Orthotics and Prosthetics, Volume 38, Number 1, Spring, 1984, pp. 29–35.

Ottawa Experience With Hip Disarticulation Prostheses

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INTRODUCTION

By far the greatest rejection rate among prosthesis users in the group of lower limb amputees is that of the high level amputee, i.e., very short above-knee, hip disarticulation, and complete or incomplete hemipelvectomies (or trans-pelvis amputations). In order to assess the state of the art in these categories, a study was initiated in 1980 among patients who had failed to gain satisfaction from their prostheses and had ultimately resorted to ambulation on crutches rather than be restricted by ungainly and awkward artificial limbs.

Numerous letters written to well-respected prosthetists, physicians and rehabilitation engineers around the world solicited opinions on the apparent lack of success in fitting these clients. After compiling the data from these sources, and an extensive literature search, no definitive protocol or fitting technique emerged to be used as a base for further development (Figure 1). As well, direct patient feedback on a number of prosthetic designs with readily available combinations of prosthetic joints and socket materials showed no apparent increase (or decrease) in prosthetic use by amputees.

In 1982, several amputees were again fitted with slightly different combinations of components and sockets. Through the use of questionnaires, speaking to other professionals in the field, and client feedback, a pattern began to develop which identified the areas of greatest concern to the patient. Some of these were as follows: socket discomfort, mobility, weight of prosthesis, insecurity, and energy expenditure.

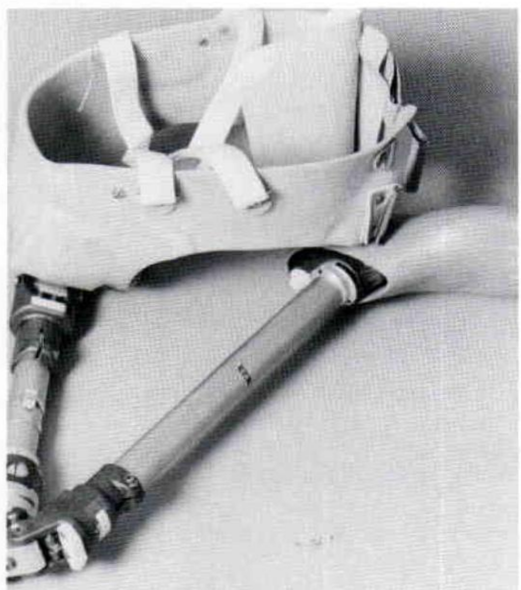

Figure 1. Hip disarticulation prosthesis fabricated in Japan (Yaesu-Labour Corp.) consisting of a diagonal polypropylene socket and knee rotator and adjustable multiaxial foot.

METHODOLOGY

Utilizing the rehabilitation engineering gait laboratory of the Royal Ottawa Regional Rehabilitation Centre, angle-time diagrams from hip, knee, and ankle joints were recorded by electrogoniometers; graphs were plotted by a PDP11 computer to focus on such concerns as mobility, speed, and energy expenditure. The same was done for step length, force displacement, and weight distribution as recorded by a force platform. A split image video recording projected the patient simultaneously from a lateral aspect as well as from an anterior or posterior view. This latter feature was extremely helpful in analyzing the various stages of the gait cycle, as the recording could be replayed frame by frame.

The amputee also found viewing the video tapes helpful in understanding why he/she walked in a certain fashion. Once taught how to correct these gait faults, the individual did so quite readily. By cross examining both video recordings and computer graphs, the prosthetist was able to align the prosthesis more accurately.

The amount of energy expenditure required to walk (at a standard walking rate) while wearing different prostheses can be measured by an oxygen consumption analyzer. By measuring energy expenditure, it has been observed which type of prosthesis requires the least oxygen consumption. This observation should affect future prosthetic designs.

