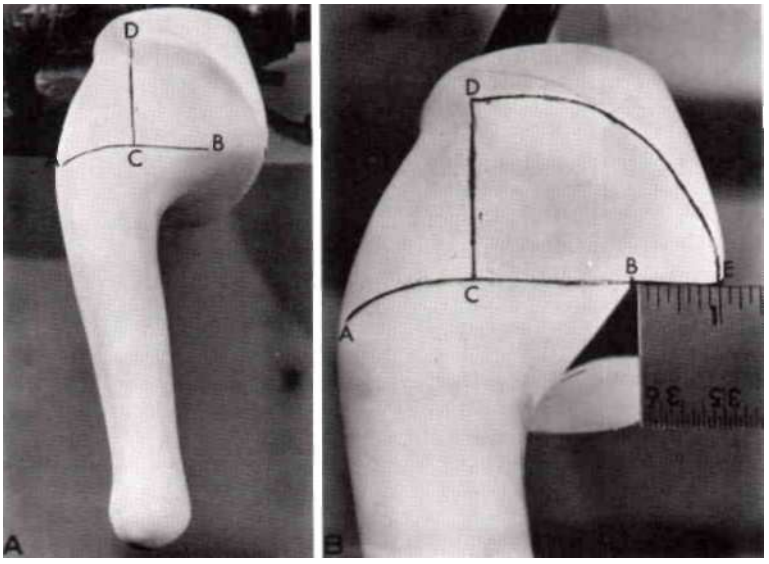


Fig. 20

1. Draw a line down the posterior aspect of the mold, bisecting it into medial and lateral halves.

2. Set the goniometer at 90°; hold one arm on the line described and the other arm at the level of the ischium. Draw a line at right angles to the line on the posterior aspect of the mold.

3. If the shaft is in *adduction,* remove plaster from the outside edge of the ischial seat. If the shaft is in *abduction,* add plaster to the outside edge of the ischial seat. The shaft should be at 0° of abduction or adduction.

To modify the anterior brim (fig. 20):

1. Form the height of the anterior brim: Draw a line at the ischial level across the anterior aspect of the mold from point A to point B. Divide the line in half at point C. From point C, draw a line at right angles to AB, extending it two inches proximal to point D. Line CD forms the height of the anterior brim.

2. To establish the anterior brim line, extend a line from point B one inch medially to point E. Point E should be in line with the ischial seat when viewed from the front. Draw a line on a smooth curve from point D to point E (fig. 20).

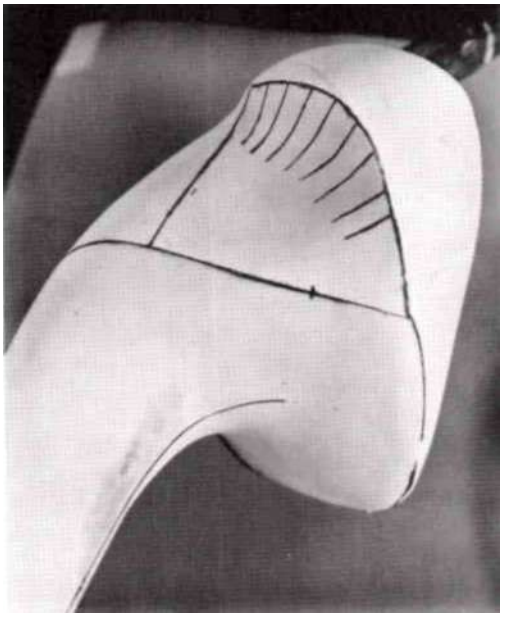


Fig. 21

3. Form a reverse curve along line DE to facilitate sitting and bending. Using a rasp or gouge, remove up to 1/4 in. of plaster from the area medial to line CD. This will ensure good contact along the anterior

