VARIANTS OF THE PTB (PATELLAR-TENDON-BEARING) BELOW-KNEE PROSTHESIS

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FOREWORD

The VA's Prosthetic and Sensory Aids Research Program was responsible for the development of the PTB (Patellar-Tendon-Bearing) Below-Knee Prosthesis in 1957. This prosthetic design has since enabled many amputees to have a less cumbersome artificial limb that provides improved comfort and control.

Further improvements have taken place since the PTB was first offered to clinicians. These innovations or new variants of the PTB, however, do not affect the basic principles underlying PTB fitting and alignment as first set forth by the University of California-Biomechanics Laboratory and later by the University Educational Centers. One of the new variations permits an improvement in the distal weight-bearing design for certain kinds of cases, while the others provide new suspension systems which might be employed.

The below-knee prosthesis is becoming more significant as a clinical tool, especially as a result of a desirable trend toward more conservative election of lower-extremity amputation sites for dysvascular cases. Moreover, such below-knee amputation levels should be more successful as a result of early and immediate postsurgical fitting of prostheses and the coordinate increase in attention and care associated with such regimens of treatment. Thus, information about the variants of the PTB so that these additional tools can be employed should be made available to clinicians.

Modifications in PTB design will probably continue to occur in the future. Our Service will strive to make this information available as soon as possible.

Clinical personnel should now become familiar with all present variations in the PTB design shown in this program guide. Our contractual program for the procurement of artificial limbs now requires commercial prosthetists to meet special qualification requirements before being authorized to fit these prostheses to VA beneficiaries. Correspondingly, clinicians involved in prescription, checkout, and training should have a sound understanding of the new designs. This
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program guide should contribute to such understanding. Clinicians are urged to refer to the references cited for additional insights.

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1. HISTORY OF THE PTB (PATELLAR-TENDON-BEARING) BELOW-KNEE PROSTHESIS

a. In 1957 the University of California-Biomechanics Laboratories in Berkeley and San Francisco, working under a prosthetics research and development contract with the VA's Prosthetic and Sensory Aids Service, held a symposium on below-knee prosthetics which resulted in a synthesis of the many concepts of prosthetic fitting then prevalent. The result was the PTB below-knee prosthesis (Fig. 1 and 2) described in a

FIGURE 1.—The Patellar-Tendon-Bearing Below-Knee Prosthesis with cuff suspension.

FIGURE 2.—A cutaway showing the original PTB socket with liner and cuff suspension.
b. Since that time and especially with the introduction of PTB instruction into the University Educational Program, information on the clinical employment of this concept of fitting has been disseminated and utilized throughout the world. Generally, clinics have had a great deal of success with their PTB fittings. The difficulties that have been experienced probably were caused by deviations from the original principles offered by the University of California. Mr. James Foort, one of the original participants in the development of the PTB, recently reviewed (3) the critical factors in PTB socket shaping and offered key points about the weight-bearing concepts, particularly the shape of the brim (Fig. 3). Clinicians should continually refer to this article to determine if some of the problems being experienced could not be solved by the points raised by Foort.

c. In the meantime, prosthetists were making other successful deviations, especially by elimination of the liner in the PTB. A soft custom-contoured distal pad was provided in these so-called “hard” PTB sockets (Fig. 4). A few prosthetists were having success with completely “hard” PTB sockets, without the soft distal pad. These successes seem to be
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directly related to the diligence and expertness of the prosthetist as well as to the suitability of the stump for general weight-bearing and total-contact pressures. It has often been said that the liner offers nothing more than a compensation for inaccurate fitting of the weight-bearing areas and improper relief of sensitive areas.

