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The UCLA Total Surface Bearing Suction Below-Knee Prosthesis

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Introduction

While there was clear evidence to support examination of suction as a suspension technique for below-knee prostheses[1] in the early 1950s, overwhelming activity was in a direction that led ultimately to the development of the PTB design.[2] What is truly remarkable is the almost blind obedience that the practitioners and educators have given to PTB theories, a recognition that has rendered them all but untouchable gospel. Introduction and widespread use of transparent check sockets has probably done more to cause the prosthetist to question the accuracy of his PTB fitting methods than any other development in the last decade. Inaccuracy in socket fit that this powerful tool has revealed has led to the obvious conclusion: more precise casting and modification methods are required. This is the intent of the technique described here.

This paper presents a departure from PTB philosophy and technique. The methods described freely borrow from and recognize individuals who have developed alternative ideas, many of which have been integrated into the UCLA Total Surface Bearing Suction Below-Knee Prosthesis. The substance of this paper includes suction as the obvious mode of suspension. However, the essence of suction suspension, and of this article as well, is the critical anatomical accuracy of the socket fit. We refer to it as the total surface bearing or TSB technique. Without TSB, successful long-term suction suspension cannot be achieved. With TSB, the prosthetist can achieve suction if desired or may choose to fit with a sock and without suction if so indicated. Whatever the case, the final result will be improved fit and better patient comfort.

Suction Suspension

Suction below-knee prostheses are unique in that they do not require auxiliary suspension systems such as straps, cuffs, thigh lacers, or sleeves to maintain the socket on the residual limb. This is not to suggest that auxiliary suspension need not be employed as an extra measure of protection, particularly with a very active patient. However, in principle no other suspension should be required (Figure 1).

Three variations of suction socket are discussed in this article. The first is the "tension suction" variation.[3,4,5] This socket is made volumetrically smaller than the residual limb. Suction is maintained in the same manner as with the rigid above-knee suction prosthesis. This is probably through tension placed on the skin, thereby enhancing the friction between the tissue and the socket. Normally, a valve is placed at the distal end to release air while the socket is being applied. The second classification is "atmospheric suspension," mentioned by Murphy[6] in 1950 and later by others.[7] In atmospheric suspension, a non-elastic, but flexible interface is used, which virtually collapses around the residual limb when the prosthesis is unweighted. The third type of suction will be called "active compression suction." In this case, the socket interface is made of an elastic or elastomeric material which must be stretched or rolled over the residual limb, thereby gripping the skin through compression as well as through friction created between the skin and the socket.[8]

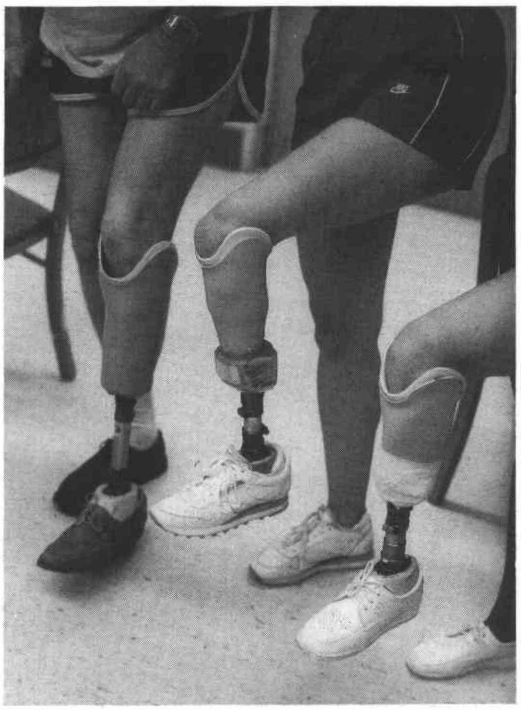

Figure 1. UCLA Total Surface Bearing Suction Prostheses.

Fitting Variables

The primary concern of any prosthetist attempting to fit a suction below-knee prosthesis should be the general health of the residual limb tissues. The UCLA experience has been similar to studies by Holmgren[9] and Bedouin.[4]

Types of Patients

The suction below-knee prosthesis, properly fitted, appears to stimulate circulation and can be used on vascular amputees as well as amputations due to other causes. The suction below-knee may actually help to more quickly stabilize tissue fluid volume. Ages of patients have ranged from five to 88 years.

Skin Problems

A suction below-knee prosthesis virtually eliminates skin problems caused by movement and friction created between the residual limb and the socket interface. Problems of skin irritation related to hygiene and allergic reaction are covered in a later section.

Bony Prominences

Grevsten,[10] using x-ray evaluation of suction below-knee fittings, found that the movement of skeletal anatomy inside the socket is less than one-half that inside ordinary PTB sockets. The UCLA experience, which employs a more intimate casting and cast modification technique (TSB), suggests an even greater reduction in skeletal movement. More importantly, few problems with bony prominence pain or discomfort were reported by patients in the over 150 fittings conducted at UCLA and other locations during the teaching of this technique.

Length

We have found no correlation between residual limb length and the ability to wear a suction below-knee prosthesis. Fittings and suction suspension have been successfully achieved with residual limb lengths as short as 3½". However, these are not all long-term results.

Volume

More important was the finding that many residual limbs initially fit with suction would lose this effect within one or two hours of wear. There is an immediate fluid volume adjustment. Patients fit with suction over longer periods of weeks and months will continue to experience residual limb volume changes until a point of volume stability is achieved. This normally will occur within six weeks. Any loss of body weight will certainly contribute to loss of suction as well.

