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PNEUMATIC SUPRACONDYLAR SUSPENSION FOR KNEE-DISARTICULATION PROSTHESES

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There is considerable controversy over through-knee amputations due to the technical complexity of the prosthetic fitting. The biomechanical advantages, however, resulting from knee disarticulation in provision of an end, or load-bearing, stump overrule all other considerations. We therefore believe that knee disarticulation should be preferred over above-knee amputations whenever this is possible (2).

The two major sources of problems in through-knee (T.K.) amputations are the lack of space below the stump for installation of a conventional or controlled knee mechanism and the broad femoral condyles which impose severe socket design limitations. The shape of the stump requires the use of either a leather corset type of socket or a hard socket with a flexible or open area at the supra-condylar region, so as to enable passage of the wide bony end of the stump (femoral condyle). The leather socket is disappearing gradually from prosthetics practice due to its disadvantages of too much flexibility of the socket as a whole, and tightness resulting from use of laces, which causes muscle atrophy. The hard (fibre reinforced plastic) socket is gaining popularity but the procedure for fabrication involves various casting stages including a flexible silicone rubber window with a hard flap for tightening, and therefore is rather complex and requires special skills. Due to the flexibility of this arrangement and inaccuracy in the production process, significant "piston" action may occur during gait.

The use of surgical techniques by which the width of the condyles is reduced is contradictory to the end-bearing concept. Reduction of the load-bearing area increases the interface pressures to a point that it is not comfortable for the patient to support himself on the end of the stump.

This paper describes a technique that uses inflatable pneumatic bags fitted inside the socket at the supracondylar region to provide a practical means of suspension.

Method

In the first prototype, the conventional technique for plastic socket fabrication was employed. A plaster cast of the stump was produced. "Pe-Lite" was used for an inner lining of the hard socket and two shaped rubber bags were designed to engulf the narrow supracondylar neck of the "Pe-Lite" socket. The outer hard socket, therefore, obtained a more cylindrical shape and allowed free passage of the femoral condyles when the bags were deflated. The two bags (Fig. 1)

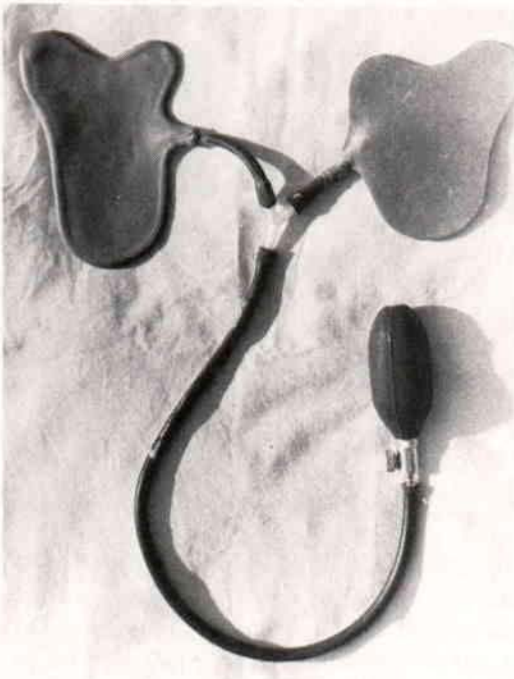

Fig. 1. The pneumatic rubber bags and the bulb.

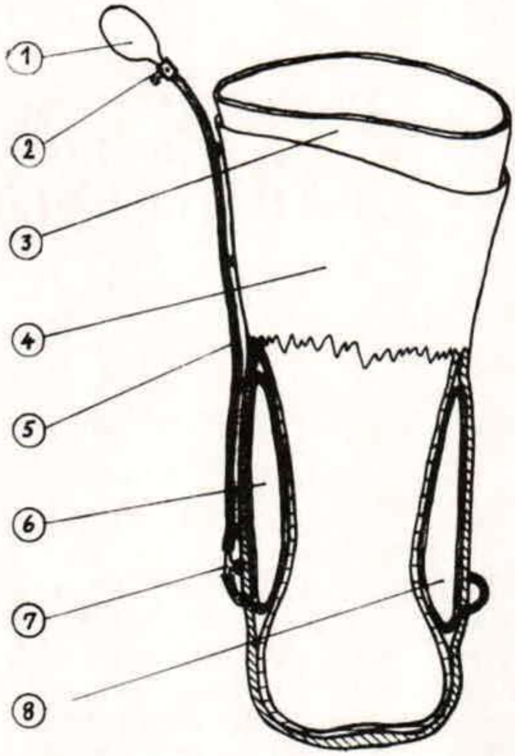

Fig. 2. Schematic drawing of the socket during use. Parts: 1. The bulb (hand pump), 2. Valve, 3. Hard-fiber-reinforced plastic socket, 4. Rubber tube, 5. Lateral bag, 6. Mainfold, 7. Medical bag, 8. Inner (Pe-Lite) lining.

were fitted between the socket and the liner, one on the medial side and one on the lateral side as illustrated in Figure 2. The bags were connected via a three-way manifold and a rubber tube fitted with a manually operated valve to a pneumatic bulb (hand pump). The bulb, valve, and tubes were taken from a standard blood pressure cuff (5).

