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Non Ischial Weight Bearing Soft Socket Design

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INTRODUCTION

The criteria used for fitting the above knee socket seems somewhat ingrained into the prosthetic community. The rationale of socket design taught by most institutes of education has been regarded as the critique and guideline for above knee prosthetics. This article's intent is not to disregard the "Berkeley" quadrilateral socket design as inadequate—a good number of amputees are ambulating comfortably on limbs using its principles—yet a closer evaluation of the criteria appears warranted due to the very nature of some of the socket's shape requirements.

CONSIDERATIONS

The medial two-thirds of the anterior wall is the area of the Scarpa's or femoral triangle. Anatomically, the femoral artery, nerve, and vein are located in this area. It presents itself as a pressure sensitive area to which as little localized pressure as possible should be applied. On close examination of a "Berkeley" quadrilateral socket, bivalved through the Scarpa's triangle, it becomes apparent that the socket is becoming choked at a progressive rate from the zero to four inch level below the height of the ischium. This suggests that the excessive pressure and tapering of the brim over major blood flow areas may be a contributing factor to muscle fatigue and distal edema problems (Figures 1 and 2).

Moving laterally on the anterior wall, the socket expands to the rectus femorus channel. When reviewing the characteristics of the rectus femorus, it is a site of high activity during ambulation and, more importantly, the muscle changes shape and position during contraction. Keying the muscle into a channel provides an area for the muscle to work against, aiding in muscle fatigue and poor gait habits. The point to note is that as active as the muscle is, and as radical as its change in shape and position, the volume of the muscle remains constant at all times.

On evaluating the posterior wall design, the basic premise of the Berkeley socket has been "the ischial tuberosity can tolerate total weight bearing, therefore the ischial tuberosity must bear total weight." This one stipulation in itself tends to explain other socket requirements and inefficiencies experienced during socket fit. With the ischial tuberosity posteriorly positioned, both the sciatic nerve and hamstring tendon are bowed sharply over the posterior brim. This tends to cause a slight burning

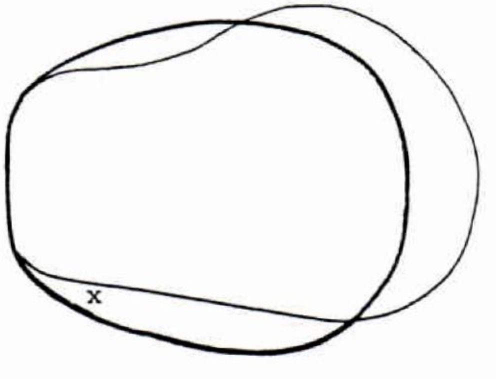

Figure 1. Overlay of the Berkeley ischial weight bearing quadrilateral socket and IPOS soft socket design. The Berkeley shape has a 3" AP, 6" ML dimension with a 46 cm. circumference. The IPOS soft socket design has a 46 cm. circumference with AP and ML as dictated by the casting brim. The sizing ratio of these brims have been calculated on a basis of average residual limb size, therefore, 85 to 90% of patients can be provided a secure fit without significant modification to the brim or positive mold. The "X" indicates the preferred location of the ischial tuberosity for both sockets.

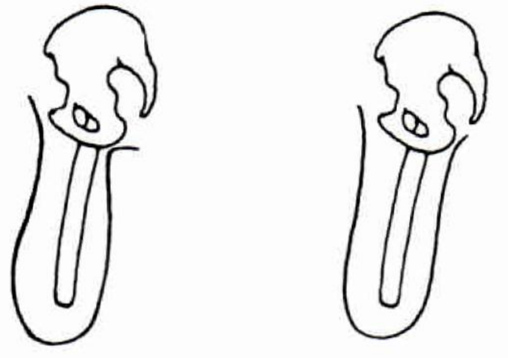

Figure 2. Socket shape of Berkeley quadrilateral ischial weight bearing socket (left) and IPOS soft socket (right) while bivalved on a sagittal plane at the ischial tuberosity and apex of the Scarpa's triangle with relation to skeletal positioning.

sensation and leads to muscle fatigue. With ischial weight bearing, the necessity of total contact along the femur to maintain lateral stability and an adduction angle is self-evident. This rationale presents itself as a basic cause and effect. If the ischial tuberosity wasn't positioned firmly on a pivot point (the posterior shelf) the femur would not be pushed laterally to such an extreme degree.

With respect to maintaining adduction angle, anatomically, the majority of hip adductors originate in the pubic region and insert in the upper half of the femur with some inserting at the trochanteric region. This tends to suggest that maintenance of the proper adduction angle can be maintained at a more proximal level along the femur.