Shape

Generally, with enough effort almost any shape residual limb can be fit with suction. However, to achieve suction with conical shape residual limbs, whether bony or fleshy, can be difficult. With such cases, it is often necessary to enlarge the gastrocnemius muscle bulge area of the socket while tightening slightly proximal to this to maintain suction. Many prosthetists might question the long-term effect of this technique on the health of the residual limb. Short

term effects have not been adverse and results look encouraging.

Patient Cooperation

Patients who intend to wear suction below-knee prostheses must be intelligent, cooperative and aware of the critical nature and accuracy required in this type of fitting. Numerous adjustments may be required during the first several months to maintain the intimacy of the fit. The patient must fully understand the function of the valve and the socket liner. It is imperative that any patient wearing a suction below-knee prosthesis, no matter how effectively fit, wear an auxiliary suspension as a back-up in case loss of suction does inadvertently occur.

Comparison of Theories

In the below-knee prosthesis, suction is a mode of suspension that can only be maintained through a precisely fit socket. A major aim of this article is to present a technique whereby such a fit can be achieved. Development of the total surface bearing (TSB) below-knee socket combines a staged precision casting method with a significantly different model modification to yield this result. In order to understand these differences, it is necessary to contrast the TSB and the more traditional PTB sockets.

The basic philosophy of the patellar tendon bearing below-knee prosthesis can be stated as follows: Increase weight bearing on areas of the residual limb over pressure tolerant areas and relieve pressure over those areas which are pressure sensitive. With the total surface bearing below-knee prosthesis weight is distributed over the entire surface of the residual limb, including areas which have in the past been considered pressure sensitive. In TSB, the accuracy of fit and careful use of measurements has eliminated the need for relief buildups over bony areas of the residual limb during the plaster casting and model modification procedures. The resulting corrected model for a TSB socket is thus distinctly different from that developed in accordance with PTB modification techniques.

Evaluation and Measurement

Measurements include all standard below-knee prosthetics parameters. The following additional considerations are necessary.

Circumferences

Carefully located circumferential measurements are taken at one inch intervals. The intervals are laid out from a bony landmark which can be defined accurately during the plaster casting procedure. Normally, the apex of the head of the fibula or the distal anterior tip of the tibia are chosen, depending on which is more prominent. The tibial tubercle may also be used. However, it is necessary to measure at least one interval more proximal when this location is chosen. In very fleshy or redundant residual limbs, it is wise to select the fibular head as some elongation may occur during casting which will obscure the distal end.

Length

The length measurement must be accurately gauged from the distal end of the residual limb to both the medial tibial plateau and to the inferior edge of the patella while under forceful upward loading.

Evaluation

Patients with chronic skin problems or burn scar tissue may not be suitably fit in sockets where the skin is directly in contact with the socket liner, unless the interface surface is impervious to body fluids. Perspiration can cause maceration even in healthy skin and an appropriate interface must be selected in such cases.

Plaster Casting Technique

An essential element of a successful TSB socket is a precisely cast residual limb. The diagonal four stage casting technique which draws from work adapted from Fillauer,[11] Gleaves,[12] Tranhardt,[13] Morris,[14] Hayes,[15] Stokosa,[16] and Vinnecour[17] was developed to best achieve that end. Unusual elements of the technique include:

1. Sheer nylon stockings for an ultra-thin barrier between skin and plaster, resulting in a more accurate cast.

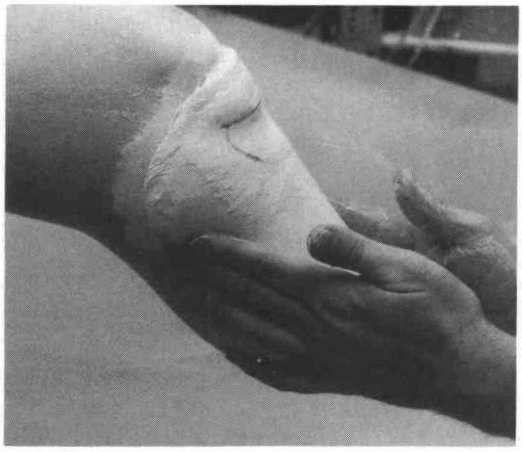

Figure 2. The entire medial tibial flare and all bony prominences are carefully molded.

2. A beveled anterior first stage splint which is very accurately tailored to encompass the head of the fibula, the shaft of the tibia, and the entire medial flare. This first stage (Figure 2) is carefully molded to all bony anatomical structures. If properly applied, it will establish the mediolateral dimension within ⅛″ of patient measurement in most situations and require little or no model modification of the anterior aspect of the medial flare of the tibia.
3. A second stage of elastic plaster bandage which is wrapped with about half the available stretch applied. This stage must not extend more proximal than about 1″ to 1½″ below the crease of the skin in the popliteal fold. The anterior stage is maintained in position during this second procedure with firm proximal compression. As the second stage sets, the proximal posterior aspect is lightly compressed to help define the antero-posterior dimension of the cast. The medial lateral dimension is never sacrificed in any attempt to decrease the antero-posterior dimension.
4. A third stage splint, which creates the posterior brim shape and completes the basic cast used when a non-supracondylar trim line, is desired. The salient point of the third stage is the hand molding of the plaster bandage in the hamstring tendon region. When properly applied, the posterior brim will appear premodified with a diagonal trim which accommodates the lower anatomical insertion of the medial hamstring muscle group. It is necessary to do four things simultaneously to create an acceptable third stage, and generally will take considerable practice before repeatable accuracy and skill is achieved. It is necessary first to locate and create the shape of the tendons; secondly, compress the antero-posterior dimension of the cast both proximally and compressionally; third, mold the medial and lateral posterior areas of the third stage to prevent looseness in the hamstring areas proximal to the medial tibial plateau region; and fourth, spread the fingers of both left and right hands to stretch the plaster bandage to prevent a ridge from forming in the posterior aspect between the second and third stages (Figure 3).

