CANADIAN EXPERIENCE WITH THE PATELLAR TENDON BEARING BELOW-KNEE PROSTHESIS*

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With the conventional below-knee prosthesis weight is borne on the flaring upper end of the stump, and slipping of the stump within the socket is prevented by a combination of a thigh corset and some form of body suspension. Although this is a durable and time-proven appliance it is unnecessarily cumbersome and the thigh corset prevents the wearer from taking full advantage of the normal thigh muscles. Moreover, the moving parts in the knee hinges and ankle joint are subject to frequent break down. Previous attempts to eliminate the thigh corset, as in the old-fashioned Muley limb, in which the corset was replaced by a cuff passing above the patella, have proved unsatisfactory because of excessive movement of the stump within the socket. Recently the prosthetic research group at the University of California (Berkeley) introduced a new design of below-knee prosthesis which successfully eliminates many of the undesirable aspects of the conventional limbs (Prosthetic Research Group, Biomechanics Laboratory 1959). Termed the "patellar tendon-bearing, cuff-suspension prosthesis," it combines the best features of several different types of prosthesis. These include total contact of the stump with a "soft" socket, setting the stump in slight flexion so that considerable weight can be borne on the patellar tendon, and making the upper edge of the socket higher than usual at the front and sides to control rotational slipping of the prosthesis (Figs. 1 and 2). The result is a limb which fits the stump so snugly that suspension by a simple cuff around the lower thigh is all that is required, and which allows the wearer substantially greater control than can be achieved with a conventional limb.

The standard limb as manufactured in the United States consists of three parts: a plastic soft-lined socket, a wooden shank, and a prefabricated S.A.C.H. (solid ankle, cushion heel) foot (Gordon and Ardizzone 1960). Alignment of the socket and foot is secured by means of a jig which enables fine adjustments to be made while the amputee is actually using the limb. The Prosthetic Services Division of the Department of Veterans Affairs of Canada has modified this manufacturing procedure so that the limb is made entirely of plastic materials. The socket and its liner are identical with the American design. The foot piece consists of a hollow plastic horn over which is fitted a foamed plastic foot, which we have found simpler and quicker to produce than the standard solid ankle, cushion heel foot. After these two components have been correctly aligned by means of the jig they are joined by a laminated plastic tube. In this paper the steps in the manufacture of this prosthesis are described as well as our present experience with it.

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Construction of the limb—First a plaster cast moulded closely to the patient's stump is prepared. The patient sits in a chair with the hip flexed to 90 degrees and the knee on the side of the amputation flexed to 30 degrees. A dampened stockinette stump sock is pulled on to the stump and bony prominences are marked on the sock with indelible pencil (Fig. 3). Plaster-of-Paris bandages are applied to the stump, beginning with a few vertical layers over the end of the stump and continuing with circular turns until the desired thickness is obtained. While the plaster is setting the fitter grips the stump with both hands, applying firm pressure with his thumbs on each side of the patellar ligament and with his fingers over the bellies of the calf muscles just below the popliteal space (Fig. 4). This pressure is maintained until the plaster hardens. A male cast, made from the hardened mould, is built up with leather patches over the bony prominences (Fig. 5). Plaster is then removed from the weight-bearing areas including the patellar tendon, the area immediately below the popliteal space, the medial tibial plateau, a strip down each side of the tibial crest, and an area over the shaft of the fibula below the neck and above its cut end.

The socket is built over this plaster model of the stump. It consists of an outer plastic socket (Fig. 6) and a socket liner (Fig. 7). The liner has an inner layer of horse hide and an outer layer of sponge rubber one-eighth of an inch thick. The outer socket is made of epoxy glass cloth laminate with an extension of pure resin which is used for attaching the socket to the walking jig during fitting.

**FIG. 2**
Diagram illustrating the weight-bearing areas with the new prosthesis that are not usual with the conventional prosthesis.

**FIG. 3**
Figure 3—Patient ready for cast taking, wearing dampened stump sock with bony prominences outlined in indelible pencil. **FIG. 4**—Plaster cast being moulded. Notice the thumbs on either side of the patellar tendon and the fingers just below the popliteal space.
The foot is made from standard prefabricated components. It consists of a hollow laminated plastic horn (Fig. 8) over which slips a polyurethane foam foot (Figs. 9 and 10). As the foot is compressible, it will fit the corresponding size of shoe, or one half size larger or smaller. Thus four standard sizes of foot moulds will fill the normal range of adult male shoe sizes from 7 to 12½.

