A Patellar-Tendon-Bearing Socket With A Detachable Medial Brim

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Following our initial exposure to the German idea of supracondylar suspension of BK Prostheses (1), we have fitted a large number of amputees; first, with custom-made wedges, then with a standardized set of three which evolved eventually into a selection of eight sizes. The experiences of these four years have resulted not only in some minor changes in the initial concept of the wedge, per se, but also in casting and fabrication techniques. Sockets with and without sponge rubber (Kemblo) liners can use the wedge principle equally well. Fortunately, a liner is not required for successful application of the wedge system of suspension.

The introduction of the detachable wedge (Fig. 1) should not be considered a refutation of any claims previously made for the supracondylar wedge suspension. The hundreds of successful fittings that have been carried out to date testify to the soundness of this approach, and it is anticipated that the plastisol wedges, as such, will

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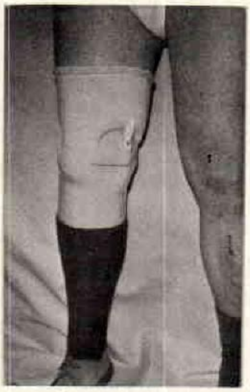

Fig. 1

Antero-medial view of a patellar-tendon-bearing socket with a detachable medial brim.

continue to be used for the forseeable future.

However, donning problems in cases where patients have extreme discrepancies between the mediolateral dimensions at the supracondylar (A) and epicondylar (B) levels, usually in the range of 1⅛ inches to 1⅜ inches (Fig. 2), prompted the search for a new approach. In the past these unusual cases were accommodated in a fashion by wedges of extra thickness, but not always successfully.

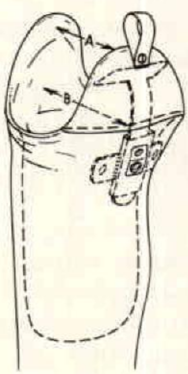

Fig. 2

Some details of the detachable medial brim.

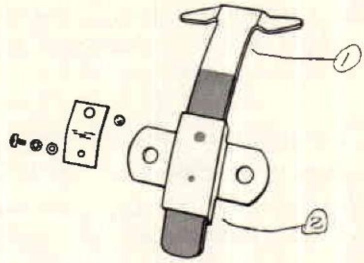

Fig. 3

Hardware required for the detachable medial brim.

It seemed logical that if the medial wall above the epicondylar level could be made so that it could be detached and replaced easily, donning would be simplified. The thickness of the proximal-medial brim then could be quite thin, ⅜-½ inch resulting in less bulk than when a Kemblo or some other removable liner is used.

The design we advocate is a PTB supracondylar socket with provisions for separation of the medial brim from the socket at the epicondylar level (the widest part of the knee, usually about midpatella level). Upon replacement of the medial section, the socket is intact without interference or influence from the related hardware.

The hardware necessary (Fig. 3) consists of an upper, Teflon coated, stainless steel bar formed to match the convexity of the medial tibial condyle and a lower unit which consists of a flanged retangular steel channel formed with a radius to match the upper bar. Included with the channel is a spring-ball assembly for retention of the upper bar.

Both units, fitted together, are sandwiched into the center of the lamination of the socket at a level so that the proximal edge of the channel will be ¼ inch below the line where the cut in the socket will be made.

Anatomical Considerations in Supra-Condylar Suspension

The use of the supracondylar areas of the knee for suspension of the PTB type prosthesis has received considerable impetus since its introduction to clinical use via the wedge and the PTS prostheses. When these techniques are used, suspension and comfort depend upon the correct positioning of the contact area, or wedge, in the proximal socket in relation to the surface of the medial femoral condyle and upon the forming of the socket to obtain counter pressure from an area above the lateral femoral condyle.

The medial femoral condyle is more prominent than the lateral, its most prominent part being the epicondyle. The *adductor tubercle* forms the uppermost part of the condyle, and is the insertion point for the *adductor magnus muscle.*

On the posterior aspect of the femur the medial lip of the linea aspera extended to the adductor tubercle forms the medial supracondylar line.

Above the lateral condyle is the origin for the lateral head of the gastrocnemius muscle. Below this point close to the articular surface is the origin and groove for the tendon of the popliteus muscle. On the posterior aspect of the femur there is a continuous, well defined line from the lateral lip of the linea aspera to the lateral condyle known as the lateral supracondylar line. The space between these two ridges is the popliteal surface.

The surfaces of the lateral and medial condyles are not parallel but form an oblique angle somewhat in the shape of a segment of a concave cone. These angles are not completely reflected on the outer surface of the knee but are reduced by muscles and tendinous fibers attached to the femur and the condyles.

