

# The Patellar-Tendon-Bearing Prosthesis for Below-Knee Amputees, a Review of Technique and Criteria<sup>1</sup>

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*At a recent meeting of the Workshop Panel on Lower-Extremity Fitting (2), which is sponsored by the Subcommittee on Design and Development of the Committee on Prosthetics Research and Development, there was prolonged discussion of below-knee prostheses. Questions were raised concerning the adequacy of the PTB design for many patients, especially patients who were longtime users of the joint-corset, below-knee limb. The view was expressed that the expenditures of time and money in achieving a successful PTB fit did not justify the selection of the PTB prosthesis or a conversion to it, and that the use of a joint-corset prosthesis initially would shorten the prosthetic restoration process for most patients.*

*It was recognized that the private practitioner is often forced to elect the simplest and least expensive procedure for his patient. Institutional facilities, on the other hand, can take more of the patient's time, without having the often-required succession of visits reflected in direct cost to the patient or to the sponsor. Yet, the panel was of the opinion that some prosthetists probably are still committing errors in fitting PTB prostheses, resulting in deterioration of the stump, excessive shrinkage, or edema. Moreover, criteria for use of the joint-corset prosthesis are still misunderstood.*

*Fortunately, the Workshop Panel on Lower-Extremity Fitting had the benefit of the counsel of James Foort, formerly of the University of California (Berkeley) but now of the Prosthetics-Orthotics Research and Development Unit at Manitoba Rehabilitation Hospital, Winnipeg, Canada. Mr. Foort spoke at length on the PTB design and then agreed to put his comments in writing for the benefit of clinicians the world over. Presented below is his helpful review of the subject.*

*We are indeed indebted to Mr. Foort for his contribution. The clear expression of certain axioms will, hope-*

*fully, solve some of the problems experienced in the fitting of this very important prosthetic appliance.*

*Anthony Staros<sup>3</sup>  
Chairman, Workshop Panel  
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The patellar-tendon-bearing (PTB) prosthesis has been in use for more than five years. It was fully discussed in the June 1962 issue of *Artificial Limbs (1)*. Although experience suggests that approximately 90 per cent of all below-knee amputees can benefit from the use of the PTB prosthesis, a substantial number of prosthetists continue to fit joint-corset prostheses to a large proportion of their patients. Apparently, these prosthetists and their clients have found that maintenance and replacement costs outweighed the fabrication and functional advantages of PTB prostheses. Difficulties developing from the use of the PTB prosthesis are said to be edema, stump breakdown, and stump shrinkage. With these difficulties in mind, the purpose of this review is to examine the fitting technique for PTB's, emphasizing factors to be considered in avoiding or overcoming the difficulties and outlining criteria for use of joint-corset prostheses.

## PTB FITTING TECHNIQUE

The most common error made with a PTB socket is an excessively tight fit in the popliteal area of the stump. Too large a bulge in the popliteal area can be constrictive, affecting circulation, causing edema, and in turn leading to deterioration of the stump end. *Posterior pressure needed to balance the posteriorly directed*

<sup>1</sup> An outgrowth of the discussions of the principles of PTB fittings at the Third Workshop Panel on Lower-Extremity Fitting conducted under the auspices of the Subcommittee on Design and Development of the Committee on Prosthetics Research and Development at Hollywood Beach, Fla., November 4, 5, and 6, 1964.

