THE FITTING OF THE ABOVE-KNEE STUMP

The fitting of the above-knee stump is a subject unto itself. After the alignment of the artificial leg, the fitting is the next most important factor that influences the usefulness of the prosthesis. In contrast to the problems of alignment, for which certain rules and regulations have been established, the effectiveness of fitting of the stump cannot be measured or proven by scientific data. For this reason, there are probably as many shapes of sockets as there are prosthetists. Each of them is convinced that his socket is the best and fervently dislikes making any changes.

The shape of the socket is, generally speaking, only the so-called ischial-bearing ring, i.e., the upper 5 cm of the socket where the tuber ossis ischii meets the socket. What happens below those 5 cm is often neglected or overlooked. Several shapes of sockets are shown in Figure 1. Although the upper part of these sockets is formed very effectively, at the lower end they are all circular and without a purposefully designed profile. I assume that the reason for this is the historical development of the sockets for aboveknee stumps. In Germany the material most often used for AK prostheses, until well after World War I, was leather. Occasionally, a plaster-of-Paris mold was taken of the stump. over which the leather was formed, but generally wooden molds were used. Most prosthetics workshops owned an assortment of these molds and used them again and again for their prostheses. If the mold had been a little too large, or if stump shrinkage had taken place after some time, the difference in circumference was compensated for with an appropriate piece of felt.

Missing, of course, in those sockets or "stump pipes" was any kind of contour designed to meet the individual needs of the patient. Since the muscles of the stumps atrophied more or less into the shape of a cone, contours in the socket were not judged to be necessary. It should be pointed out that the cone-shaped stumps were a Rudolf Poets¹

result of the amputation techniques used at that time as well as of the prosthetics fitting.

After wood had replaced leather as the material most often used for artificial legs, the demands which were made on the fitting technique rose considerably, since the consistency of wood caused the patient to feel pain in pressure areas more readily than was the case with leather. Some prosthetists thought they solved the problem by fitting the socket so tight that the amputated limb would soon ride on a bulge of soft tissue. This kind of fitting does not give rise to complaints at first, but the method definitely has to be rejected firmly because of the severe problems that will occur later.

Naturally, the wooden sockets at first were shaped like the leather sockets; that is, funnelshaped, into which the stump, usually covered by a wool sock, was placed. Because no amount of suction could be achieved in this way, cumbersome harnesses and other suspension methods had to be used. It was hoped that inadequacies in alignment and fitting of the prosthesis would be made up for by such harnesses.

About 1930, the suction socket was introduced by Oesterle but did not come into general use until after the beginning of World War II when many soldiers with war injuries had to be fitted with prostheses. The suction socket makes much higher claims on the art of fitting of the stump because, to create a vacuum within the socket, the uppermost part of the stump has to seal off the socket at the top. At the distal interspace about 5 cm will be left between stump and the bottom of the socket. This space is sealed off by a suction valve. Since no more air can enter the socket, the vacuum produced keeps the stump in close contact with the socket. However, this kind of fitting easily leads to stump edema, particularly after the prosthesis has been worn for some time.

Favored by the existing vacuum below the stump, tissue fluids and blood are drawn into the lower part of the stump. Any counteraction which presses out the fluids and the blood is missing, and painful congestion of the stump is seen. This often leads to reamputation.

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Fig. 1. Variations in the shapes of above-knee sockets.

To counter this problem the total-contact socket was developed in Münster in the late 1950s, based on the work done by Canty and in California at the Biomechanics Laboratory, University of California at San Francisco and Berkeley. The main criterion of the total-contact socket is the entire contact between stump and the wall of the socket. Although the pressure will be distributed unevenly, the contact with the socket must be 100 percent, including the distal end of the stump, enclosing the tip. Therefore a suction valve which conforms to the shape of the lower end of the socket must be used. Because of the complete contact with the socket, a pumping action is created in the stump which pulls tissue fluid and blood into the stump when the prosthesis is lifted, and squeezes it out when weight is put onto the prosthesis.

The total contact, however, is not the only criterion for the optimal fitting of the stump. First, we have to ask ourselves what is meant by "optimal fitting." In my opinion, the following points must be considered:

- 1. The fitting should not obstruct blood and tissue-fluid circulation.
- 2. The stump should be fitted in such a way that a stabilizing action of the muscles of the stump against the wall of the socket can take place, and, when the sound leg is lifted, the pelvis can be held in a horizontal plane above the prosthesis.
- 3. The bone of the amputated leg must be grasped by the socket in such a way that the prosthesis can be well guided in flexion and extension.

CIRCULATION

Besides the total-contact element, a shape of socket has to be found which allows the musculature of the stump to stabilize itself within the socket without obstructing blood flow. To Prof. Dr. Oskar Hepp goes the credit for developing a socket shape which fulfilled these requirements, namely, the so-called undercut socket (Fig. 2). It shows that the diameter of the socket enlarges below the entering point. The undercuts are more pronounced at the medial and dorsal aspects while at the anterior wall they are only required to a small degree. They are not necessary at the lateral wall and here can even be a disadvantage. Because the musculature of the stump corresponds more correctly to the shape of the socket and clings to it, adherence in this type of socket is considerably better than in a funnel-shaped socket which would be pulled down by the contracting muscles.