On the medial aspect of the femur, anteriorly and just superior to the condyle, the vastus medialis muscle reduces the effective angle considerably. The sartorius crosses the medial femoral condyle and inclines forward to be inserted into the upper part of the medial surface of the shaft of the tibia, above and in front of the insertions of the gracilis and the semitendinosus. Posteriorly on the condyle the adductor magnus tendon attaches to the adductor tubercle. The gracilis, semitendinous, and semimembranous tendons cross this area to their insertions on the postero-medial surface of the tibia.

The *iliotibial band* is dominant on the lateral surface of the femoral condyle extending from the tubercle of the iliac crest to the lateral condyle of the tibia and the capsule of the knee joint. The lateral ligament of the knee is attached to the lateral epicondyle of the femur and attaches to the head of the fibula.

The undercut proximal lip of the medial wall of the socket must be positioned rather accurately over the proximal aspect of the medial femoral condyle. When the lip is positioned too far distally, constant pressure between the lip of the socket and the medial femoral condyle produces pain. When the knee is flexed, excessive pressure is produced between the anterior lip of the brim and the anterior medial aspect of the condyle. When the knee is extended fully the posteromedial lip of the brim tends to produce pressure in the area of the adductor tubercle.

Hard Socket

When well-fitted, rigid, non-yielding, medial and lateral walls are provided, very little piston action can take place within a below-knee socket. Some practitioners feel that soft supracondylar pads or yielding lateral and medial walls provide more comfort, but this is not consistent with the experience many have had with "hard" sockets, where interface pressures in other areas of the socket are much higher than those required for suspension. Our experience over the past 5 to 10 years in fitting hard sockets has consistently supported the position that the inclusion of soft liners contribute a negligible amount to comfort of the amputee. Perhaps an ill fitting socket is less uncomfortable with a soft liner, but the real problems remain unsolved. We feel that the average below-knee stump is provided with adequate natural padding by the soft tissues. Other factors such as cosmesis and financial costs, both short and long term, overwhelmingly favor the clean, maintenance-free hard socket.

M-L Dimension

Regardless of the stump-casting procedures used, it is important that an impression of the supracondylar area of the knee in a narrowed state must be obtained. Our experience has shown that even though the reduced M-L dimension may appear severe, no more than a comfortable reduction is required. When the patient stands in the prosthesis, he should not have the conscious feeling of a tight grip, but rather a feeling of snug contact between the socket and the soft tissues immediately above the epicondyles.

Success in the proper shaping of the medial wall is related to casting and formation of the area over and proximal to the condyles.

Casting Theory

For checking the male mold during modification certain measurements of the stump and condylar areas of the femur are required. The M-L diameters of the femoral epicondyles and of the supracondylar thigh are determined with calipers. The supracondylar M-L dimension of the thigh is measured with either a modified Ritz stick or a combination square with two heads.

The casting procedure we advocate now was developed independently of the change over to the new supracondylar suspension design. As a result of several problems that we encountered, it became obvious that conventional plaster wrapping procedures failed to provide an accurate reproduction of the critical areas of the stump. We contend that circumferential wrapping tends to "round" the usual triangular cross-section of the stump, and at the same time displaces soft tissues to the weight-bearing areas. More specifically, the M-L dimensions of the stump are increased as much ⅜ inch depending on the density of the soft tissues. Other casting techniques, such as pouring plaster around the stump, and the use of negative and positive pressure bags, create distortion.

Before describing the new technique we would like to establish a few basic points we consider essential to acceptable fitting of a BK stump. Let us think of the BK stump in terms of its anterior and posterior halves. The major weight-bearing areas are in the anterior half. Intimate contact medio-laterally is critical for comfortable weight-bearing and stability against lateral forces. The bony structure is almost completely in the anterior half of the stump. Bony prominences in this area such as, crest of the tibia, the lateral tibial prominence, the tibial tubercle and the head of the fibula, require accurate reproduction and a sculptured shape in the socket as they are not tolerant to high pressures. Finally, and not least in importance, is the necessity to copy the true shape of the anterior distal tibia, because it is uniform socket contact, not an exaggerated relief cavity, that provides comfort in this area.

The posterior half contains the bulk of the soft tissues, where volume changes occur and contours generally are less critical. Other than at the proximal margin the A-P dimensions are not related to skeletal size and shape.

In summary it seems that the major objectives of a casting technique for the below-knee socket are to capture (a) the M-L skeletal outlines and bony prominences of the anterior half (b) the A-P dimension at the level of the tibial tubercle and (c) the soft tissue volume of the posterior half. Heretofore, efforts to obtain a reduced A-P dimension in the wrap usually result in distortion of the M-L dimension at the level of the tibial tubercle.