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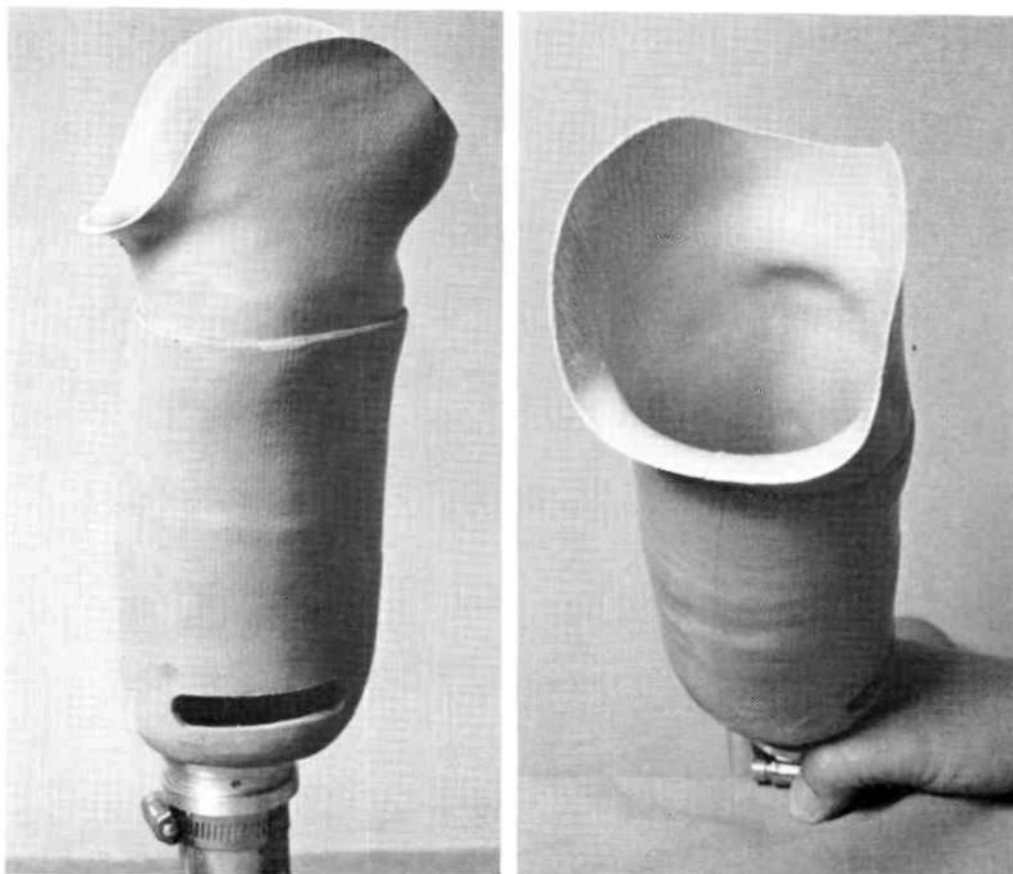


Fig. 1. Two views of a temporary plastic PTB socket showing the flared posterior brim.

force against the patellar tendon by the weight-bearing bar of the socket must be provided by the posterior and posteromedial aspects of the tibial condyles and the overlying tendonous structures, as well as by the popliteal area of the stump. (First factor.)

Emphasis on the patellar tendon as a weight-bearing structure has contributed to constriction of the stump in the popliteal area. The posterior and posteromedial aspects of the tibial condyles and the overlying tendonous structures are important weight-bearing surfaces of the stump. (Second factor.)

In order to make the area for pressure against the popliteal surface of the stump larger, many prosthetists have extended the back of the socket up into the space between the hamstring tendons, cutting grooves to relieve the tendons during knee flexion. This

design can contribute to constriction of circulation in the popliteal area when the amputee stands or sits. The back brim of the socket should be formed into a broad, flared surface against which the hamstring tendons can rest when the amputee sits. (Third factor.) So shaped, the back brim of the socket can be made sufficiently high to provide the large support area needed to minimize pressure while holding the patellar tendon in position on the weight-bearing bar and still ensure sitting comfort (Fig. 1). When the back brim is made higher, as for a short stump, the flare also lifts the stump out of the socket and supports it when the amputee sits.