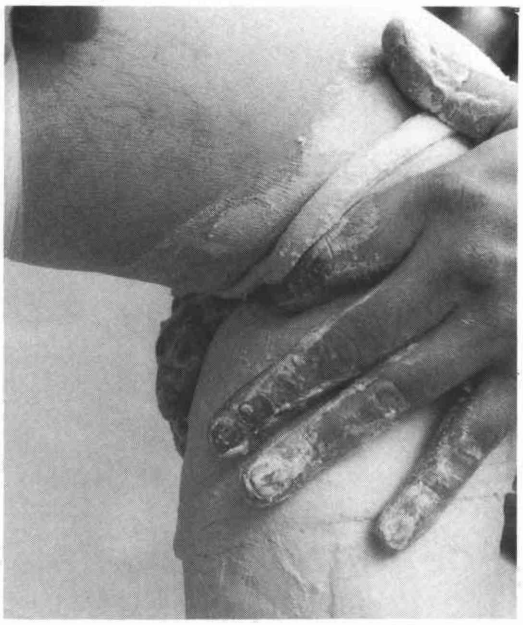

Figure 3. The posterior trim and hamstring muscle reliefs are created during the wrap casting procedure.

5. A fourth stage splint is used when supracondylar suspension is planned. It is applied in a manner similar to that used in Fillauer's three stage casting technique.

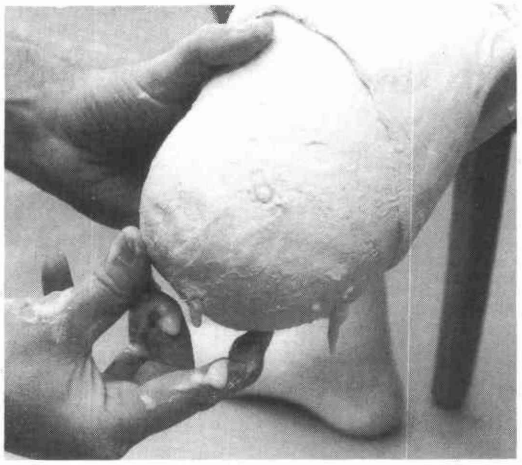

Figure 4. The wrap cast is alginated and pressure fitted.

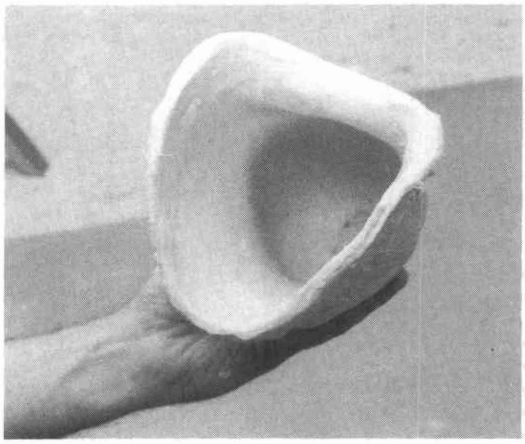

Figure 5. The completed diagonal four stage wrap cast.

Alginate Pressure Fitting

The first step in the fitting process occurs immediately after the hardened cast is removed. Through application of dental alginate to the inside of the wrap and a refitting on the patient, a more intimate contour is achieved. Though somewhat of a messy procedure, this will minimize the need to remove plaster from the model during modification. When casting very obese patients or those with excessive redundant tissue, this step may not be successful and may result in distortions in the final model.

The nylon stockings are carefully removed from the cast and a hole is cut in each of the distal, lateral, medial, and posterior aspects to permit air to escape when the alginate is applied. The holes should be approximately ¼″ in diameter and should be cut using a knife. (A hand drill or drill press will likely grab the fabric in the wrap and destroy it.) About eight to ten ounces of dental alginate are mixed to a thick, but creamy consistency and quickly applied to the entire inner surface. The cast is replaced on the residual limb and forced proximal with moderate pressure. Alginate should exude from all cut holes (Figure 4).

The instant the alginate stops flowing from the holes, they are covered with the hands or fingers to prevent further leakage. Any excess alginate can be smeared about the proximal brim to perfect the fit in this area (Figure 5). This procedure must be conducted quickly and precisely or air pockets will occur. If air pockets do occur, we have found that additional algination attempts have been unsuccessful.

Total Surface Bearing Model Modification

The antero-posterior and medial lateral are modified exactly to residual limb measurements. The anterior modification of the antero-posterior is markedly different from the PTB ''Bar.'' The TSB modification follows the shape of the anatomy in this region as shown in the xeroradiograph of the below-knee amputation (Figure 6).

Notice that the shape of the tibia angles posteriorly immediately above the tibial tubercle. Plaster removal follows this shape. The inferior edge of the patellar area is modified as though the patella were being lifted proximally about ¼″. In other words, the true tibial plateau is below the inferior edge of the patella in most cases (Figure 7). The posterior aspect of the model normally requires only smoothing or only slight reduction to establish the correct AP.