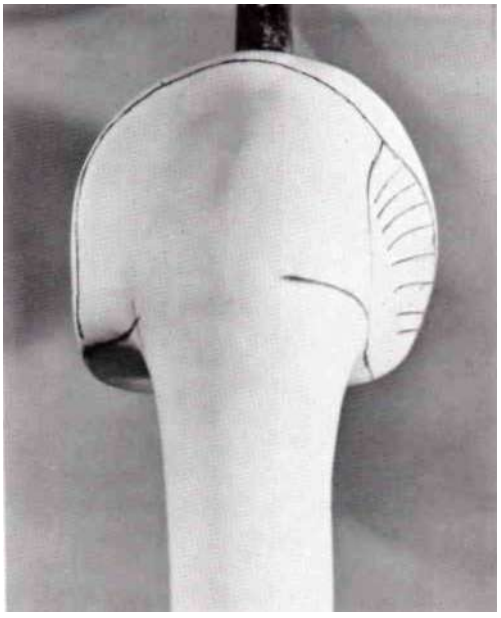
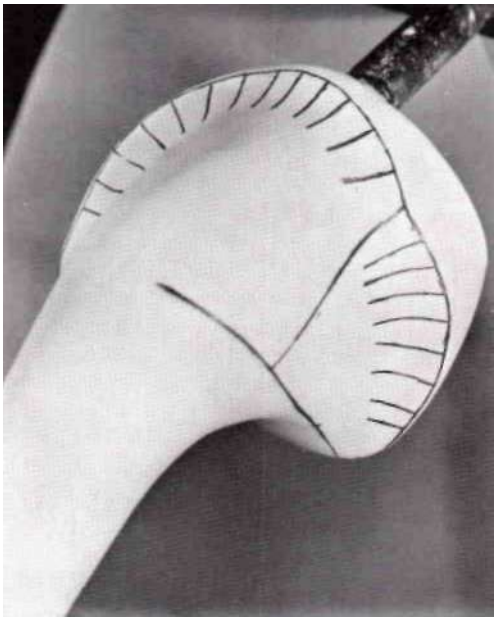


Fig. 22



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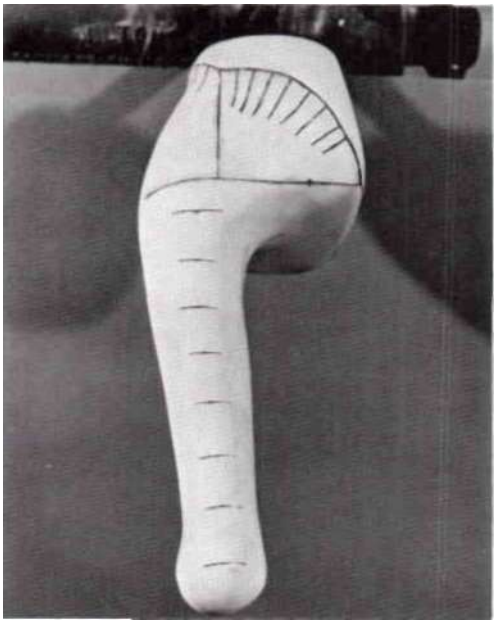


Fig. 24

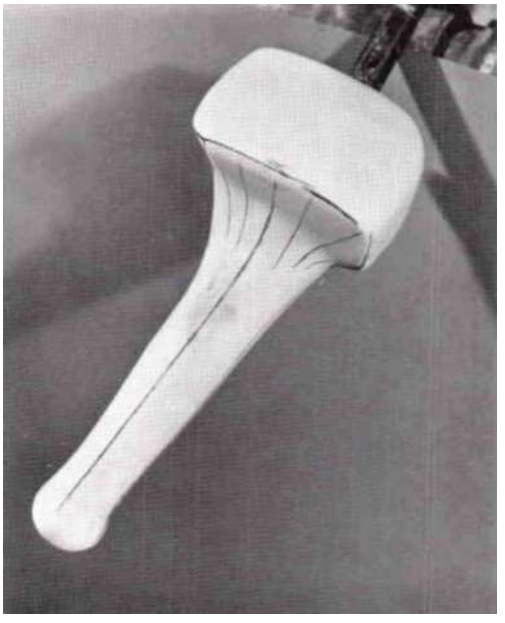


Fig. 25

brim wall with the stump. If necessary, build up with plaster along line DE to form the reverse flare (fig. 21).

To modify the lateral brim:

1. Continue line DE from the anterior brim proximally to encompass two-thirds of the distance between the ischium and the iliac crest. Continue laterally, following the contour of the lip, then distally to the posterior-lateral corner of the ischial seat (fig. 22).