Edema is also caused by constriction at the mid-stump level, and such constriction can result from the cumulative effects of modifying the plaster stump model. The least desirable



Fig. 2. A very short stump which is capable of bearing considerable weight on the end.

modification is that made in the lateral fibula area. This modification is meant to help stabilize the stump mediolaterally in the socket, but the fibula is a poor structure against which to stabilize. *To achieve mediolateral stability of the stump in the socket, the socket should fit securely against either side of the tibial crest and against the medial and lateral surfaces of the knee joint. (Fourth factor.)* Mediolateral stability is a problem only if the foot is set in or out too far. *The socket should be placed over the foot so that there is little tendency for the prosthesis to tilt medially or laterally on the stump as the amputee walks. (Fifth factor)*

Although breakdown at the end of the stump is sometimes attributed to pressure on the end, a more likely cause is constriction at the mid-stump level. Tightness around the middle third of the stump gives the amputee the feeling that the end is contacting the bottom of the socket or that the tissues are being pulled up against the end of the bone. There are, however, circumstances in which end pressure is damaging and painful. *The socket should support distal tissues with sufficient pressure to*

*aid venous and lymphatic return without pressing against the bone ends. (Sixth factor.)* If the stump has been amputated through cancellous bone, however, the bone end may be an important weight-bearing surface (Fig. 2).

Frequently, the anterodistal tibia area is painful because of the thin cutaneous covering; it is also vulnerable to excessive pressure because of poor circulation. Hollowing out the socket in this region usually does not give the expected relief. Foot alignment, as viewed from the side, and a stiff heel action can be the causes of difficulty. *The foot should be pliant and aligned to give a smooth rolling action as the amputee walks, as though the foot were a segment of a wheel run. (Seventh factor.)* If, so to speak, the "hub of the wheel" is too far back, the end of the stump is forced forward painfully against the socket as the amputee attempts to control the prosthesis at heel contact by active extension of the knee. This problem is especially pronounced with recent amputees who have not become skilled at regulating the forces against the stump by appropriate coordination of knee and body

actions. A softer heel wedge, increased plantar-flexion of the foot (or extension of the socket), or moving the foot forward (least likely) can reduce discomfort at the anterodistal end of the stump resulting from these causes.

General tightness is sometimes considered a source of trouble—and may be initially. But a socket should fit snugly, especially for a recent amputee or one who has not worn a PTB prosthesis before. The newly fitted amputee may have to remove the insert from the socket shell, put it on the stump, powder it, and force it back into the socket shell, even when he is wearing only a cast sock over the stump. One should be sure, however, that the socket bears weight evenly on the main support areas and that it also supports the distal tissues. If the socket does provide proper support, the imprint of the stump sock on the skin will be even in appearance, with the important support areas on the stump somewhat reddened. During the early phases of walking, the amputee should not use the prosthesis excessively. Soon his stump will become accommodated, and then he will be able to use a wool sock. *Tissues which are snugly pressed in a socket will shrink until pressures are reduced to suitable levels. (Eighth factor.)* Sometimes when the stump is fitted snugly, a vacuum develops during the swing phase and has a tendency to produce edema. To correct this problem, holes—sufficiently large to prevent hissing noises—may be drilled into the prosthesis, or the suspension system should be made more effective.

All these factors must be kept in mind when an impression is made over the stump and the plaster model of the stump is shaped for use as a socket mold.

#### TAKING THE PLASTER IMPRESSION

It is not easy to outline a specific procedure for taking a plaster cast of an amputee's stump. Stumps vary in the amount and resiliency of tissue covering the skeletal frame to be fitted. Moreover, the size, strength, and shape of prosthetists' hands and their sense of pressure—all unique to the individual—vary considerably. But if the impression is made tightly over the weight-bearing areas of the stump, these areas will be better defined than

if the cast is made looser, regardless of these other differences.

1. The impression should be started at the knee. The plaster-of-Paris bandage is wrapped tight, starting at the superior edge of the patella. As each pass is made around the knee, the plaster is formed up higher on either side of the knee by guiding it upward with the fingers of the left hand (Fig. 3). At the back, the cast should cover the knee crease by about two finger widths. Wrapping continues in this manner down to the level of the tibial tubercle.

2. Next, an effort must be made to obtain an accurate imprint of the medial flare of the tibia (Fig. 4). The plaster-of-Paris bandage is pulled up against the medial flare with even tension, and each turn is anchored to the lateral surface of the knee. Thus tissue tension is prevented from driving the plaster away from this important support area.