Fig. 2. Cross sections of the "undercut" socket developed by Professor Doctor Oskar Hepp of Münster.

STABILITY

It is general knowledge that, to obtain the maximal strength of a muscle, the origin and insertion must be as far from each other as possible; that is, the muscle has to be extended as much as possible. To translate this to our conviction: those muscles which keep the pelvis in a horizontal plane over the weight-bearing leg (the gluteus medius and the gluteus minimus) have to be put in tension. This can be achieved by adducting the stump. Therefore, the stump should always be fitted in adduction. But, more: the adduction has to be maintained when weight is put onto the prosthesis and, in its upper part, must not be allowed to tilt medially. The shape of the ischial weight-bearing ring plays a decisive role here. To bring the hip joint and the upper part of the femur into the socket as far as possible laterally, we must allow as much room as practicable in this area. Conversely, to prevent the tendency of the proximal end of the stump to move toward the medial side, we must fit the socket as tightly as possible medially. One can picture it in this way: the distance of the ischial support to the anterior brim should be smaller than the total distance at the lateral part of the socket (Fig. 3). In this way the desired stabilization of the upper part of the stump can be achieved and the pressure on the perineum and the adductors (with the vessels saphena magna and vena femoris) can be avoided. Better conditions for return of the blood are thus achieved at the same time.

ANTEVERSION AND RETROVERSION

Conversely, the stump has to brace itself in



Fig. 3. Top view of socket designed to provide optimal stability.

adduction in the distal area of the socket. To grasp the bone snugly, the distal end of the femur has to be given a reaction area that can be provided by the shape of the lateral wall of the socket (Fig. 4). To fit the femur at the ventral and dorsal aspect at the same time, the distal-lateral part



Fig. 4. Cross section in sagittal plane of socket showing shape of lateral wall to provide optimal stability.

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Fig. 5. Horizontal cross section in distal portion of socket that provides optimal stability.

of the socket is molded, as recommended by Burger, like a clasp (Figs. 5 and 6). Because of this, the prosthesis can be well guided by the femur. If the socket is not shaped in the described way, and is allowed to end in a circular pattern instead, the femur can escape toward the front and toward the back and thus create an unnecessary space which makes the guiding of the prosthesis more difficult.

FURTHER CONSIDERATIONS

I would like to mention one more point, although it is debatable if the shaping of the brim belongs to the fitting of a stump. In my opinion this is true owing to the many difficulties that are encountered especially about the brim. Often there are complaints about pressure in the area of the tendons of the adductors (on the brim on the anteromedial side). Because it seems logical, one is easily tempted to solve such complaints by cutting away some material in the anteromedial area. But this rarely meets with success. A pos-



Fig. 6. Schematic drawing showing relationship between femur and socket design shown in Figures 4 and 5.



Fig. 7 (left). Unsuccessful fitting caused by lowering the height of the anterior brim.

Fig. 8 (right). Photograph showing build-up on brim of unsatisfactory socket shown in Figure 7.

sible cause for this can be that the anterior brim opposite the ischial support is too low. The anterior brim should be 2-3 cm higher if the tuber ossis ischii is to remain on its supportive area. If the anterior wall is lower, the tuber ossis ischii will slide forward and will create considerable pressure on the opposite side. The patient with the socket shown in Figure 7 complained about pressure on the anteromedial side and relief was attempted by cutting away, which proved to be a failure. Only by building up the brim-this piece is clearly visible on Figure 8-could the complaints be obliterated. Another cause for these complaints may be a gluteous maximus which is fitted too tightly. When contracting, the stump is pulled forward and is pressed against the anterior brim. This can easily be determined when a finger is placed in the area of the gluteus maximus. The patient then contracts the muscle and the pressure felt will tell the experienced prosthetist what to do. The same holds true for the medial brim of the socket: one again is tempted to relieve localized pressure by localized measures and also mostly without success. If the patient reports pressure in the area of the perineum, the cause most often is that the prosthesis tilts medially when weight is put onto the prosthesis. Therefore too much pressure is put onto the upper medial part of the stump. The cause for this may be that the upper-medial distance of the socket is too great and at this place some material should be added. One should definitely not cut away in this area. The medial brim of the socket should only be a little lower than the ischial weight-bearing point and should lead in a shallow curve to the anterior brim (Fig. 9).

Because I believe that difficulties in fitting an AK amputee do not only exist in Germany, and

because we have had such good results with the socket described, I have tried to point out some of the experiences we have had in our clinic. I have not mentioned any connection between fitting and alignment of AK prostheses, although this of course is important.



Fig. 9. Sagittal cross section of above-knee socket showing the relationship of the medial brim to the anterior and posterior aspects of the brim.