The amputee inserts his stump into the socket and after finding the correct position inflates the bags. The Pe-Lite liner is compressed against the stump and the condyles are locked into place. The liner assists in spreading the pressure of the bags over a larger area of the stump (4). The pressure in the bags can be adjusted by the amputee and once the desired pressure has been reached, the valve can be locked and the bulb removed. To remove the prosthesis, the amputee opens the valve to let the bags deflate.

The advantages of the proposed technique are the following:

1. Good grip of the socket over the stump and thus reduced "piston" action.

2. Easy and quick assembly of the prosthesis.

3. A good fit and large range of adjustability to variations in the stump volume due to climatic changes, weight variation, and edema.

4. Even pressure distribution in the vicinity of the bags and, therefore, elimination of stress concentration on the soft tissue and reduction of the risks of developing pressure sores.

5. Ability to reduce pressures on the stump during prolonged sitting by deflating the bags temporarily, without the necessity to undress to remove the leg.

Evaluation of the Concept

A preliminary study was conducted to evaluate the concept with special emphasis on the "piston" action phenomenon. At this stage only one patient had been fitted with an "OHC" knee-disarticulation prosthesis[4] (four-bar knee joint with a Dynaplex hydraulic unit) (3) employing the proposed suspension technique. The patient was a 38-year-old war veteran, who had used a prosthesis for 2½ years, and was a current user of the "OHC" prosthesis.

A comparative study between the performance with the conventionally fitted socket and the experimental socket was carried out with respect to three points:

1. Relative displacement between the stump and the socket during gait.

2. Convenience especially in donning and removing the prosthesis.

3. Adequacy of fitting.

The relative movement between the stump and socket was measured by taking X-rays (l) of two simulated gait positions (Figs. 3-6):

1. When the prosthesis was bearing all of the weight of the patient.

2. When the prosthesis was suspended on the stump and the other leg was bearing all of the weight of the patient.

Although this approach disregards the effects of inertia and the dynamics of the walking cycle, it can provide significant information on the "piston" action. The X-rays also provided information in relation to the geometrical match between the socket and the stump. Figures 3 and 4 illustrate the locking action which the bags apply to the femoral condyles. By comparing these results to the ones in Figures 5 and 6 which illustrate the same positions with the conventionally fitted prosthesis, it is evident that the relative

Fig. 3. X-ray of the new socket with both legs bearing weight.

Fig. 4. X-ray of the new socket when the prosthesis is not bearing weight.

Fig. 5. X-ray of the conventional socket with both legs bearing weight.

movement is far less with the pneumatic suspension.

The displacement which was measured from the X-rays was 42mm with the conventionally fitted technique and only 23mm with the pneumatic bags. The patient's subjective opinion was that during movement there was far less "piston action" than with his previously fitted prosthesis. This, in his opinion, improved his gait performance.

The patient was also filmed by a television system and video-tape-recorder with slow motion facilities, and the ground forces applied by both his feet during gait were recorded by two "Kistler" force plates. The T.V. and force records will not be discussed here since they require further exploration.

Conclusions

From the limited evaluation of the concept, it was evident that the suspension of the prosthesis was improved considerably by use of the pneumatic system. As a consequence the kinematic features of gait were improved. The pressure distribution on the stump was assessed subjectively by the patient and he commented on a more uniform distribution with this arrangement.

It is recognized that the analysis is rather

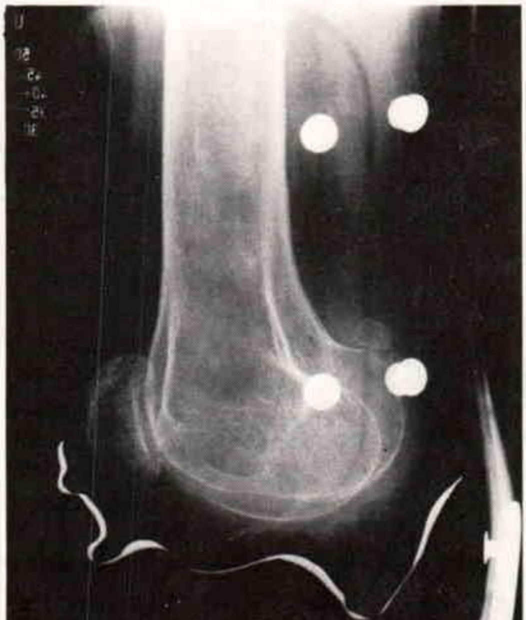

Fig. 6. X-ray of the conventional socket when the prosthesis is not bearing weight.

limited at this stage but a further study with a larger group of patients is now being planned.

Acknowledgement

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Footnotes

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