3. The rest of the stump is wrapped with less tension.

4. The plaster is smoothed over the entire stump and worked around the bony areas. As the plaster is worked, the stump is palpated to determine how it should be held for shaping.

5. Just before the plaster begins to set, the thumbtips are positioned on either side of the patellar tendon,



Fig. 3. Starting the plaster impression and guiding the plaster upward along the sides of the knee.



Fig. 4 Pulling the plaster-of-Paris bandage against the medial flare of the tibia to obtain an accurate impression of this important support area.



Fig. 5. Holding the cast with moderate pressure and with the fingers flat across the back.

close to its edges, so that the plaster-of-Paris bandage is pulled in against the tendon as pressure is applied. This position of the thumbs precludes intrusion into the spaces under the edge of the patella medially and laterally. The fingers are placed around the medial flare of the tibia and held flat against the back of the stump. It is important *not* to push into the popliteal space with the fingertips. Where the fingers encircle the lateral side of the stump, they are not in contact. Across the back of the stump, they are straight and exert pressure against the posterior aspects of the lateral tibial condyle and the popliteal area. Very little force should be used. The cast has been wrapped tight at the top to obtain an imprint of the stump close to the required shape, and the cast is held to ensure that the required support areas will be well defined when it sets (Fig. 5).

6. When the plaster impression can hold its shape, the thumbs are used to obtain a clear imprint of the anterior crest of the tibia by moderately caving in the semi-set plaster along a 3/4-in. strip on each side of the tibia to within an inch of the end (Fig. 6). The impression will now be wedge-shaped in front. Just before the plaster sets firmly, the hands are returned to the holding position, and the cast is held until it can be taken from the stump. This holding-squeezing action

flattens the back and ensures retention of the required anteroposterior width.

#### MODIFYING THE MODEL

It is desirable to modify the plaster stump model as soon as possible after the impression is taken, while the recollection of details is still strong.

1. A groove is carved in the patellar-tendon ridge with a 1/2-in. self-cleaning rasp to a depth of about 1/2 in. The groove is made halfway between the inferior edge of the patella and the tibial tubercle. The groove should be about 3/4-in. wide between the upper and lower edge, and the edges should be smoothly curved toward the patella and toward the tibial tubercle (see Fig. 7).

2. Modifications on either side of the crest of the tibia are made in the usual way (3).

3. The medial flare area is smoothed first with a curved self-cleaning rasp to make the flare blend in with lower sections of the model and then with wire screening, which should be swept around the natural contours of the flare extending into the posterior area and even over the hamstring tendons (see Fig. 8).



Fig. 6. Caving in the plaster on either side of the tibial crest.

4. The back of the model is flattened and smoothed over the popliteal area; care must be taken *not* to indent this area.

5. The flattened surface at the back of the model is extended downward and blended in with the more distal parts of the model by shaving off small amounts of plaster.

6. The model is smoothed on either side of the knee. If necessary, material is carved away to reduce the model to the measured width of the knee. This area is important, because it contributes to stabilization of the stump in the socket. The lateral side of the socket stabilizes the medial flare of the tibia against its weight-bearing surface in the socket. Sometimes a very slender amputee will find that when he sits, the wide part of his femoral condyles binds against the socket at the top. To correct this, the socket should be heated in that area and forced outward to give relief.

7. Plaster is added to the model in bony areas such as the head of the fibula, the crest of the tibia (especially toward the distal end), and the ends of the fibula and tibia. If the crests of the tibial condyles are prominent, extra space should be provided for them in the socket. They and the tibial tubercle seldom present problems if the patellar-tendon shelf has the proper dimensions, because then the socket is forced away from those prominences.