Plaster is removed from the posterior aspect of the medial flare of the tibia. This half moon shape sweeps into the medial hamstring area. Up to ⅜″ of plaster may be removed in a very redundant residual limb. It is not unusual to see a medial hamstring ½″ to ¾″ lower than the

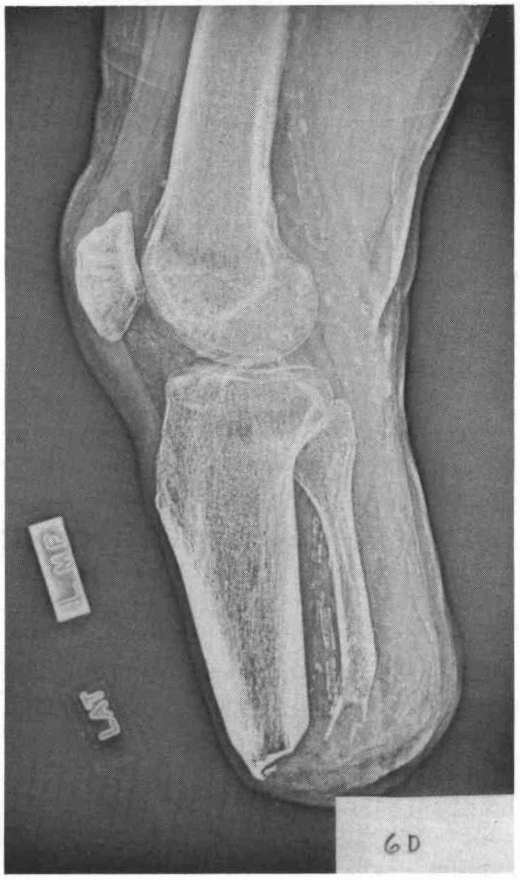

Figure 6. Xeroradiographic lateral view of below-knee amputation. Notice the shape proximal to tibial tubercle.

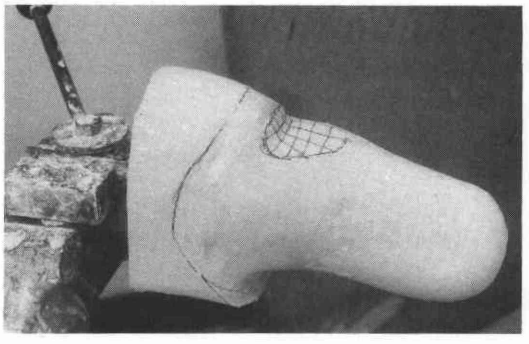

Figure 7. Modification inferior to patella simulates shape of anatomy rather than "PTB" patellar bar.

lateral side. Generally, the lateral side hamstring can be kept almost at tibial plateau level and is maintained at this level across the popliteal fossa.

Absolutely no buildups are applied to the crest of the tibia, the head of the fibula, the anterior distal aspect of the tibia, or any other bony prominences. Reliefs are created by removal of plaster from around these areas to accentuate their shapes and to compress the tissues. Usually no more than ⅛″ of plaster is carved away using a curved blade flexible knife (Figure 8).

The model is next measured for circumferences using the previously established bony landmark as a guideline for accurately locating the measurement levels (Figure 9).

It is generally found that the model at this point will be approximately at the residual limb measurement or somewhat larger, even if fairly liberal modifications have been performed. If the model were to be smoothed and a socket fabricated at these measurements (0″ to +⅛″) it will result in about a two-ply heavy cast sock fit or about one "Socket Liner Stump Sock."[18] However, this may not in itself achieve suction.

In order to create a suction fit, the model must be carefully reduced in its circumferential measurements starting from a point approximately one inch above the tibial plateau and proceeding distally the entire length of the cast. As a beginning, a minimum of ½″ of tension reduction less than the patient's measurements is applied at each measured level. Ultimately, in a new patient (any patient who has never

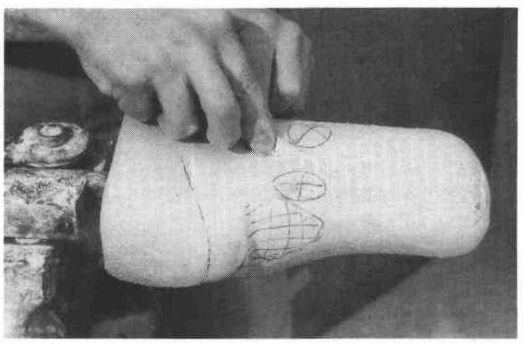

Figure 8. No plaster buildups are added to master model. Plaster is carefully removed around bony prominences and over bony prominences.

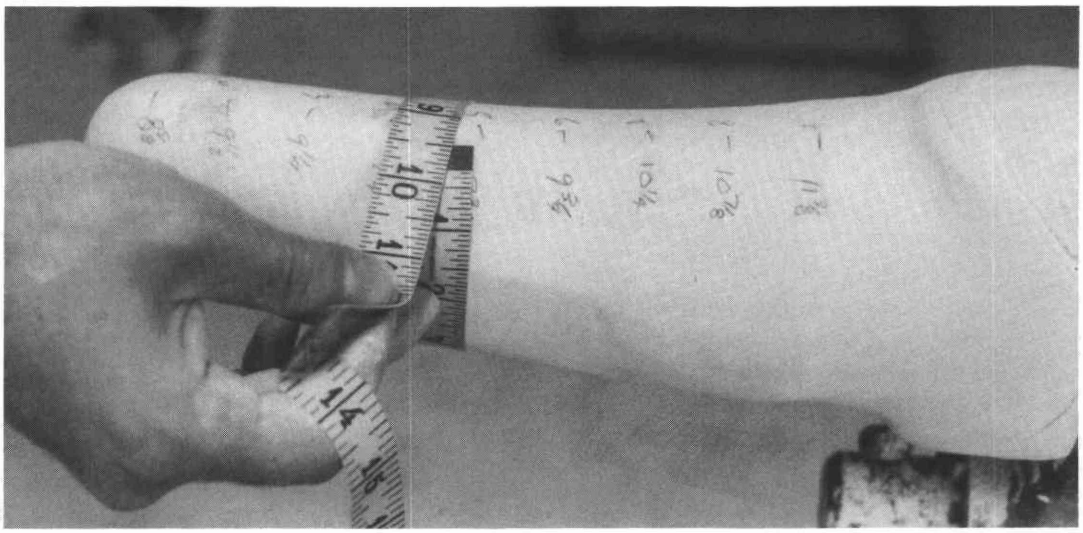

Figure 9. Circumference measurements of master model are reduced below patient measurements to achieve suction.