2. DESIGN CHANGES

a. Other groups, particularly in France and Germany as well as in the United States, were making changes based on dissatisfaction with the suspension mechanism offered in the original manual on the PTB. The cuff suspension, especially when improperly designed and fitted, not only offered restriction to knee rotation but could provide deleterious constriction. Woodall of the United States, Fajal in France, and later Kühn in Germany offered designs which extended the proximal brim of the PTB socket higher to provide suspension either around the condyles alone or around the condyles and over the patella to achieve advantages in improved suspensions and the elimination of constriction.

b. At about the same time, the University of California-Biomechanics Laboratory with Mr. Erik Lyquist of Copenhagen, Denmark (who was working at the Biomechanics Laboratory on a temporary assignment), developed a socket design to improve the weight-bearing features of the PTB. In some PTB fittings the distal portion of the PTB socket was not contoured properly to assure total contact and edema ensued. There was also difficulty in maintaining distal contact with minor stump volume changes. Moreover, skin damage in the distal portion of the PTB socket resulted from stretching the skin against the unyielding socket wall. To assure the attainment and maintenance of total contact and possibly to employ even higher pressures in the distal portion of the socket when feasible, the University of California developed the “Air-Cushion Socket” (Fig. 5). This design utilizes an elastic sleeve to enclose an air chamber providing pressures on the distal stump area.

c. Recognizing the work which had gone on throughout the world to vary some of the design aspects of the PTB socket, the Design and Development Subcommittee of National Research Council’s CPRD (Committee on Prosthetics Research and Development) authorized its Workshop Panel on Lower-Extremity Prosthetics Fitting to hold a Symposium in December 1968 to gather all the information on PTB variants so that they might be offered to the University Educational Programs and through the clinics to below-knee amputee patients who could benefit. As a result of this Symposium, a report (1) was published by CPRD and the University Educational Program developed a series of advanced below-knee prosthetics courses to upgrade prosthetics
A. B. Wilson, Jr., has summarized progress in prosthetics leading to the clinical availability of the new variants as well as other innovations in below-knee limb design (8).

3. THE TYPES OF VARIANTS

a. The new variants of the PTB are of two types: (a) the Air-Cushion Socket to improve distal pressure and weight-bearing control and (b) mechanisms for improvement in suspension.

b. Figure 6 (1) shows all of the present variations in PTB prosthesis design. Included are the regular "conventional" PTB, with a liner and a cuff suspension; the hard socket PTB, with or without distal pads; the new Air-Cushion variant; and the new and old variations possible for suspension and knee control.

c. These variants do not affect the fundamental principles of PTB fitting which should involve careful planning of the proximal weight-bearing areas of the below-knee stump and provision for total contact. Although the term "total contact" has not been applied to the PTB, it is designed as a total-contact socket to function in the same way as the above-knee ischial-gluteal quadrilateral total-contact socket (TCS).

d. The PTB with a hard socket and soft end will offer advantages to
the patient in that retention of fit will probably be maintained longer. A liner will deteriorate quite rapidly due to perspiration and will compress and take on a permanent set which may require modifications earlier than necessary. However, adjustments by the addition of pads are probably easier with a liner than with a hard socket, although hard sockets too can be adjusted by the addition of pads. This process involves more time.

e. The PTB without the liner will permit the employment of a porous socket wall when necessary (Fig. 7). Although porous sockets are not on VA contract, in certain cases for whom they are considered absolutely necessary due to severe perspiration problems and where the prosthetist has obtained the required skill, such sockets might be constructed on a noncontract basis.

f. Soft ends for PTB sockets are best done by foaming-in-place to assure total contact. Carving distal pads is not recommended because this method is not as error-proof as the foaming-in-place process.

4. PTB AIR-CUSHION SOCKET (A WEIGHT-BEARING VARIANT)

a. The PTB Air-Cushion Socket will assure adequate pressures on the distal portion of the stump, minimizing the risk of edema. The elastic sleeve which will displace longitudinally under weight bearing will tend to minimize abrasive skin damage which might occur with the stump in contact with a rigid socket wall.

b. The Air-Cushion Socket offers a possibility for higher distal load-
ing, when feasible. Increasing the distal pressure will decrease the need for the more constrictive proximal loading and thus benefit circulation. The higher distal pressure will maintain total contact with slight stump volume changes.

c. Because of construction and design, the Air-Cushion Socket involves a much more rigorous procedure. Moreover, modification of the fit of the distal sleeve, if necessary after fabrication, will be very difficult. Rapid stump shrinkage will even be accelerated with the higher distal pressures possible. Thus, there will be a major problem in maintaining proper fit. The Air-Cushion Socket will not generally be indicated as the first permanent socket for an amputee. Obesity and conditions such as neuroma which limit distal contact may also indicate the employment of the conventional PTB, with or without liner, instead of the Air-Cushion Socket. An excellent description of this socket design and the method for its construction are given by Wilson, Lyquist, and Radcliffe (9).