8. Before constructing the posterior flare on the plaster model, it is necessary to mark the socket trim lines on the model. First, a line is drawn circumscribing the model at the mid-patellar-tendon level and perpendicular to the long axis of the model. This line defines the back brim for the average type of stump. A shorter stump will be fitted higher at the back, depending on how short it is. Next, a line drawn through the middle of the patella and upward on either side gives the shape of the medial and lateral extensions of the socket. On the lateral side, the line will pass straight down through the posterolateral corner of the model to cross the posterior reference line. The corner can be rounded so that the lines join with a 1/2-in. radius. On the medial side, the trim line should be further in from the side so that the posteromedial curve is retained in the socket to help provide posterior support to the stump. This is possible because the medial hamstring tendons are toward the midline of the stump. After the model has been secured in a vise with the popliteal area up and the long axis of the model horizontal, plaster is poured above the trim line at the back (Fig. 9). When the plaster has set slightly, a 3/4-in. flare is formed by smoothing the plaster with wet fingers and thumb. It is seldom necessary to adjust the fit of the flare for relief of the low-set medial hamstring tendons, even though the socket curves around to the back on that side, because the flare allows the tendons to support considerable pressure comfortably. (For a medial view of the modified model, see Fig. 10.)

#### STUMP SHRINKAGE

Even the seasoned stump can shrink. To the prosthetist this is a problem of economic significance, because his guarantee provides for repair or replacement. The worst of it is that when the socket of a PTB prosthesis is no longer satisfactory and must be replaced, there is little the prosthetist can do but rebuild the prosthesis completely. The least that can be done is to lay in material between the socket shell and the insert or to cast RTV Silastic resin under the stump. This sometimes affects alignment, which then must be adjusted. If the weight-bearing area can be modified easily, it is good practice to take a new cast of the stump, prepare a new model, and make a new insert over it. The new insert will support the stump distally, while the modified brim area gives satisfactory weight support and stabilization.

Actually, what is needed is a different approach to the provision of prostheses. The recent amputee should be provided with a well-fitted limb to which a series of sockets can be easily attached until the stump has become stable. Then a final fitting can be made. At

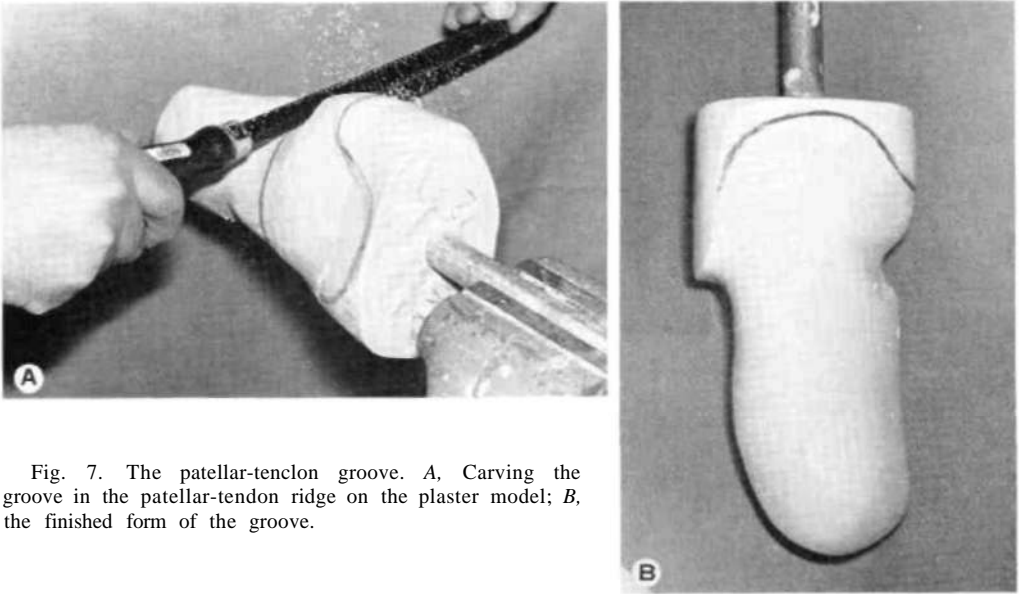


Fig. 7. The patellar-tendon groove. A, Carving the groove in the patellar-tendon ridge on the plaster model; B, the finished form of the groove.