Fig. 26

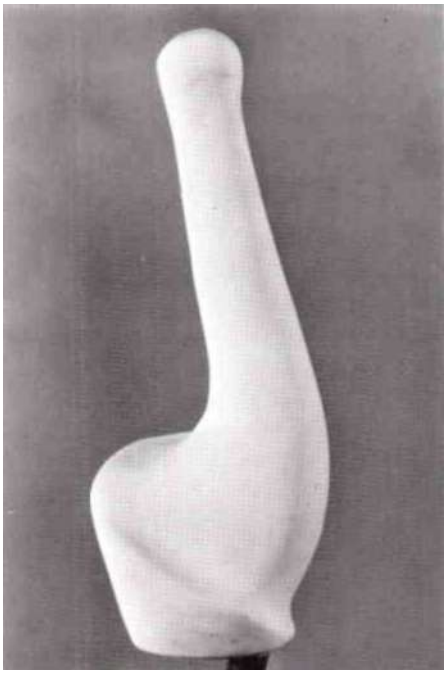


Fig. 27

2. Contour the lateral wall. Do not remove plaster below the ischial level (fig. 23). Establish flare along the lateral brim line.

To modify the shaft:

1. Correct the circumference measurements. Mark off the levels at which the circumference measurements were obtained. Note each measurement on the mold. Where it is necessary, the circumference measurements of the mold should be modified to be the same as those of the stump (fig. 24).

2. At the brim area, blend the medial and posterior walls smoothly with the medial brim and ischial seat (fig. 25).

To modify the bulb:

Build up over the bony projections no less than 1/4 in. (These projections should be marked during the measurement and casting procedure.) *Be extremely careful while accomplishing this, as attempting relief in this area is extremely difficult* (fig. 26).

Recheck the mold measurements. Smooth the entire mold (fig. 27).

FLEXIBLE-SOCKET FABRICATION

MATERIALS

- Ambroid varnish or the equivalent
- Five PVA sleeves (regular size and shape)
- Two 1-oz. fitted Dacron (TM) sleeves
- Four or five regular-length fitted nylon stockinettes (for fabricating the flexible layers)
- Three extra-long fitted nylon stockinettes (for fabricating the hard socket)
- Cast sock(s) (to equalize the stump sock)
- Flexible polyester resin #4134
- RTV elastomer Dow Corning #384
- Rigid polyester resin #4110
- 150-A yellow wax (available from E. S. Browning Co., Los Angeles, Calif.) or any wax suitable for shaping
- Outside calipers
- Wood rasp
- Vacuum machine
- Oven with at least 200°F temperature range

Make the Dacron sleeves to fit the entire brim area. The Dacron must not be incorporated in the flexible layers.

The number of stockinettes needed depends upon the size and activeness of the patient. Four are used on the less active patient, and five on the more active. These are separate pieces, sewn on one end and trimmed to 1/2 in. of the stitching. The width of the stockinette should be such that it stretches very minimally in what is to be the flexible wall.

The three extra-length stockinettes must be long enough to double over in the brim area.

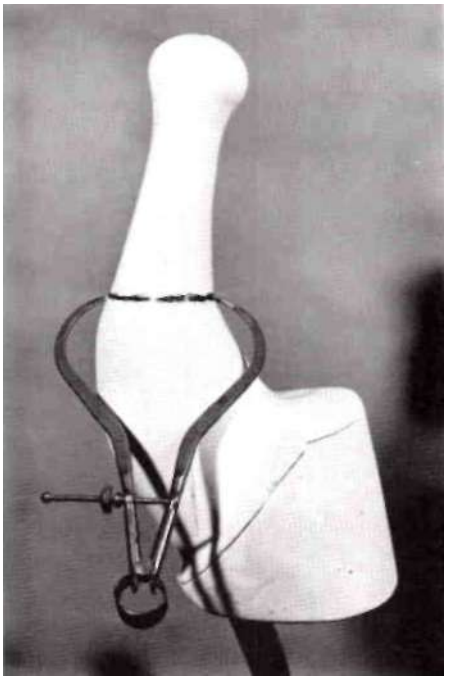


Fig. 28

One heavy and one lightweight cast sock are used for a 3-ply wool sock; two heavy and one lightweight cast sock are used for a 5-ply wool socket, etc.; or an old wool stump sock of the same weight can be used.

The 150-A yellow wax is heated until it is soft enough to work with a spatula. With this type of wax, it is never necessary to melt it completely and pour it into a cone.

PROCEDURE

1. With the outside calipers, measure for the area where the bulb can pass through freely. Mark this area heavily with a pencil (fig. 28).
2. If the cast is wet, seal it with three coats of ambroid varnish.
3. Apply the appropriate number of cast socks (or an old stump sock) needed for stump-sock clearance. Tie them off securely on the mandrel.
4. Apply the first PVA sleeve, which will be the parting agent. Cap it on the end and tie it off on the mandrel.