worn a suction socket) the tensions may well reach ¾″ to 1″ less than the original anatomical measurements. However, it is not a simple matter of initially bringing the tensions on the model to these values. This is inadvisable and potentially harmful for the patient. A gradual reduction process over time must be followed in order to achieve the results just stated.

In pilot studies and in pilot courses conducted at UCLA in 1984, an attempt to empirically arrive at appropriate TSB suction tension values was made. Each prosthetist was asked to carefully record how much reduction in residual limb measurements was required to finally achieve suction suspension. The compiled results of these efforts suggest an initial tension value of ¾″ is necessary at each level to achieve suction. This value may vary depending on residual limb musculature, length, and tissue type.

Check Sockets

It is advisable, if not imperative, to use transparent check socket fittings to confirm the accuracy and precision of the wrap cast and subsequent model modifications. The UCLA technique involves two types of check sockets: flexible check sockets and more conventional rigid check sockets.

The Flexible Check Socket

A check socket is vacuum formed using ⅛″ Surlyn® plastic. On a five to seven inch residual limb this will result in a very thin socket probably no thicker than 1/32″. A valve is located distally to release air from the socket as it is donned (Figure 10).

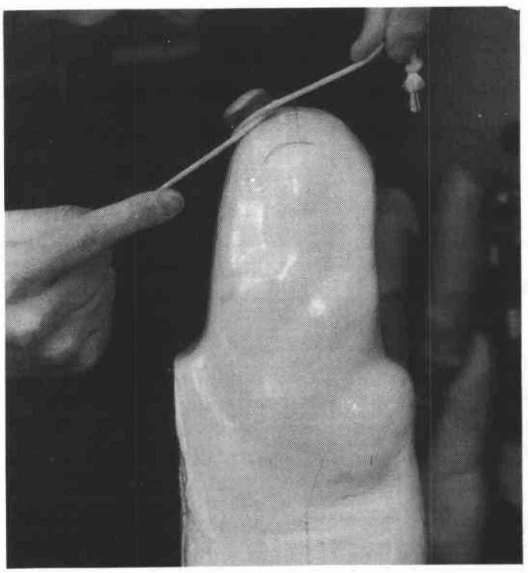

Figure 10. A flexible check socket is vacuum formed with small valve placed distally.

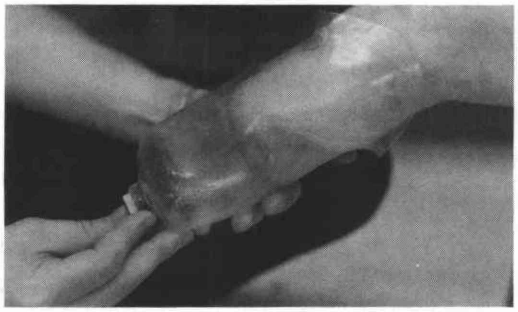

Figure 11. The flexible check socket is "wet" fit to the patient.

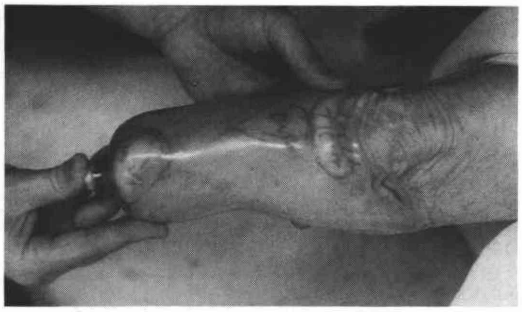

Figure 12. Suction, total contact, volumetric and anatomic accuracy of check socket are determined in the flexible check socket.

Lotion or Vaseline® is used to lubricate the surface of the residual limb to aid in donning[19] (Figure 11). Flexible socket fit can be confirmed by direct palpation of the anatomy from the outer surface. Any air spaces or otherwise loose areas are located and subsequently corrected on the model. It is not unusual for this flexible socket to hold suction even if inadequate tensions were applied to the model (Figure 12).

Accordingly, if the socket is made rigid by an application of a roll of fiberglass casting tape to the outer surface, suction will invariably be lost almost immediately. This demonstrates one of the many problems facing anyone wishing to fit or wear a suction below-knee prosthesis. The flexible socket in this case is exhibiting atmospheric suction. The socket collapses around the residual limb as any attempt is made to remove it. Rendering the socket rigid transforms this flexible membrane into a rigid socket and as the socket wall cannot move, suspension is lost.

The Rigid Check Socket

A rigid check socket may be used after the model corrections, determined by the fit of the flexible check socket, have been performed. With the rigid fitting, it is common to find the need to increase tension values to an average of ⅝" to ¾". It must be assumed that fluids rapidly leave the residual limb as a more rigid, accurate fitting socket is applied. It might also be speculated that the muscles flatten out somewhat as excess fluid leaves the residual limb. Examination of residual limbs in properly fit rigid transparent suction check sockets after several hours of wear reveal good color and lack of a distal discoloration which one might expect in a "tight" socket.