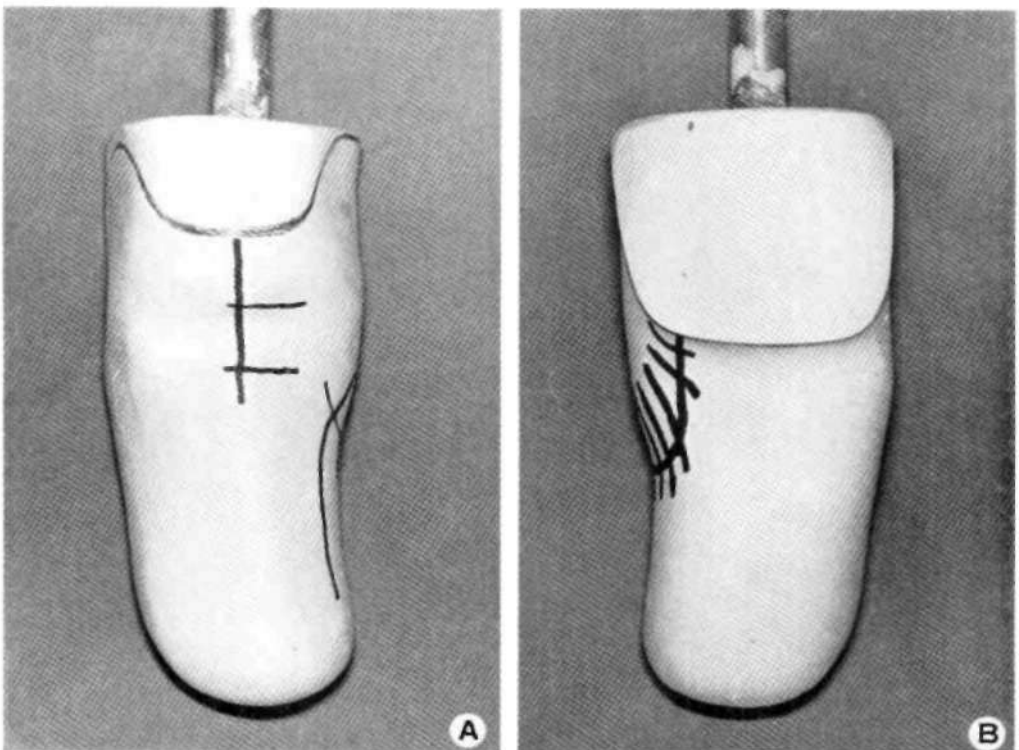


Fig. 8. The finished form of the medial flare area on the plaster model. A, An anterior view; B, a posterior view.

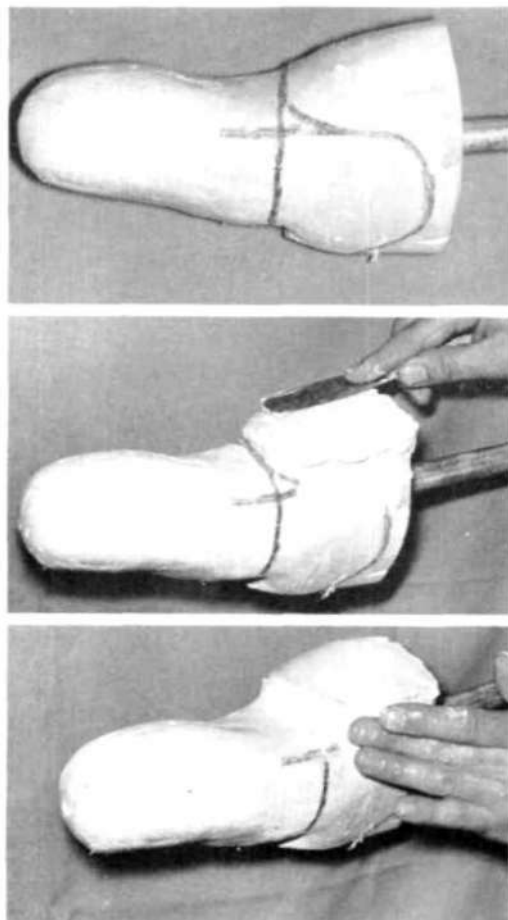


Fig. 9. Marking and forming the posterior flare on the plaster model, which has been secured in a vise with the popliteal area up. *Top*, the line circumscribing the model at mid-patellar-tendon level defines the level of the back brim of the socket. *Center*, plaster is poured onto the model above the trim line and allowed to set slightly. *Bottom*, wet fingers and thumb are used to form the posterior flare

present, the permanent limb is often fitted as soon as the shrinker bandage treatment has been completed. The forces imposed on the stump by the prosthesis are much greater than can be developed by the shrinker bandage. Also, the socket forces are different in location. In addition to the loss of control and harmful forces that develop between the stump and the prosthesis, the reduced bulk of distal