When assessing the degree of muscle activity at the ischial level in a Berkeley socket, the levels of output can be listed: anterior, posterior, medial, and lateral quadrants, in order of diminishing activity. The highest levels of natural muscle activity during walking take place on the anterior and posterior aspect of the brim, yet this is the area that displays the greatest amount of compression in a Berkeley brim. To further complicate the fitting process of a suction total contact socket, a series of reduction tables was devised in order to apply a varying degree of tension on the tissue. It appears somewhat inappropriate to radically modify any cast taken from a patient; if the plaster negative fit the patient well and maintained a comfortable fit, why change it?

Upon evaluation of the criteria for the Berkeley quadrilateral socket, it seems that the entire casting, cast modification, and fitting rationale revolve around the fact that ischial weight bearing is essential in order to maintain proper socket fit and prosthetic gait. However, ischial weight bearing may often be the cause and catalyst of the majority of socket comfort and gait inadequacies. Thus, an alternative socket shape seems appropriate in an attempt to provide the amputee with a comfortable, functional prosthesis. A significant development in above knee fitting has been the progression of the Active Shaft[1] or flexible socket. The subsequent adoption of this system by the North American prosthetic community is rapidly increasing, yet with varying levels of success. A possible explanation for this may be the fact that the outer carbon acrylic frame and flexible socket have been successfully applied, but no regard appears to have been paid to possibly the most important factor of the flexible socket, the shape and resultant tissue containment.

It is unfortunate that this critical point appears lost in the translation of literature from Europe to the United States. This factor perhaps explains difficulties experienced in North America and not in Europe. One disadvantage of the flexible socket has been stress fractures and socket cracking, an occurrence noticed here but not commonly experienced in Europe, which tends to suggest that socket design with radical channels and corners with excessive tension on active muscles aid in this plastic failure. Also, lateral instability is a common occurrence, caused by ischial weight bearing, insufficient medio-lateral contact, and flexible counter pressure along the femoral shaft. This is a problem not experienced with European socket design.

In developing and designing a functional socket shape, the residual limb and its demands were reevaluated to determine the goals and considerations for a socket.

These considerations for the socket include:

- the ability to accommodate the highest degree of muscle activity possible
- allowance for easy donning and doffing
- no impairment of blood flow
- no excessive pressure on bony landmarks
- constant uniform tension on the limb
- accurate casting method
- consideration for structural strength of the socket
- maintenance of the ischial tuberosity inside the socket

Each wall of the socket requires specific demands to provide a well fitting prosthesis with a stable gait. The following criteria will provide an excellent foundation for a functional flexible socket.

A SOFT SOCKET DESIGN

This socket design, though designed for a flexible interface, will increase muscle activity and circulation, decrease muscle fatigue, and benefit in patient comfort when used with a laminated rigid socket. In addition, during early development stages, ischial weight bearing was integrated into this socket design and found to provide superior comfort and gait over the Berkeley quadrilateral ischial weight bearing socket shapes. The ischial weight bearing design is referred to as the "Hard Socket Design."

THE ANTERIOR WALL

Anatomical Considerations

—Adductor longus
—Sartorius
—Rectus femoris
—Tensor facia lata
—Femoral artery
—Femoral nerve
—Femoral vein
—Pubic tubercle
—Inguinal ligament

Criteria

- The region over the medial ⅔ of the anterior wall contains the femoral triangle (the femoral nerve, vein, and artery). This area should provide uniform tension without excessive socket grooves or bulges.
- The medial and lateral border of the femoral triangle are the adductor longus and sartorius muscles, both highly active during the walking cycle. Uniform tension without restrictive socket shape should be applied at these points.

[1]Registered: 1976 in West Germany by IPOS K.G.

- The inguinal ligament borders the proximal border of the triangle. During sitting this ligament provides a natural crease between the anterior superior illiac spine and the pubic tubercle. Care should be taken to shape the brim along this landmark and not to exceed proximally past it.
- The rectus femorus and tensor facia latae accommodate the lateral third of the anterior wall. This is perhaps the region of the highest level of muscle activity in regard to the muscles changing shape and position during walking. This area should be uniform in shape and consistency without any restrictive angles or channels for the muscles to work against.

POSTERIOR WALL

Anatomical Considerations

—Ischial tuberosity
—Hamstring group
—Gluteus maximus

Posterior Wall Criteria

- The ischial tuberosity should be maintained inside the socket, and located against the posterior radius of the brim. By maintaining the ischial tuberosity against the socket wall, it makes a good reference point to ensure proper socket fit. This allows for unimpeded muscle activity and blood flow, and allows the ischium to accommodate normal sensation during sitting.
- The gluteal shelf should remain uniform with the gluteal fold, cupping about the posterior lateral corner and maintaining uniform tension.
- The shelf should be rolled to allow for a smooth transition between the brim and posterior wall.
- The relationship between the lateral wall and posterior brim should remain constant with the degree of residual limb adduction.
- The angle between the medial and posterior wall should correspond to the negative impression of the amputee's limb.