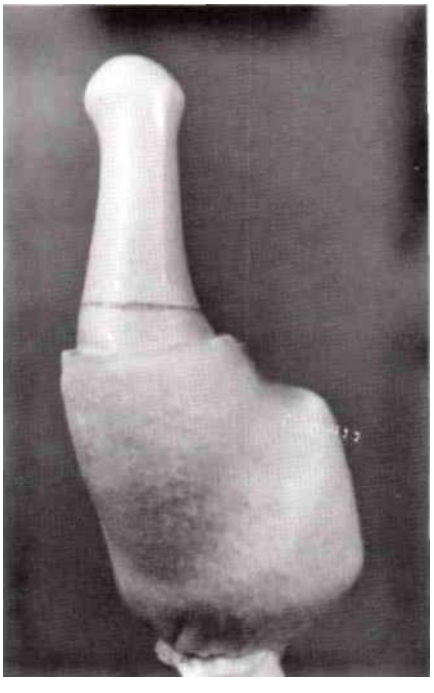


Fig. 29

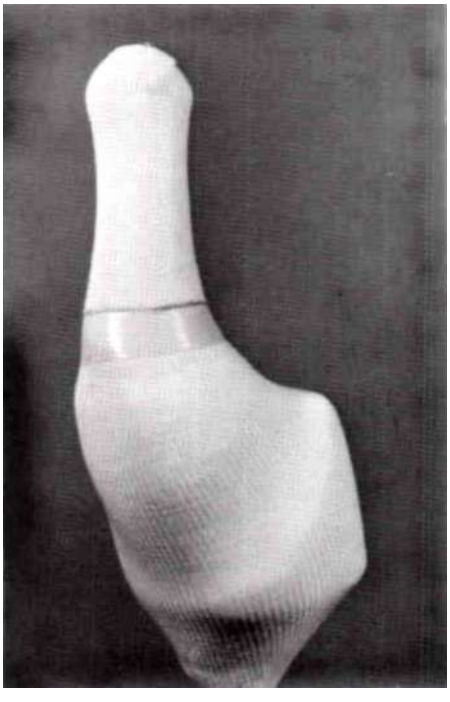


Fig. 30

5. Apply two Dacron sleeves, being sure not to overlap into the flexible walled area which starts at the mark made in step 1. It is advisable to leave at least 1 in. between the mark and the Dacron sleeves (fig. 29).

6. Apply one layer of stockinette and tie it off on the mandrel. If necessary, separate and smooth the extra half-inch of material. With the outside calipers, measure again for the area where the bulb can pass through freely, and mark this area with a pencil.

7. With pressure-sensitive tape, make a full turn around the model at the mark made in the previous step (fig. 30). This seals off the proximal end of the flexible wall.

8. Attach the vacuum line.

9. Apply the second PVA sleeve and seal it off on the mandrel, then repeat step 7.

10. Mix thoroughly enough 4134 flexible polyester resin to cover the area from the tape to the end of the model. Using vacuum, laminate this area *only.* (It is helpful if, at the end of each laminating step, the

Fig. 32

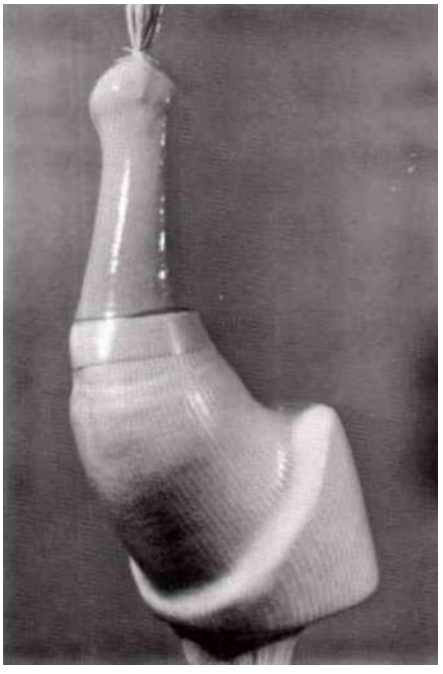


Fig. 31

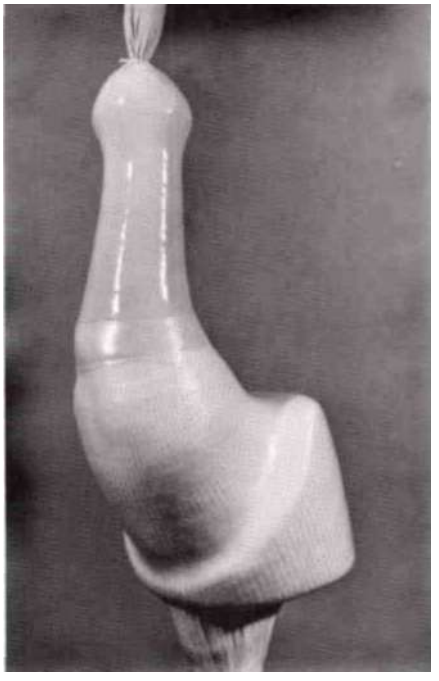


Fig. 33

excess is tied off, thus saving the time of grinding it away.) Allow to set well (fig. 31).