Socket Materials

A variety of materials and fabrication techniques have been examined for their application to the suction socket. Varying levels of success have been achieved; however, there are usually trade-offs involved. Suction may be achieved with a removable liner/insert alone that keys into the prosthesis much like a liner in a PTB socket. A prosthesis may also be constructed with a hard suction socket with no liner or with a soft liner that is permanently attached. In any case, some type of valve is usually necessary, installed either in the liner, in the socket, or at the end of a tube extending from the distal end of the socket to the outside finish lamination of the prosthesis. Valveless liners are also possible; they will be discussed later.

In considering a method of constructing a suction socket, it is important to realize that there will be no sock to absorb moisture; the patient will likely require some type of powder, cream or lotion application to don the socket, and the skin will be in direct and intimate contact with the inner material. All of these factors dictate a non-porous, easily cleaned material that will minimize the growth of bacteria, yet provide the necessary cushioning and comfort for daily or specialized activities. Whichever approach is taken, the prospects of success are limited only to the ingenuity of the prosthetist and the materials employed.

Hard Socket Variations

This is perhaps the most difficult variation with which to achieve success since the demands of precision required for fit and comfort are the highest. Firm residual limbs of good muscle mass are the most likely candidates for this design.

The hard socket is undoubtedly the easiest to fabricate, and for the patient is the easiest to keep clean. Even if accepted by the patient, these sockets will feel hard and, while suitable for walking, they are probably not appropriate for heavy activities such as running. However, hard sockets, with the addition of a single nylon sheath, have been very successful in the long-term with low activity level patients. Flexible acrylic and polyester laminates backed on the outer surface with soft foams such as PE-LITE™ or Aliplast™ have enjoyed about the same level of success as a hard socket. Patients report that these sockets feel hard despite the padding. Additionally, allergic skin reactions seem to be more common when flexible resins are used. Minute cracking in the interface may create a breeding ground for bacteria or lead to skin irritation through surface friction.

A number of thermoplastic liners have been successfully fit (Figure 13). Some have been quite comfortable, notably the "total flexible brim" variation suggested by IPOS[20] and Sabolich.[7] Both are frame-supported polyethylene designs. Since thermoplastics may exhibit "cold flow" and may actually shrink, they are not ideal materials. An interesting characteristic of thin thermoplastic sockets is the enhanced capability of atmospheric suction. However, this advantage is basically negated by a lack of long-term durability. The suggested ease of refabrication and/or inexpensive nature of replacement does not hold up to criticism by patient used to no-nonsense prosthetic care. Another negative characteristic of thin thermoplastic liners such as Surlyn® and polyethylene is the inability to make adjustments after fabrication.

A major point of consideration in fitting any socket material that directly contacts the skin is the coefficient of friction at the interface. There are definite differences which are recognized empirically and clinically, but not objectively related to prosthetic fit in the below-knee as well as in above-knee suction sockets. For example, Surlyn® and Durr-Plex both seem to have a surface which adheres very well to slightly damp skin. When these surfaces are lightly sanded, they lose some of this gripping capability. This can be both a positive and a negative factor, depending on the skin tolerance of the patient involved.

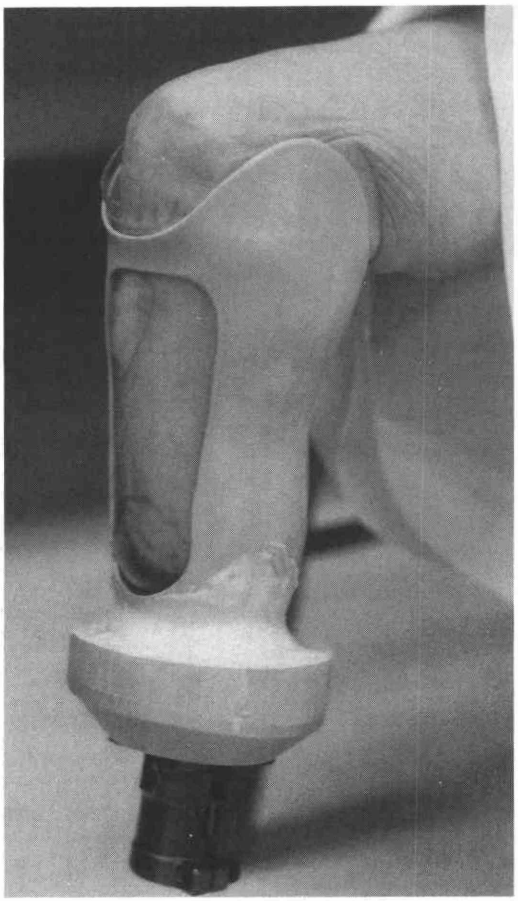

Figure 13. Surlyn® inner flexible socket with outer frame fitted in 1985 as a suction below-knee prosthesis.

Generally, hard socket variations of suction below-knee prostheses, while feasible, are not very practical for most patients. Moreover, the instance of inadvertent loss of socket suction must be expected. This is not really considered a problem since we recommend that auxiliary suspension be worn even on the best suction below-knee fitting.