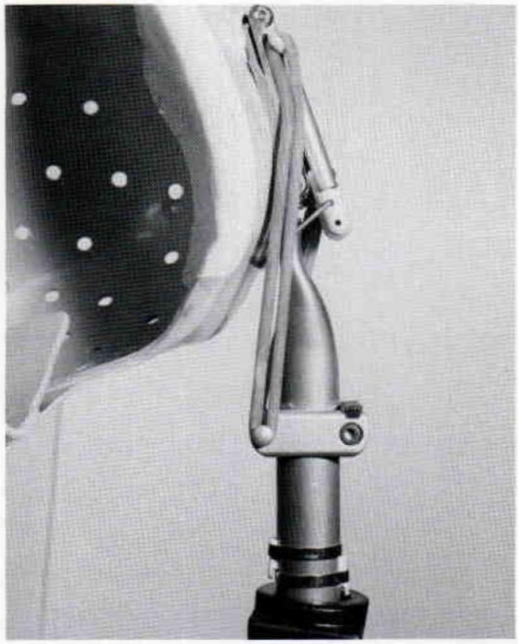

Figure 2. Standard Otto Bock design with 7E4 hip joint, semirigid acrylic laminated socket, showing significant distance between the ischial tuberosity and the bottom of hip joint mechanism.

AREAS OF CONCERN

• *Socket Discomfort*

The location of greatest pressure is usually on the ischial tuberosity where most of the weight is borne, both in walking and sitting. Most conventional sockets with rigid or semi-rigid polyester laminations or thermoplastics are only slightly padded with felt, PELITE or leather in this area. In some cases, weight was borne in the symphysis pubis area which resulted in an abducted gait and awkward sitting positions (Figure 2).

Patients complained of skin breakdown, heat rashes and general discomfort. They also complained of problems from the proximal socket rim which tended to dig into the lower ribs during sitting and bending, usually leaving large bruises.

Some of these complaints were overcome by using rubberized sockets fabricated from various commercial RTV silicone rubbers, e.g., IPOCON* or ORTHOSIL*. Some custom socket changes to create different weight-bearing areas i.e., below the iliac crest, proved satisfactory in several cases. Further studies need to be done to fully assess the advantages and disadvantages of the use of these materials (Figures 3 and 4).

• *Mobility*

Lack of mobility can lead to painful and embarrassing situations. Most patients complained of the necessity of thoroughly

Figure 3. Silicone socket indicating the amount of flexibility.

Figure 4. Indicating the deformation of the rubber socket in extreme trunk bending position.

planning ahead, once away from their familiar home or working environment. Within the area of mobility, two concerns arise for the amputee—velocity and maneuverability.

Most amputees are quite adept at crutch walking and can cover a larger distance in a shorter period of time on crutches than by walking with their prostheses. In a number of cases, to encourage prosthesis use, special hip and knee extension assists were used to increase the velocity of walking. However, new but undesirable elements were brought into play by these adaptations. These additional features were eventually rejected by all patients (Figure 4).

Maneuverability is a daily problem encountered by hip disarticulation patients on a large scale. Some of these problems lie in the type of terrain covered, lack of space to maneuver, and the motion of sitting and standing.

- *Weight of Prosthesis*

The average weight of the hip disarticulation prosthesis varies from four to nine kilograms—depending on the additional optional extras in the prosthesis—which is generally deemed acceptable. The use of torque absorbers, 4-bar linkage hip and knee joints, and multi-axial feet all add significantly to the overall weight. The selection of lighter materials for the components as well as for the socket is of great importance.

- *Insecurity*

The fear of falling unexpectedly is a great concern to most hip disarticulation amputees. Despite the use of mechanically sophisticated hip and knee joints, using self-locking and braking mechanisms, extension assists propelled by springs, pneumatic or hydraulic cylinders, insecurity still remains with the patient. The use of more than one prosthetic foot with various heel heights and/or the use of a T-handled Allen key can alleviate the problem of maintaining proper alignment to a certain extent, when changing heel heights of footwear.