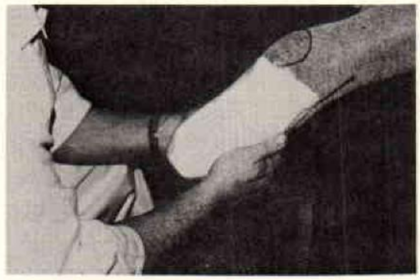

Fig. 4

Step one of the casting procedure: Formation of the pre-tibial shell.

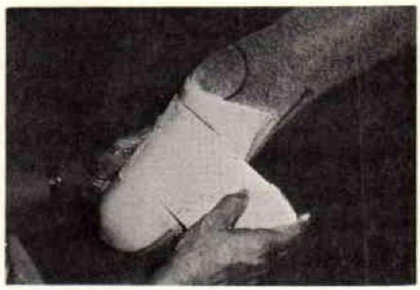

Fig. 5

Step two of the casting procedure: Application of the circumferential wrap below the level of the patella.

A two-step procedure is recommended when cuff-suspension is to be used; a three-step procedure, when supracondylar suspension is to be used. The three-step procedure is described here.

The three-step casting technique consists of forming a rigid splint cast of the critical, bony anterior half of the stump (Fig. 4), a circumferential wrap below the patellar (Fig. 5), and splint casting of

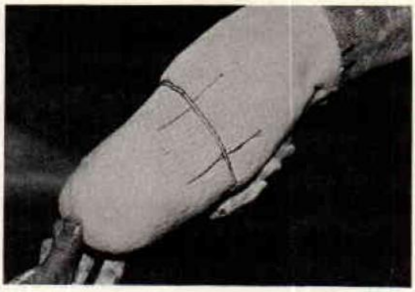

Fig. 6

Step three of the casting procedure: Application of the supracondylar shell.

the anterior, medial and lateral supracondylar areas (Fig. 6).

Given a model which presents a reliable reproduction of the weight tolerant areas of the stump, the prosthetist will find that the preparation of the model will be simplified. No longer will gross reductions of plaster be required to obtain medio-lateral weight-bearing and lateral support along the shaft of the fibula.

The key steps in the procedure for measuring and cast taking and steps for lamination of the socket and placement of the hardware follow. A list of supplies needed is given in Appendix A.

Casting Procedure

1. Measure and record the M-L diameter of knee at the widest point (Epicondylar Level).

2. Measure and record the M-L diameter immediately above the condyles (Supracondylar Level).

3. Apply a loose fitting double layer of tubegauze, #5 or #78, over the stump up to the middle of the thigh. A soft, elastic waist belt should hold the tubegauze lightly in place so that contact between the tubegauze and the stump in the undercut area is maintained.

4. Define on the stump with an indelible pencil the median line between the anterior and posterior halves, and other conventional marks.

5. Make a paper pattern of the anterior half of the stump below the distal edge of the patella.

6. Cut out simultaneously 8 or 9 layers of 8 inch wide, fast-setting plaster bandage to the pattern of the anterior half.

7. Dip all layers of plaster as one unit in tepid water.

8. Lay plaster as a unit over the anterior portion of the stump.

9. Smooth out all wrinkles, stroking the plaster from anterior to posterior. Light thumb impressions should be made on each side of patella tendon.

10. Allow the plaster to set until hard (about 10 minutes).

11. Starting proximally, wrap circumferentially with elastic plaster bandage all of the stump below the distal patella level.

12. Narrow the A-P dimension by flattening the posterior wall using conventional finger pressure. The M-L dimension will not spread because of the anterior splint.

13. On the tubegauze, mark a line anteriorly 1 inch proximal to the superior edge of patella. Outline with longitudinal marks the adductor magnus tendon medially and the iliotibial tract laterally.

14. Measure off a sufficient length of 6-inch wide, regular fast-setting plaster bandage to cover me-

dial, anterior, and lateral areas of knee. Make an 8- or 9-layer splint of this length.

15. Lubricate the proximal third of the previously made wrap with oil or petrolatum. Avoid getting the lubricant on the tubegauze.

16. Dip all layers of the plaster splint as one unit in tepid water.

17. Drape plaster over the knee. Be sure to cover the area to a point 1 inch proximal to the patella.

18. When plaster begins to set, form the M-L, supracondylar area with firm pressure. Place both thumbs on the medial side, straddling the adductor tendon. Then place second and ring fingers above lateral condyles straddling the iliotibial tract. (For left BK the right hand is anterior, the left hand is posterior; vice-versa for right BK).