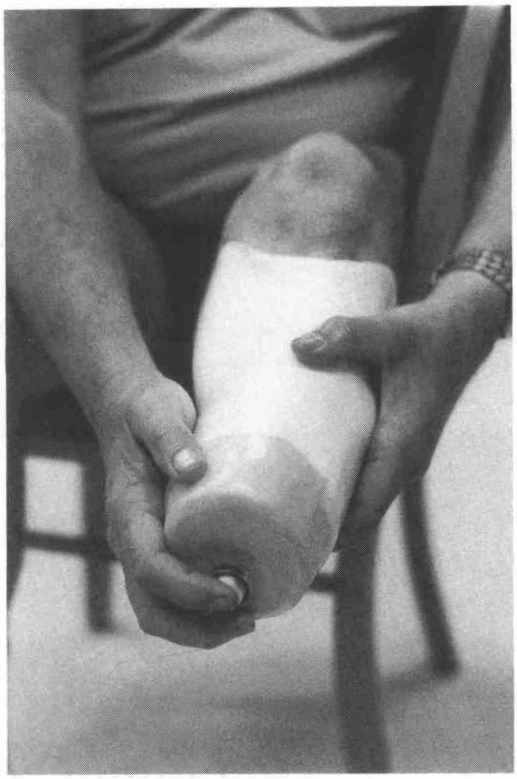

Figure 14. Pelite™ liner with Plastozote distal end, distal valve and Surlyn® outer shell fitted as suction below-knee prosthesis in early suction below-knee courses at UCLA in 1985.

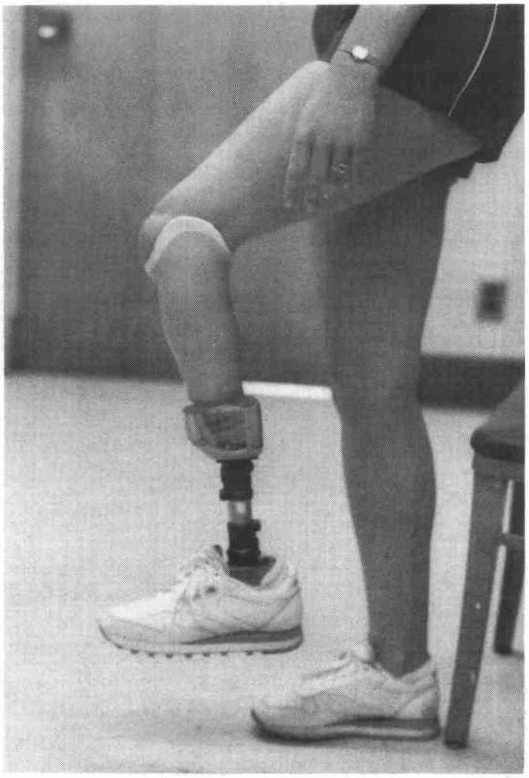

Figure 15. The TSB Suction below-knee can be fitted on almost any length below-knee residual limb. Auxillary suspension is not shown in this diagram but is recommended for all suction below-knee wearers.

Soft Socket Variations

Early suction liners were made of leather backed with Neoprene®. Even when given a sealant coating, the leather will begin to deteriorate and develop offensive odors in a fairly short period. However, good comfort has been achieved as has adjustability. Replaceability is not really possible in this variation.

PE-LITE™ and Surlyn®-backed PE-LITE™ have both been successfully used for soft suction liners (Figures 14 and 15). It wears fairly well and can be cleaned with baking soda, vinegar, or rubbing alcohol to eliminate both odor and dirt. These liners will likely pack-out in time, and thus, normal prosthetic delivery should include a duplicate. Replacement duplication after wearout of thermoplastic foam liners is not really practical to the level of precision necessary to maintain suction.

Another major advantage of these materials is that they may be easily added to or otherwise adjusted. By use of selectively placed materials of varying durameters, comfort can be achieved in very bony patients and those with poor skin conditions. It is important to further note that some foams are not closed cell and will, therefore, permit moisture, dirt, and bacterial buildup which may not be easily removed. However, coatings have been developed which may solve the interface cleansing problem. Additional considerations in the use of a liner coating are potential allergic reactions, alteration of friction and shock absorption charac-

teristics of the liner material, and adequacy of adherence.

Foam liners, it must be remembered, provide comfort by absorbing load forces of axial, shear, and torque. The shock of impact is absorbed in the compression of the foam or in the compression of the gases within the individual cellular structure of the foam. Any buildup of heat within a liner could lead to problems for the patient in an intimate suction fit.

In summary, soft foam liners are very practical from the point of view of comfort and the ability to adjust to maintain fit. Their major drawbacks are that they change shape with wear and they do get dirty and smell if not meticulously cleaned daily.

Three known types of silicone liners are presently in use or in experimentation at this time. Koniuk[21] reported fabricating cast silicone liners (Figure 16) which can be later duplicated from the same mold. There have been some problems with tearing of these liners in early phases of development, but this is viewed as a materials problem only. Early liners were fairly thick and heavy which can be detrimental. Some problems of skin reaction to direct contact with silicone have been reported. Since silicones are relatively inert, skin irritation most likely may be attributed to friction between the skin and the liner. It may actually be holding the skin too well. Some patients may also be allergic to the catalysts used in the preparation of the silicone elastomer.

Experiments with very thin laminated sheath-like silicone liners have been attempted with some positive initial results. However, adjustments are not possible because of the inability to cement to the material, a characteristic of the entire silicone group. Bedouin has reported using fills between the socket liner and the outer lamination as a means of reestablishing lost suction.

Kristinsson[8] has demonstrated a preformed silicone liner which either rolls on or is pulled on the residual limb. The effect is to create distension of the distal tissues. Some problems have been seen in initial demonstrations, among which are tearing of the liners during application, some discomfort by patients with a hairy limb, and heat build-up. It may be too early in the development of these direct-contact silicone liners to determine with fairness their ultimate practicality. It is certainly true that lack of adjustability will likely continue as a source of considerable concern.