The socket and foot piece are temporarily joined by the walking jig (Figs. 11 and 12). This enables the foot to be placed in any position relative to the socket by adjusting various set screws (Fig. 13). In the initial alignment the height of the prosthesis is set to match the normal leg, and the socket is provided with an arbitrary 5 degrees of lateral tilt and 10 degrees of forward tilt in relation to the foot. At this stage the prosthesis is ready for "walking in the rough" by the patient. After preliminary adjustment of the alignment and suspension the patient's gait is carefully examined. Simple adjustments of the walking jig allow for changes of the position of the socket in relation to the foot in any plane. Adjustments of the jig are continued during the walking trial until the patient's comfort and gait are completely satisfactory. Usually this can be accomplished within a single working day, but occasionally several days are required. The prosthesis is then completed by clamping the socket and foot in a vice that absolutely fixes their position in relation to each other (Fig. 14). The jig is removed (Fig. 15) and replaced by a temporary plastic tube which is filled with beeswax. When the wax has hardened the tube is removed and the wax is carved until it has the desired shape (Fig. 16). A further plastic laminate is applied to the whole limb, permanently joining the socket and foot. The wax is then removed from inside by melting it and letting it run out through holes in the foot piece. The suspension straps are attached, and the limb is ready for use (Fig. 17).

**DISCUSSION**

The new limb has been fitted to twenty-three patients with various types of below-knee amputations in order to determine its place in the armamentarium. Fittings have been satisfactory in fifteen patients. Of these, thirteen had formerly been wearing conventional below-knee prostheses and two were new amputees who had not previously worn any prosthesis. All the thirteen patients who changed over from the conventional to the new prosthesis
preferred the new one because it was more comfortable, lighter, and more convenient to put on and take off. They also noted these further advantages: there was less abrasion of the stump, cysts and calluses gradually disappeared, less energy was needed when walking, and the thigh muscles gradually hypertrophied until they nearly equalled those of the normal side. Most of these patients noticed a short initial period of discomfort with aching thigh muscles and "scalding" of the stump, but these symptoms disappeared quickly when they became accustomed to their new limbs.

All eight patients who were not satisfactorily fitted had previously used conventional limbs. Two had scars adherent to bone. We believe that they could have tolerated the new limb if the socket had been relieved over these areas. Two had soft flabby stumps which underwent further shrinkage that destroyed the fit. Two had very sensitive stump-ends and could not tolerate contact with the bottom of the socket. One had a stump only two and a half inches long. Although he could bear weight in the new limb he could not control it against angular strains. One patient could not tolerate the limb because he insisted it was too long.
We considered that most of these patients could have been successfully fitted by minor changes to the socket. Even in the case of the patient with the short stump, we believe that the addition of conventional side irons and thigh corset would have solved his problem. However, as all these patients were veteran users of conventional prostheses, they were not anxious to pursue the matter further.

The ideal stump length for the new prosthesis seems to be between four and eight inches below the knee joint. The longer stump is to be preferred in an elective amputation because it affords the patient the greatest control over his prosthesis. Although the cost of some of the plastic materials used in the new limb is relatively high, this is compensated for by eliminating the thigh corset, knee hinges and conventional foot and ankle assembly. Moreover, since manufacture requires about half the man hours needed for a conventional limb, the total cost is almost halved. And the weight of the new limb is less than half that of the conventional prosthesis.

REFERENCES


Staff of the Prosthetic Research Group Biomechanics Laboratory, Manual of Below Knee Prosthetics. University of California (Berkeley), November 1959.

ADDENDUM

At the time of publication sixty-three additional patients have been fitted with the patellar tendon bearing prosthesis. Twenty of these were new amputees, and forty-three were old amputees who had previously worn a conventional limb. Of this group, nine were considered failures. The contra-indications for fitting now include: 1) coincident knee derangement such as cruciate or collateral ligament laxity (the trauma that causes the amputation often produces knee injuries as well; in this event the side irons of the conventional prosthesis help to support the knee); 2) scars in the popliteal fossa, such as those produced by exploration of the popliteal vessels; 3) marked variation in stump size such as in rapidly growing children or obese people; and 4) labourers obliged to work on rough ground, which places additional strain on the knee.