5. PTB SUSPENSION AND KNEE-CONTROL SYSTEMS

a. The cuff suspension strap (Fig. 1) of the original PTB, if properly designed and fitted, can still provide an adequate mechanism for suspension for many patients. This design, with the strap above the patella, may in certain cases cause difficulty either in not reducing piston action sufficiently or in restricting circulation (especially if the diagonal straps are not optimally located or if the patient tightens the circumferential cuff in an attempt to improve suspension). Often with short stumps the strap may be found to be inadequate, forcing the
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Clinic team to prescribe the sidebars and lacer suspension. Medial-lateral instability of the knee is a particular problem which may be solved with the use of the metal joints and thigh lacer.

b. For most cases, the PTB has allowed the elimination of the sidebar and lacer suspension with its restrictive effects. But, when below-knee stumps are not able to take full weight bearing, the use of a thigh lacer may be indicated to assist in that function. When used, the guidelines offered by Gardner and Clippinger (4) should be followed. However, in many cases with short stumps particularly and with instability of the knee, the new suspension variants of the PTB will have great clinical applicability. Included in these variants are the Supracondylar system and the Supracondylar/Suprapatellar system.

6. THE NEW SUSPENSION VARIANTS

a. The Supracondylar suspension system employs high medial and lateral socket walls to encompass fully the medial and lateral aspects of the femoral condyles. If these proximal extensions were flexible enough, one could easily don the prosthesis by expanding them and then allowing them to retract over the condyles. Since the laminate used in the socket walls is generally not that flexible and no liner is normally used in the socket, the Supracondylar suspension of the PTB now being introduced uses a prefabricated wedge of a flexible material which can be inserted between the socket and the medial condyle to obtain a locking fit over that condyle (Fig. 8 and 9). The wedge has to be carefully fitted with special attention given to the construction of

![Figure 8](image1.png)
**Figure 8.** The PTB socket, with Supracondylar suspension, employing a medial wedge.

![Figure 9](image2.png)
**Figure 9.** Photograph of the wedge and socket of the Supracondylar PTB limb.
its seat in the medial socket wall. Properly fitted over the condyle, the wedge provides very adequate suspension. The amputee removes his prosthesis by first removing the wedge and puts the wedge back in after donning the limb. With this type of suspension, there is probably less restriction to knee flexion in comparison to the circumferential strap, and medial-lateral stabilization of the knee is provided. Significant in the fitting of this device is the care that must be taken in the medial-lateral dimensioning over the condyles.

b. A description of the Supracondylar suspension is given by Fillauer (2). This design has sometimes been called the condylar clip, the KBM, or the STP, but terminology recommended will be addition of the letters SC (for Supracondylar) to the PTB, such as PTB-SC. Figure 10 presents the recommended abbreviated terminology for this and other variants.

c. Another variant, sometimes called the PTS but preferably the PTB-SC/SP (Supracondylar/Suprapatellar PTB), employs high medial-lateral walls to encompass the condyles as well as a high anterior wall coming up and over the patella, as described by Marschall and Nitschke (6). This suspension (Fig. 11) was also designed to eliminate the cuff suspension strap and, normally, is used with a liner unlike the Supracondylar design described above. The compressibility of the liner al-
lows the stump to pass the close-fitting proximal brim and achieve full entry into the socket. The anterior brim line is brought into direct contact with the quadriceps tendon with a properly designed flare. The anterior fitting provides a main support function.