11. Remove the second PVA sleeve. Remove the pressure-sensitive tape around the model. With the wood rasp, roughen the bulbous end enough to raise the half-inch of stockinette. Do not break through to the parting PVA (fig. 32). Apply two more layers of stockinette, again separating and smoothing down the extra half-inch of material. Tie them off on the mandrel, then repeat step 7.

12. Apply the third PVA sleeve, seal it off at the mandrel, and repeat step 7.

13. Mix thoroughly enough 384 RTV to cover the laminated area. Using vacuum, laminate this area only. Allow to set well (fig. 33).

14. Remove the third PVA sleeve. Remove the pressure-sensitive tape around the model. With the wood rasp, roughen the bulbous end enough to raise the half-inch of stockinette beyond the stitching (as in figure 32).

15. Apply one or two more layers of stockinette, again separating and smoothing the extra half-inch of material. Tie them off on the mandrel, then repeat step 7.

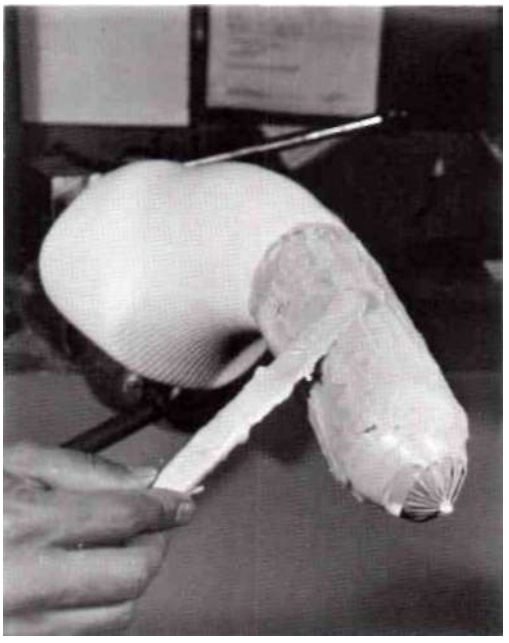
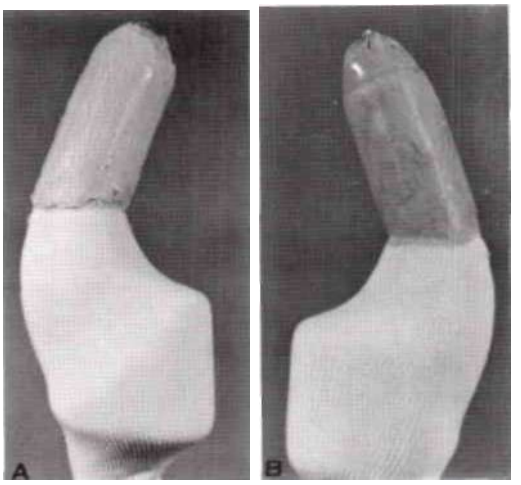


Fig. 34



Figs. 35 and 36

16. Apply the fourth PVA sleeve, seal it off on the mandrel, and repeat step 7.

17. Repeat step 10.

18. Remove the fourth PVA sleeve. Remove the pressure-sensitive tape around the model.

19. For the wax build-up (fig. 34), apply wax to the model from the proximal end of the flexible wall distally to the *largest* circumference of the bulb end. The thickness of the build-up should be sufficient to allow the bulb to expand the flexible wall through the narrow area. Use the outside calipers to measure the thickness of the build-up. Allow 3/16-in. thickness for the flexible-wall lamination. (Keeping in mind some goals for the finished prosthesis, such as cosmesis and lightness in weight, in most cases it is possible and advisable to "go overboard" on the wax build-up. Cosmetic build-up is kept to a minimum, and air space is weightless.) Allow the wax to cool and harden (fig. 35).

20. Smooth the surface and taper the proximal and distal edges (fig. 36).

21. Using the wood rasp, roughen the exposed tip of the bulb end enough to cut through to the RTV layer and to raise the half-inch of stockinette beyond the stitching on the final 4134 resin layers.