MEDIAL WALL

Anatomical Considerations

—Pubis
—Adductor longus
—Adductor magnus
—Gracilis
—Hamstrings tendon

Medial Wall Criteria

- This wall should be made relatively flat so as not to interfere with the sound limb.
- The brim should be sloping distally from the posterior shelf to give room for the pubis and to aid in function and relief for the adductor longus.
- The anterior medial corner should have a smooth radius allowing room for the adductus longus tendon.
- The posterior medial arch should have a uniform radius to allow for free uninhibited muscle activity.

LATERAL WALL

Anatomical Considerations

—Vastus lateralus
—Greater trochanter
—Gluteus maximus
—Femoral shaft

Criteria

- The lateral wall should be maintained with uniform tension and pressure. The angle of adduction to maintain proper gait is achieved at the trochanteric level; therefore, increased proximal and distal trochanteric contact should be maintained along the proximal lateral brim.
- The greater trochanter should be noted and adequately padded. Contact in this area aids in maintaining proper gait and socket function.
- The length of the wall should proceed uniformly from the anterior brim to encompass the greater trochanter, not exceeding the level of the iliac spine.
- The general line of the lateral wall should be parallel with the medial wall.

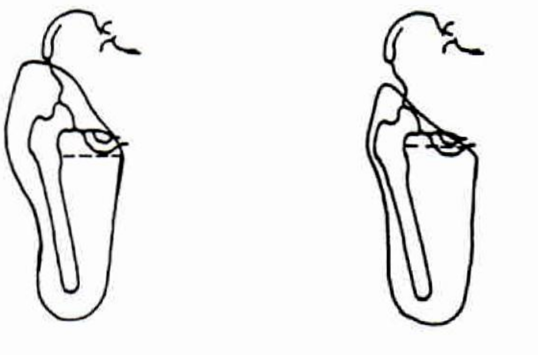

Figure 3. Socket shape of the Berkeley ischial weight bearing socket (left) and IPOS soft socket (right) while bivalved on a frontal plane with relation to skeletal positioning.

TAKING THE NEGATIVE IMPRESSION

To take an impression of the limb, a flexible casting brim is used to maintain the proper shape at the ischial level. The brim is held in place by a shoulder harness, allowing the brim to remain in a stable position in relation to the body, and to hold the femur in a relative degree of adduction and flexion. The measurement recorded from the patient's residual limb is the circumference at the ischial level to aid in selecting the proper brim size. No other measurements are required. All measurements will be recorded on the negative impression. Care is taken for a well fitting mold. This will be reflected in the degree of modification required and fit of the socket.

A wet compression Modelsoft stockinette is placed over the distal limb and brim, giving a uniform compression throughout the residual limb and a smooth transition between the brim and soft tissue. On a conical or bulbous limb, the distal aspect of the brim can be modified with scissors. By cutting slits in the brim, one can allow for a very clean flow of the tissue at the brim's distal edge. The Modelsoft is pulled on and then slightly pulled back distally and tied off so as not to "mushroom" the limb's soft tissue, as commonly happens with a sewn casting sock. The femur is held in its relative position while the plaster hardens with a counter pressure on the medial aspect of the limb.

CAST MODIFICATION

Once a patient has been measured for a total contact socket and has stated the mold was "comfortable," it appears inappropriate to start using a reduction table and measuring device to reduce the positive model dramatically, changing both the shape and volume. Using the aforementioned impression method, the negative mold is taken to be correct, needing only a slight modification. If the shape fits the patient once, it will fit the patient again. At the proximal brim area, modification consists of smoothing the plaster to an even consistency. For the distal aspect of the socket, slight modification or reduction is done, depending on the tissue consistency of the patient. If a very soft residual limb prevails, the positive model circumference is reduced one centimeter from the measurement of the model. On a firm limb, one-half centimeter is reduced. In regard to the question of total contact, although it is not necessary, it is preferred, to aid in proprioception. In terms of valve placement, the most common North American position is the distal medial portion of the socket, highly regarded as the most pleasing cosmetic position and easiest for the patient to don the prosthesis. A consideration to the medial valve placement often disregarded is that the distal lateral femur has very little natural padding. This lack of natural padding is even further reduced by the action of the pull sock being drawn medially during donning of the prosthesis.

Distal lateral placement of the suction valve presents itself as a more suitable position, due to the fact that the excessive tissue covering the distal-medial aspect of the limb can be drawn around the distal-lateral aspect of the limb by the pull sock, thereby providing a natural pad to this sensitive area. It is interesting to note that the distal lateral valve placement is preferred in the West German prosthetic community.

CONCLUSION

In an attempt to provide the above knee amputee with a comfortable prosthesis, numerous socket shapes, designs, and casting techniques are used throughout the prosthetic community. Recently, there has been an influx of ideas and radical changes to the steadfast "rules" for the above knee socket shape.

The intent of this article is to present the basic principles and rationale behind the "European" soft socket design as compared to the standard ischial weight bearing Berkeley quadrilateral socket.

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