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d. For certain cases the SC/SP design can be fitted without the liner, but then wedges need to be employed to permit entry and removal of the socket, as suggested by Marschall and Nitschke (7). The high walls of this type of socket may take some of the weight bearing in the knee region thus decreasing the loading required in the regular weight-bearing areas.

e. The PTB-SC/SP also provides medial-lateral stabilization of the knee as well as a stabilization in the sagittal plane especially at pushoff and will reduce any tendency of the knee to go into hyperextension. The socket offers an improved suspension but is obviously more difficult to fit than a conventional PTB. The proximal brim appears somewhat bulky and in some cases may restrict extreme flexion as would be required in kneeling. The SC/SP does offer a variant of the PTB that may be employed for short stumps, particularly where the anatomical knees are unstable. Hamontree, Tyo, and Smith (5) indicate on the basis of 97 fittings the success that can be achieved with this design for cases they normally could not have fitted with PTB.

Figure 11.—The PTB socket with a Supracondylar/Suprapatellar suspension.
7. CLINICAL EMPLOYMENT OF THE PTB VARIANTS; PRESCRIPTION GUIDES

a. There is the possibility of combined variants, for example, by altering the design for weight bearing in the distal socket through the use of an air cushion plus a suspension variant such as an SC wedge or the SC/SP system. Figure 10, a summary of the terminology of the presently used PTB variants, shows combined variants using the Air-Cushion Socket.

b. The abbreviated terminology shown in Figure 10 is recommended. The system is based on specification of the weight-bearing system, PTB, followed by parenthetical designation of the weight-bearing variant such as (AC), (lined), (hard), or (soft). A dash (−) is followed by the designation of the Suspension variant such as cuff, thigh, lacer, SC, or SC/SP.

c. Figure 12 gives some of the guidelines for employment of all the PTB variants. However, for the present, VA is recommending the use of only those shown in the Decentralized Schedule Artificial Limbs, presented in Solicitation No. RFP3-70, October 1, 1969, as modified by Amendment No. 1, issued October 14, 1969. Those variants presently not included are the Air-Cushion Sockets combined with Supracondylar or Supracondylar/Suprapatellar suspension. Until more experience is gained with each individual new variant, the use of the combined variants is not recommended, nor is the use of PTB-lined sockets with Supracondylar suspensions recommended because of the bulkiness that will result. This design, PTB (lined)—SC, has therefore not been included in Figures 10 or 12.

8. CHECKOUT

a. Careful checkout of the below-knee PTB socket must be made to determine the adequacy of the suspension and weight-bearing features, especially in the patellar-tendon area, and the existence of total contact. Checkouts are required at the time of delivery and periodically at later dates to insure maintenance of the intimate socket-to-stump fit.

b. At all times, normal stump examination procedures are followed plus the checkout of the patient and prosthesis during standing, walking, and sitting.

c. For all below-knee PTB (total-contact) sockets, the following weight-bearing checks should be included:

1. Inspect stump sock ply and fit.

   Desired: If stump shrinkage is anticipated the stump sock should be of lightweight (3 ply) cotton or wool (initially, the prosthetist should consider this). If stump is mature, a 5-ply wool sock is indicated. For PTB limbs without thigh corsets, the sock
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**GUIDELINES FOR CLINICAL EMPLOYMENT OF PTB VARIANTS AS COMPARED TO PTB CONVENTIONAL WITH LINER AND CUFF.**

<table>
<thead>
<tr>
<th>Variant</th>
<th>Liner Will Compress; Joint Abnormalities with Perspiration; Easiest to Modify</th>
<th>Liner Will Compress; Leather Distempering with Perspiration; Easiest to Modify</th>
<th>Liner Will Compress; Leather Distempering with Perspiration; Easiest to Modify; Some Pat. Can Be Taken On Latch</th>
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<tr>
<td>Conv. PTB (Lined)- Cuff</td>
<td>Very Good; May Limit Knee Flexion; May Limit Knee Flexion; May Limit Knee Flexion; May Not Prevent Piston Action</td>
<td>Very Good; May Limit Knee Flexion; May Limit Knee Flexion; May Limit Knee Flexion; May Not Prevent Piston Action</td>
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<td>PTB (Soft)- Cuff</td>
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<tr>
<td>PT (Ac)- Cuff</td>
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<tr>
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**Figure 12**
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should be long enough to fit at least 3 in. above the patient's knee. The sock used with a thigh corset limb must be long enough to allow it to be turned down over the superior edge of the corset. The toe size of the sock should permit a snug wrinkle-free fit over the end of the stump.