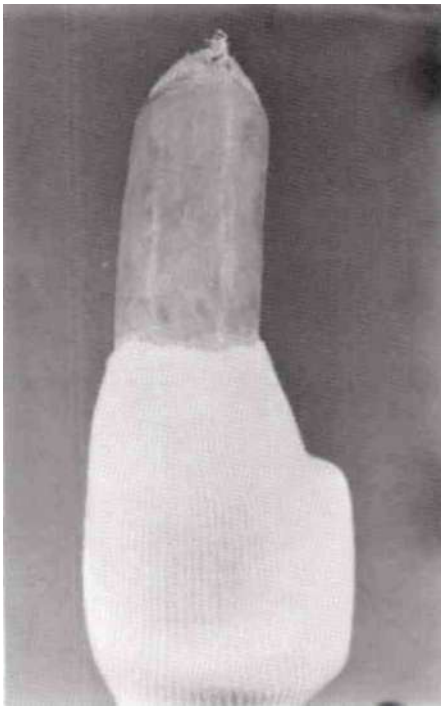


Fig. 37

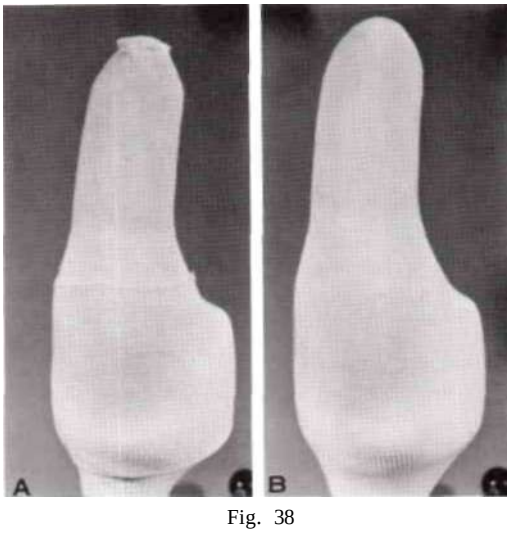


Fig. 38

This step is extremely important, as it will securely bond the flexible portion of the socket to the rigid outside shell (fig. 37).

22. Apply the three extra-long nylon stockinettes, doubling the first two layers back at the brim (fig. 38).

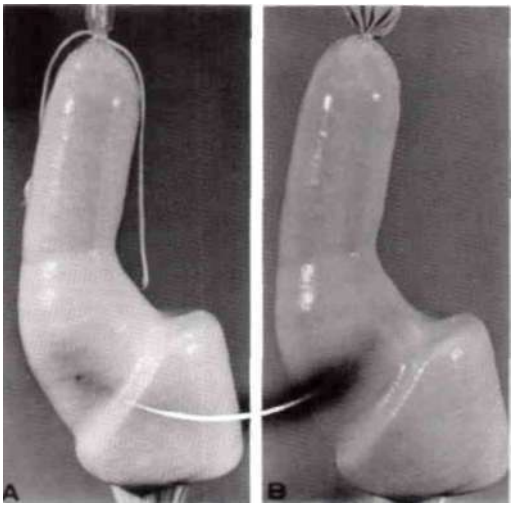


Fig. 39

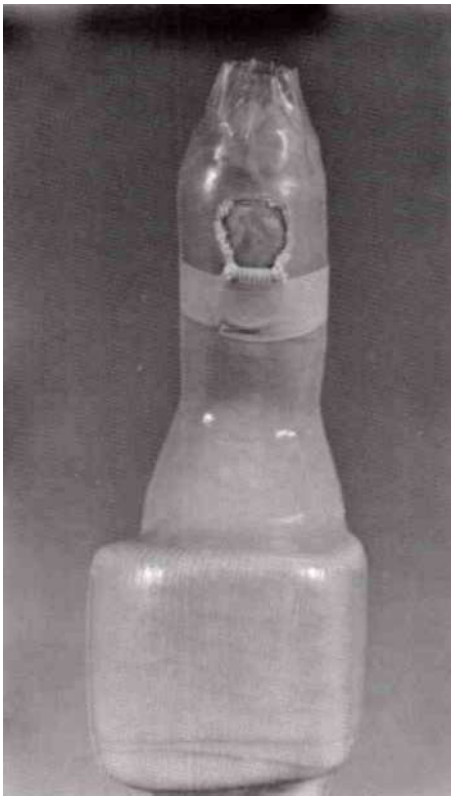


Fig. 40

Fig. 41

Fig. 42

23. Apply the fifth PVA sleeve and seal it off on the mandrel. Mix enough 4110 polyester resin to cover the entire mold. Using vacuum, laminate the entire mold. Allow it to set (figs. 39a and 39b).