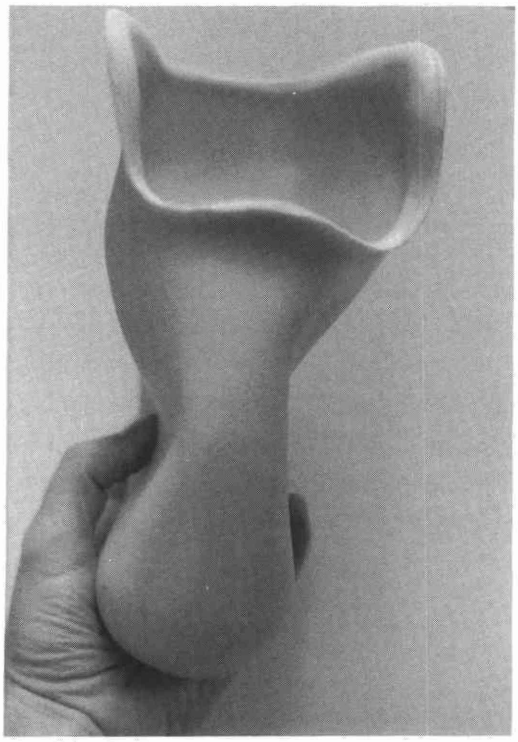

Figure 16. Silicone below-knee socket liner with expulsion valve installed.

A relatively new system, the PM Liner, developed by Peyton Massey[22] has been used as a suction below-knee liner. While proprietary in nature, it appears to be a vinyl-like foam which may be heated and formed with ease directly over the below-knee model. It has the comfort and padding of silicone but is much easier to work with and does not migrate as is the tendency with some silicone materials. Massey has been adapting this liner for use with adhesives so as to make it possible to glue patches of similar material to the PM Liner.

A new concept in liners under development, called the Socket Liner Stump Sock,[18] offers an additional variation for potential use with a suction below-knee prostheses. It is a neoprene sock that is fabric-backed on both sides. When properly fitted, it maintains suspension by compression. The problem with this variation

at present is that the smooth surface of the cloth outer face of the liner against the smooth inner socket surface does not provide sufficient friction to hold suspension. A coating is under development to resolve this problem. This liner offers an excellent compromise for the patient wishing to have an intimate TSB fit without complete suction. There is reportedly very little or no motion between the liner and the residual limb.

Suction Below-Knee Valves

Several specialized valves have been developed for the suction below-knee prosthesis although any valve can probably be used. An important feature in a valve for suction below-knee application is air expulsion capability. With such a valve, the patient simply forces his residual limb into the socket to expel the air through the distal end. Problems experienced with all valves have been accessibility and leakage brought on by inability to securely bond the valve seat to the liner.

Auxiliary Suspension

As has been previously emphasized, auxiliary suspension is mandatory on all suction below-knee prostheses. Sleeve type suspension offers the best compromise of comfort, security, and maintenance of suction. Cuff suspension in all forms has been tried, but cannot assist in sealing the socket to the residual limb. Three types of sleeves should be considered.

The Latex Sleeve

This provides the best seal and the most positive suspension, but has the problem of skin irritation, durability, odor, discoloration, and loss of shape.

The Neoprene Sleeves

These offer an acceptable seal that, while not as positive as the Latex, are acceptable so long as the sleeve has been properly manufactured. Neoprene sleeves are similar to Latex sleeves with respect to skin rashes and durability. Daily cleansing with alcohol can greatly reduce the incidence to skin problems. Providing the patient with multiple sleeves and proper hygienic education will reduce the incidence of skin rashes.

Cloth Lined Neoprene Sleeves

While these sleeves do not work well for total suspension, they can afford a margin of back-up for good suction wearers.

Some Suggestions for Skin Problems

For any serious rashes or other skin conditions, the patient should always be directed to his physician. A number of techniques have been tried by patients to clear up simple rashes. One technique is to wear a "Baggie®" or a thin polyethylene sheet directly against the skin of the residual limb until the rash clears. Some patients wear this inner protection at all times as a method of preventing rashes which might be caused by friction. When used with sock fittings, this will keep moisture out of the sock, thereby helping to prevent skin maceration. Some athletic patients apply transparent surgical tape over areas that are known to be prone to skin breakdown during heavy sports activities. Some brands that have been successfully used include 2nd Skin™, Op-Site, and Bioclusive Pads®.

Conclusion

The suction below-knee prosthesis, while an excellent option for some patients, may for others be the triumph of valor over reason. Should the decision be made to proceed with suction, both the prosthetist and patient must be completely aware of the long and difficult route involved. There will be obvious changes in the residual limb following initial fit which will require socket adjustment and refabrication over an extended period. There will probably be the need for some experimentation with materials and fabrication methods to arrive at an optimum fit for the patient. However, once these factors have been resolved, the results of a well-fit suction socket will be a marked improvement in patient comfort, satisfaction, and in a prosthesis that the patient "feels" is more a part of his person.

If, on the other hand, suction is not a goal, the Total Surface Bearing casting and modification techniques that support a suction fit are entirely valid for every below-knee fitting regardless of the socket interface or method of suspension. In the view of the authors, these

improvements over more traditional methods of below-knee prosthetics have been long overdue. Clearly, the superiority of Total Surface Bearing has been established and undoubtedly is the most important dividend of the research and education on suction below-knee fittings.

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