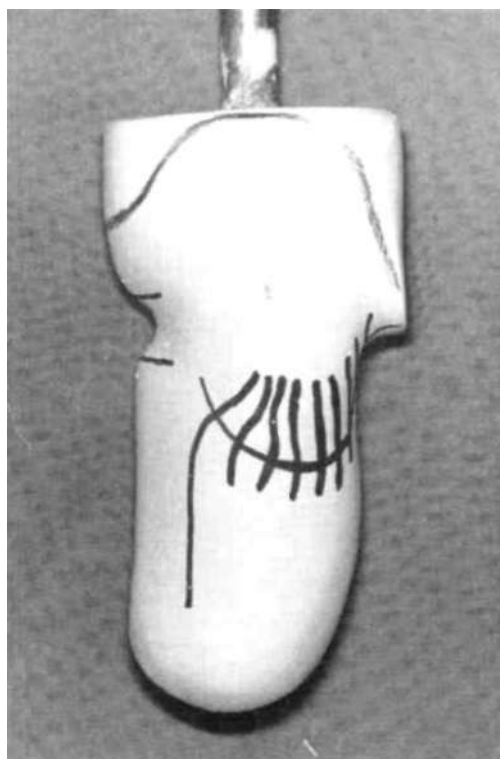


Fig. 10. Medial view of the modified model.

tissues leaves them unsupported and prone to edema.

When the stump is fitted tightly, as recommended here, the initial discomfort will diminish as the stump shrinks and molds into shape. Finally, the amputee will be able to don his prosthesis while wearing a wool stump sock.

#### PERSPIRATION AND MACERATION OF THE STUMP

There have always been amputees who have suffered maceration of the stump end as a result of accumulation of perspiration in their sockets. Contributing to the heat in a PTB prosthesis are the rubber-leather insert, the thick plastic shell and surrounding materials, the closed end of the socket, and the tightness of fit. Ventilation is poor, even when holes are drilled through the walls of the socket. Use of a valve system, such as that designed at the Navy Prosthetics Research Laboratory, which



allows air to enter slowly and forces it to escape up through the sock, could be helpful provided noise is avoided; and porous plastic laminates, such as have been developed at the Army Medical Biomechanical Research Laboratory, may be of some use as a solution to the problem. The most likely immediate solution is to make the socket thin, somewhat pliable, perforated, and without an insert. Such a socket must be titled with care, since there is no soft insert to provide a margin for error and to permit easy modification of the socket. A socket constructed of four to six layers of stockinet laminated with two turns of glass-cloth covering from the top to the tibial tubercle will serve. The socket, supported in a plastic receptacle (Fig. 11), can easily be replaced without seriously affecting the entire prosthesis.

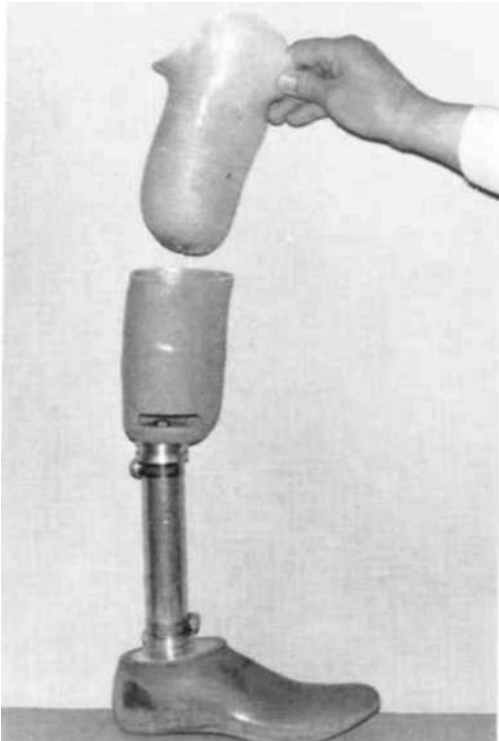


Fig. 11. Temporary plastic socket and the receptacle into which it fits.