Testing the stronger muscle groups in the pelvic region has produced good myosites to explore the possibility of voluntary joint control in the hip and knee joints. Investigations by various researchers are

Figure 5. Otto Bock 7E4 hip joint with hip flexion bias system (HFB) added for initiating hip flexion.

dealing with this issue. Presently, no motor-drive units or other safety mechanisms are commercially available for us to test this feature at the present time.

- *Cosmesis*

Cosmesis plays just as important a role as the mechanics of the prosthesis. Most endoskeletal prostheses offer a much better cosmetic appearance than exoskeletal designs. However, there are still some drawbacks with both designs. The socket area enveloping the entire pelvis adds significantly to the hip and waist circumference. The distortion of the hip area from standing to sitting should also be considered in redesigning the total shape. The appearance of the sitting position was also improved by levelling the pelvis through the use of two new hip joints (See Figures 5 and 6). Most of our test patients were either fitted with the Otto Bock 7B7 or 3R21 joint. Undesirable noises produced by some joints as well as foam covers are presently under investigation.

Figure 6. Otto Bock components: 7E7 hip joint, SR20 knee joint and Teh Lin multi-axial foot.

TECHNICAL INFORMATION ON PRESENT DESIGNS

In the early stages of the project, our main concern was to make the socket as light and thin as possible using 100 percent flexible acrylic resins with lay ups consisting of perlon, nylglass and fiberglass reinforced tricot as well as fiberglass matte. These sockets were up to 50 percent lighter as compared to those done by the standard methods of fabrication. However, the patients did not give any definitive response as to whether this actually produced any advantages.

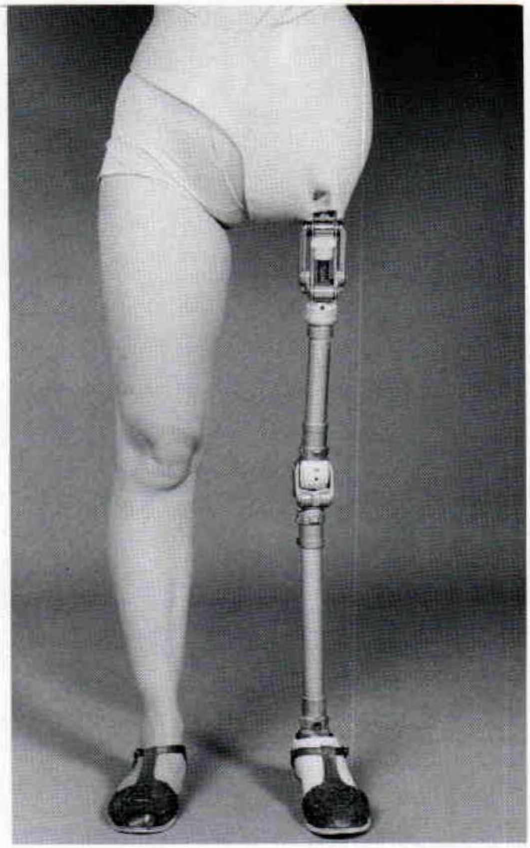

Figure 7. Otto Bock components: 3R21 hip joint, 3R20 knee joint and 4R39 torque absorber, with a 1A13 Greissinger foot.

The next stage was the incorporation of silicone gel pads on top of or in between the plastic laminations. Some felt somewhat more comfortable, but the slight elevation in sitting proved an additional negative factor. Thermoplastic sockets made of surlyn and polypropylene were also attempted, but without conclusive evidence that we were on the "right track." It was not until I received a letter with photographs from Dr. Hannes Schmidl in Bologna, Italy, that we seriously considered fabricating rubberized sockets. The standard Dow Corning #3110 was initially used in doing a 3-part lamination.