24. After the resin has set, cut a flap through it 3/4 in. in diameter at the distal edge of the wax build-up. Tape the flap back (fig. 40).

25. Hang the entire laminated cast in the oven (heated to 175° F) and allow *all* the wax to drain out.

26. Remove the laminated cast from the oven after the wax has drained. Allow the lamination to cool just enough for the rigid shell portion to harden. Mark the approximate trim line and cut along it with a Stryker saw. A strong tug, along with use of a hammer and piece of wood when needed, will separate the socket from the cast (fig. 41).

27. To complete the socket, finish sanding the brim down to the trim lines.

FITTING

MATERIALS

Fitting stool
Talcum powder
Stump sock
Mandrel padded at the end with stockinette in the shape of a bulb
Heat gun
Silicone amputation-stump spray

PROCEDURE

1. Set the socket in a wood block with the seat level.

2. Place the block on a fitting stool to get the correct ischium-to-floor length.

3. Lightly powder the socket.

4. Have the patient apply the stump sock and hold it firmly at the top as he pushes his stump into the socket (fig. 42). (If the patient cannot push all the way into the socket, the flexible layers will need to be stretched as described in the next section.)

5. Check to see that the patient's ischium is firmly on the seat, and that he has light contact at the end of the stump. Do this by having him bear weight on the socket and by requesting him to "reach down into the socket" with his stump. If as he does this, he loses firm contact with the seat, the socket is too short. If he cannot feel contact on the bottom, the socket is too long. A sponge pad in the

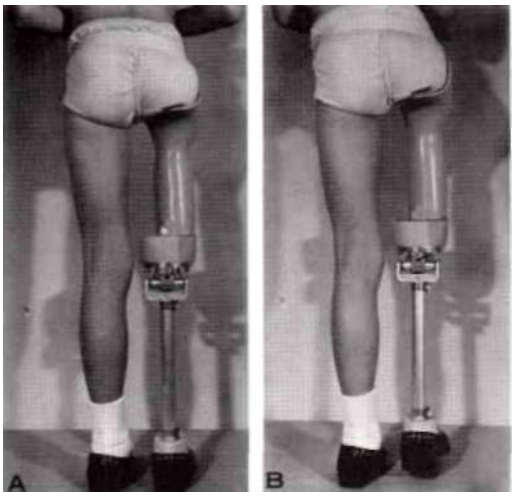


Fig. 43

bottom of the socket may give the necessary light contact.

6. Have the patient lift his hip to take weight off the socket. There should be no more than 1/4 in. of piston action (figs. 43a and 43b).

7. Check for pressure areas in the bulb. With the patient standing, have him flex his hip while you apply resistance to the distal anterior end of the socket. Then have the patient abduct, extend, and adduct the hip, each time applying resistance to the distal end of the socket. There should be no pain from these maneuvers. (Pain may be caused by a wrinkle in the sock, by the presence of wax in the air space, or from inadequate relief over the bony prominences in the bulb.)

8. Establish the anterior and posterior trim lines. In the posterior lateral area, trim the socket so that it does not encase the gluteal area. Then have the patient sit in a chair and lean forward. Check for discomfort in the anterior area, and trim the socket to fit. There should be no gapping of the lateral wall. The anterior brim of the socket should be in firm contact with the skin, for looseness here would allow the socket to rotate internally on the stump when the patient walks.

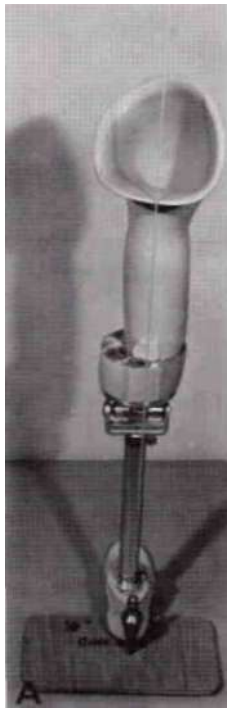
9. To remove the socket, the patient should pull up on the top of the stump sock while pulling down on the socket. In a few cases, this was the only way in which the socket could be removed (fig. 44).