#### USE OF JOINT-CORSET PROSTHESES

Under ideal conditions, the percentage of amputees who use joint-corset prostheses might be as low as 10 per cent. There is no doubt that the joint-corset system can make up for deficiencies in the fit of the socket and thereby serve as a safety factor when the proper fit of a PTB prosthesis is not achieved or maintained. But there are definite criteria which can be used for the prescription of a joint-corset prosthesis.

Sometimes the amputee's occupation requires him to use his prosthesis under heavy-duty conditions; he may be required to pry up or lift heavy objects. *When the amputee must place a force on his prosthesis which is considerably greater than the weight of his body, a joint-corset prosthesis aids him by permitting part of the weight to be borne on the thigh. (First criterion)* The joint-corset system is especially effective when the knee is slightly flexed so that forces are borne by the back of the thigh and are transmitted to the shank through the side joints. When the thrust on the prosthesis is along its axis, the amputee can prepare for it by temporarily tightening his thigh corset.

Many amputees kneel, climb ladders, or climb stairs frequently. Such activities may be especially difficult or troublesome to the bilateral amputee because of rotation of the PTB prosthesis on the stump. *The joint-corset system prevents the prosthesis from rotating about the amputated leg when the joints are flexed. (Second criterion.)*

There is the rare amputee whose knee is unstable, or whose musculature is so weak that the joint-corset system is required. *The joint-corset system can stabilize an unstable knee against extreme mediolateral motions; against dislocations; and, when a back-check is used, against hyperextension of the knee. (Third criterion.)*

For the amputee with a stable knee, however, the corset is functionally limited as a mediolateral stabilizer because of the thinness of the joints, the fleshy nature of the thigh, and the pliability of the leather corset. Only if the amputee also bears weight on the corset, or has an extremely atrophied thigh against which he laces the corset tightly, or the corset

extends to the peroneal level with cross braces between the side joints, will the corset be of much value as a mediolateral stabilizer.

Also rare are amputees who cannot bear weight effectively either on the stump or through the femur. *An amputee who cannot bear weight on the stump should be fitted with a quadrilateral ischial-gluteal weight-bearing support and have straps connecting the thigh to the side joints above the knee for control of flexion and extension and for suspension of the prosthesis. (Fourth criterion.)*

Sometimes an amputee is mentally retarded or senile. In such an event, especially if there are no qualified helpers to ensure that the prosthesis is donned correctly, the joint-corset system should be used. *The joint-corset system is an aid in ensuring that a prosthesis is correctly placed on the amputated limb when the amputee's judgment is questionable. (Fifth criterion.)*

A problem often faced by the prosthetist fitting a PTB prosthesis to an experienced wearer of a joint-corset prosthesis is that the amputee is not prepared to make the change, either because he doubts that he can do so successfully or easily, or because he has a definite bias toward the joint-corset prosthesis. *The joint-corset system should be used when there are definite psychological pressures favoring it. (Sixth criterion.)*

## CONCLUSIONS

Probably many prosthetists who fit the PTB prosthesis successfully have discovered for themselves, or have learned from previous experience with other prostheses, how to deviate from established procedures. For those who have difficulties, this review may be of assistance. But it may be necessary to have those who are successful demonstrate to those who are not. Short-term or immediate success should not mislead those who are trying to establish improvements. Often it is only after a year or so that results can be judged. Meanwhile, encouragement should be given to those who seek to develop devices and techniques which will eliminate as many as possible of the craft-oriented tasks needed to fit amputees, thereby increasing reliability and uniformity.

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