First, we did the "inner" socket with six layers of perlon stockinette; then a partial rigid acrylic with fiberglass and perlon lamination incorporating the hip joint hardware. Finally, the third lamination was done similarly to the first one. An anterior opening with an internally "built in" tongue was obtained. However, after only a short trial period, the separate laminations became detached from each other. Several other combinations were attempted, since the initial patient feedback on the rubberized sockets was extremely encouraging.

Our present design is done in two parts (Figure 7). The first one, in six layers of perlon and carbon fiber containing the hip joint hardware, is done over a PVA bag under which are six layers of perlon stockinette next to the cast.

This lamination is trimmed to the appropriate size and shape and replaced on the mold in between the first and second layer of six perlon stockinettes. The rigid plate is previously coated with silicone adhesive which is allowed to cure for two hours.

The second lamination is done with IPOCON rubber using a posterior opening. The location and size of the tongue is very critical. Instead of using Velcro® type fasteners, we use three Fixlock† clasps with webbing fastened to the socket with plastic rivets (Figure 8).

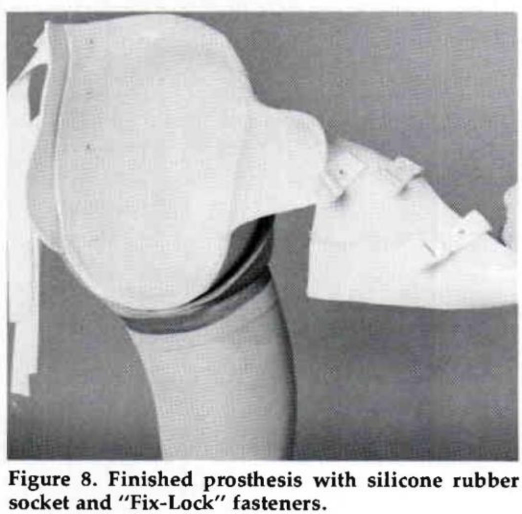

Figure 8. Finished prosthesis with silicone rubber socket and "Fix-Lock" fasteners.

Several other room temperature vulcanizing materials have been tried, including Orthosil, which proved too "floppy" and heavy for our needs.

The initial advantages of the rubber were:

1. Increased freedom of movement in all directions without increasing instability.
2. Increased total contact in sitting, standing or lying down, giving the patient more overall comfort.
3. Increased suspension through the high friction coefficient of the rubberized inner surface.

The initial disadvantages of the rubber were:

1. Increased overall weight of the prosthesis.
2. Increased heat retention, causing perspiration.
3. Clothes sticking to the outer surface of the socket.
4. Difficulty in making alterations or doing repairs.

SUMMARY

These independent findings form a basis for further investigation into priorities for the redesign of hip disarticulation prostheses in which the wearing of the limb will be optimized and normalized (Figure 9).

I want to give a special word of thanks to the many colleagues who have participated in sending information, in most cases not published yet, on their own recent attempts to improve the hip disarticulation prosthesis. A special thank you to Mr. B. Wester and Mr. P. Tiul whose article dealt with pure speculation, which in our estimation has proven to be very helpful in proving that a knee joint can be successfully used as a hip joint.

Some of the patients referred to us were initially fitted outside our geographical area. Once they had returned home, they were referred back to their original prosthetists, to whom we sent as much information as possible to help them become familiar with their patient's new prostheses.

Figure 9. Increased comfort is achieved in walking as well as in sitting.

It is anticipated that at the end of 1985 a "hands-on" seminar will be organized to invite as many interested prosthetists (and patients) to participate in an information exchange clinic in Ottawa. This study is still in its infancy and the author intends to publish updates at regular intervals to keep the prosthetic field informed.

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*IPOCON—product of IPOS, distributed by W.H. Hood Co., Victoria, Ontario. ORTHOSIL—product of Otto Bock Orthpaedic Ind. and Serum International.

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†"Fixlock," made in Sweden, is distributed by Spae Naur Products, Kitchener, Ont. or, in the U.S.A. by Therapeutic Recreation Systems, Boulder, Colorado.