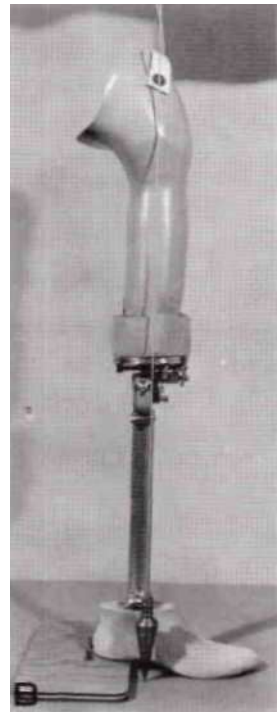
Fig. 44

Stretching the Flexible Layers

If the patient cannot push his stump all the way into the socket, it will be necessary to stretch the flexible layers to allow the bulb to pass through the narrow part of the socket. This can be accomplished as follows:

1. Place the padded mandrel in a vise.
2. Heat the inside of the socket to soften the flexible layers.
3. Work the socket back and forth on the mandrel, stretching the flexible layers.
4. Let the socket cool on the mandrel, with the padded end of the mandrel at the narrowest part of the socket.
5. Refit as in the preceding section, using silicone spray in the socket if necessary.





Figs. 45a and 45b

Fig. 45c

ALIGNMENT

BENCH

The initial set-up is made with the ischial seat level. The posterior plumb line for the heel center passes between the center of the end of the socket and the point where the ischium rests on the ischial seat (fig. 45a). The lateral plumb is taken from the center of the end of the socket and passes % in. anterior to the knee center (fig. 45b). The socket is set in 15°-30° of internal rotation to the line of progression to compensate for the patient's tendency to internally rotate the pelvis to advance the prosthetic leg (fig. 45c).

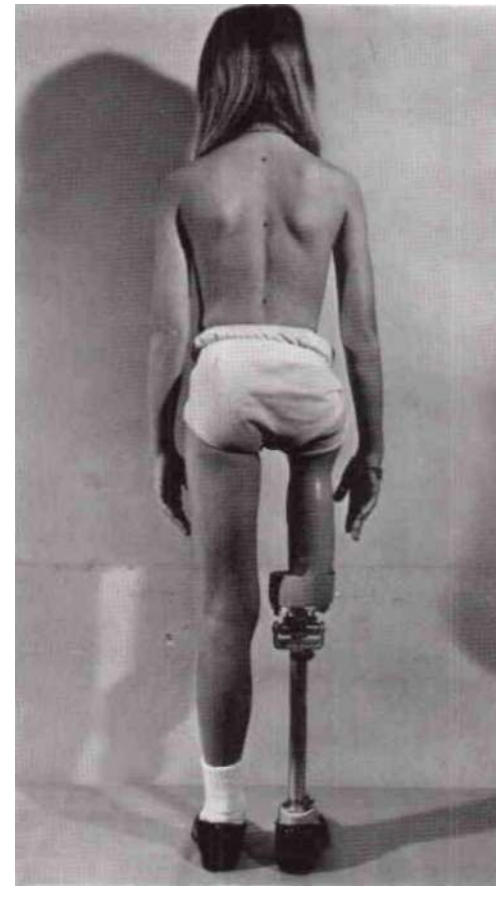


Fig. 46

FUNCTIONAL

The prosthesis is the correct length when the patient's spine is as straight as possible when he stands with his weight on both legs, i.e., in the finished prosthesis. The iliac crests of these patients are not always symmetrical, and it may not be a reliable reference point for judging the length of the prosthesis (fig. 46).

Dynamic alignment is done with the socket set on a child-size above-knee jig. Optimal dynamic alignment is based on standards set for the standard above-knee amputee.

Fig. 47

SUMMARY

This fitting technique can also be used on other stumps with bulbous ends: Syme's and above-elbow amputations and wrist disarticulations, for example.

At CAPP, more than 20 patients have been fitted in this manner: 18 PFFD's, 2 bilateral Syme's amputations, 1 wrist disarticulation, and 1 above-elbow amputation. All of these patients' deficiencies were congenital in origin.

The procedure described does require more fabrication time and material. Once the technique is mastered, it requires about three hours of the prosthetist's time, whereas a solid socket can be fabricated in an hour. However, the CAPP patients have shown a marked preference for this type of socket. It provides a very precise fitting, and in every case the child has expressed a feeling of greater security when wearing this socket (fig. 47).

Another advantage is the apparent absence of skin breakdown. When the patient comes to the clinic for post-fitting examination, the characteristic blanching of the stump skin is absent, as are signs of rubbing, blistering, or callousing so often seen with use of the solid socket.

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