2) Place talcum or a small ball of clay in the socket bottom. Have the patient walk for several minutes. After he has removed the socket, examine the distal socket chamber and stump carefully. Desired: Powdered surface erased by stump sock or ball of clay flattened to demonstrate total contact. Even stump sock imprints over the entire surface of the stump to show uniform pressure distribution.

3) Obtain subjective weight-bearing information from patient while walking.
   (a) Location of Painful Pressure, If Any.
      Desired: No excessive pressure at any time.
   (b) Weight-Bearing Distribution.
      Desired: Patient should express a sensation of more weight in and about the knee rather than on the stump end.
   (c) Stump Circulation Aspects.
      Desired: No constriction at the top of the socket or above (when standing). No constriction in the popliteal space while sitting. Entire stump of same temperature with minimal perspiration.

4) Immediately after the patient stops walking, remove the prosthesis and check for abrasions and edema. Desired: Warm, dry stump with no discoloration.

d. While the patient walks, inadequacies of suspension and control are most obvious.

1) For cuff-suspension-type PTB’s check:
   Does the suspension cuff hold the stump firmly in place during both swing and stance?
   Desired: Does not permit piston action while walking. Does not cause constriction above the knee while sitting. Does not inhibit knee motion.

2) For the PTB-type prosthesis with thigh lacer, check:
   (a) Is there excessive piston action of the stump in the socket?
      Desired: Minimal or no piston action while walking.
   (b) Does the weight-bearing shelf in the anterior portion of the PTB Socket rub against the tibial crest due to piston action?
      Desired: No indication of skin irritation over the tibial crest. If there is much piston action, the weight-bearing shelf may have to be reduced.
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(c) Are the knee joints properly located, and does the thigh lacer fit properly?

*Desired:* The prosthetic knee joints should be positioned to minimize any conflict of motion between the anatomical and artificial knee joints during full flexion and extension. The upper bars and corset should conform closely to the contour of the thigh with the anterior-inferior border approximately 1½ in. above the patella. The posterior cutout should be large enough to prevent constriction behind the knee while sitting.

(3) *In addition* to the checks made for PTB-cuff suspensions, sockets designed with PTB-SC or wedge suspensions require the following checks:

**Proper Size, Placement, and Fit of the Wedge.**

*Desired:* The wedge must be large enough to fit over the apex of the medial femoral condyle. Sufficient space must be available posteriorly for movement of the condyle in that direction during knee flexion. Upper socket structure must be rigid with a proximal lip medially to hold the wedge in place. Full freedom of knee motion must be available.

(4) *In addition* to the checks described for PTB-cuff and PTB-SC suspension, further consideration will be given to PTB prostheses with SC/SP suspension:

**Contour and Fit of the Upper Socket Borders.**

*Desired:* The medial and lateral socket walls terminate above the condyles and conform to their contours. The anterior wall rises above the patella and is reflected out to permit almost full knee motion with only minor restraint to full extension.

(5) PTB-SC and PTB-SC/SP suspensions must allow easy entry and removal of the stump while maintaining positive suspension and control. Supplementary suspension straps are sometimes used while the patient is learning to use a corsetless prosthesis. The straps are suspended from a waistbelt and should not encircle the thighs.

**Changes in Stump Size.**

*Desired:* Frequent followup will reveal the need for modifications to the combination weight support structure and suspension-control mechanism. Any such examination should provide a record of changes in size and in vascularity with all other information which might affect prosthetic fit and function.
REFERENCES