19. Determine the M-L dimension by making a mark medially on the plaster in the area between the thumb impressions and then measure the distance from one to the other with outside calipers.

20. Make indelible marks across the proximal knee-plaster section and the stump-plaster section.

21. Loosen knee-plaster section from stump-plaster and remove both from the stump as a single unit. No cutting is necessary.

22. Replace the knee-plaster section to the lower stump section and check the M-L dimension with outside calipers. Close the posterior opening with several plaster splints while maintaining the recorded M-L dimension from step 19.

Model Rectification and Lamination of the Socket

1. Make the plaster model hollow to facilitate breakout.

2. Smooth the surface of the model to remove irregularities and marks caused by the sock.

3. Supracondylar M-L dimension of the model should correspond to the patient's measurements. Plaster is removed from the medial side unless more than ¼ inch is to be cut away, in which case the extra amount should be cut from the lateral side.

4. Maintain the epicondylar M-L dimension of the model ⅛ to ¼ inch more than the stump dimensions.

5. Form the patellar-tendon bar in the same manner as is normally used for the standard PTB hard socket.

6. For mature stumps, only a slight reduction of model size is required to produce a snug fit with one stump sock. In other situations where edema or excessive soft or hypermobile tissue is present, ¼ to ⅜ inch reduction in circumferences may be required in order to obtain an acceptable fit with one stump sock.

7. A minimum amount of spotting or build-up should be applied to the distal anterior tibia, head of fibula, and lateral tibial prominence for pressure relief.

8. A posterior popliteal shelf ½-⅝ inch thick, at the mid-level of the patella tendon is added to the posterior wall.

9. Drill vacuum holes in the popliteal area, in the mid-level area of the patella tendon, and in the supracondylar areas.

10. Apply a parting agent.

11. Fit a distal pad to the size of the distal stump.

12. Apply petrolatum.

13. Pull a PVA (polyvinyl alcohol) sleeve over the model.

14. Heat and insert the distal pad in the PVA sleeve. Form the pad to the distal stump contour by tying off the sleeve close to the model.

15. Apply a layup consisting of:

a. Two ½ oz. Dacron sleeves.

b. Extra padding in popliteal, patella tendon, and medial and lateral supracondylar areas.

c. Two nylon stockinette sleeves.

d. Four short nylon stockinette sleeves above the MPT.

e. On the medial side sandwich the bar and channel between the short sleeves, being sure to:

(1) Wrap upper third of bar with Dacron.

(2) Place T (on end of bar) in supracondylar depression. N.B. The proximal ⅓ or the bar may require shaping to fit closely the model, but under no circumstances should the distal ⅔ of the bar be altered from its preformed radius.

(3) Position top of channel ¼ inch below the mid-patella level, or large M-L diameter of the knee. Replace the spring-and-ball assembly with the laminating block.

(4) Add Dacron felt to blend the channel to the socket wall.

f. Three pieces of glass fabric 2 inches x 3 inches on the proximal area of the lateral side.

g. Two or three nylon stockinette sleeves over all.

h. Add outer PVA sleeve, apply vacuum, puncture inner sleeve, and tie off around pipe.

16. Use an 80-20 rigid-flexible polyester resin mixture; 400 grams for short to medium stumps, 500 grams for medium to long stumps, and 600 grams for long and large stumps.

17. Before pouring the resin, insure that the bar-channel assembly is at the proper height, is parallel to the long axis of the stump, and is on the mid-line of medial side.

18. After the resin is cured and partially cooled, trim and remove excess laminated material in the proximal area. Then expose the laminating block over the channel, and remove it.

19. After the laminate is cooled further, make the horizontal cut in the medial wall with a cast saw. The best level is usually at the widest diameter of the knee, about mid patella level. The inner socket cannot be cut through until the plaster model has been removed from the socket.

APPENDIX A

SUPPLIES AND TOOLS NEEDED FOR THREE-STAGE CASTING OF BK STUMPS

- Measurement Chart
- Tubegauze #5 (#78 if stump is extra large)
- Elastic strap, 1 inch, light
- Yates Clamp, 2 each
- BK stump length gauge
- Pattern paper
- Indelible pencil
- Yardstick
- Bandage scissors
- 1 roll, 8″ fast-setting plaster-of-Paris bandage
- 1 roll, 6″ fast-setting plaster-of-Paris bandage
- 1 roll, 3″ or 4″ elastic plaster-of-Paris bandage
- Lubricating oil (Nivea) or petrolatum
- Outside diameter calipers
- Tape measure

References

1. Fillauer, Carlton, *Supracondylar wedge suspension of the PTB prosthesis,* Orthotics and Prosthetics, June 1968.