

The Evolution of the Canadian-Type Hip-Disarticulation Prosthesis

COLIN A. McLAURIN, BASc.¹

Not many people are amputees. Still fewer people are prosthetists. Not many amputees are hip-disarticulation cases. Hence, not many prosthetists are interested in hip-disarticulation prostheses except when occasion demands. That just about sums up the history of hip-disarticulation prosthetics.

A more intensive look at the picture reveals two more or less standard approaches to the problem, but usually there are as many variations as there are limbshops. The accompanying illustrations (Figs. 1 through 6) indicate the practice, if not the principle, of conventional fitting, together with some of the variants. A study of the principles of conventional fitting is even more revealing. The guiding one seems to be this: Take one standard above-knee leg and build on to it until it can be strapped to the amputee. The practice certainly bears this out. Even the term "tilting-table prosthesis" suggests working from the leg up to the stump, instead of beginning with the amputee, who properly should be the focal point in any attempt at rehabilitation.

This back-handed approach to problems is not something unique among limbfitters. The plumber is more interested in joining pipes than he is in the water requirements of a household. The airplane pilot is more concerned with the trim of the aircraft than

with the comfort of the passengers' seats. The prosthetist's main interest lies in making a leg he can fit on the customer, and in so doing he has shown a considerable amount of ingenuity. Perhaps had the variations not been local in nature, more progress could have been made. Many fitters have come surprisingly close to the Canadian-type prosthesis, and no doubt others actually envisioned the basic principles without achieving the mechanical design.

Generally speaking, the hip-disarticulation case has been considered very unfortunate when compared with other above-knee cases. Perhaps some of this attitude is owing to the fact that a great many cases are not of traumatic origin and that therefore the life expectancy is short. In any event, the result is that the amputee is not encouraged to expect much from his prosthesis. The usual complaints are mechanical in nature—rattling in the joints and the need for frequent repair. Accordingly, most innovations in the prostheses have been directed toward solving these mechanical problems, and more by chance than by design functional advantages evolved.

Conventional hip-disarticulation prostheses are usually classified into two main categories, the saucer type and the more common tilting-table type.

THE SAUCER-TYPE PROSTHESIS

The saucer type of prosthesis, shown in Figure 1, is essentially a standard above-knee leg with a saucer-shaped socket on top of the thigh. Suspension is by means of a single-axis joint and pelvic band and may include fore

¹ Assistant Director, Prosthetics Research Center, Northwestern University, 401 E. Ohio St., Chicago; formerly Research Engineer, Prosthetic Services Centre, Canadian Department of Veterans Affairs, Sunnybrook Hospital, Toronto.

and aft straps that pass over the shoulder. This type is most suitable for short-femur amputations because adequate stability is difficult to achieve without the additional bone structure. In accord with common practice with above-knee legs, the hip joint is placed well forward, thus providing some measure of stability. A lock may or may not be used at the hip joint. If a lock is used, it is of the semiautomatic type. A lever is pressed to release the lock for sitting, and the lock engages automatically on full extension. The lock provides stability (at some loss of function), but it offers mechanical difficulties because all the loads are funneled through the relatively small joint.

THE TILTING-TABLE PROSTHESIS

Although not so simple or as light as the saucer type, the tilting-table prosthesis is more generally used because of the additional

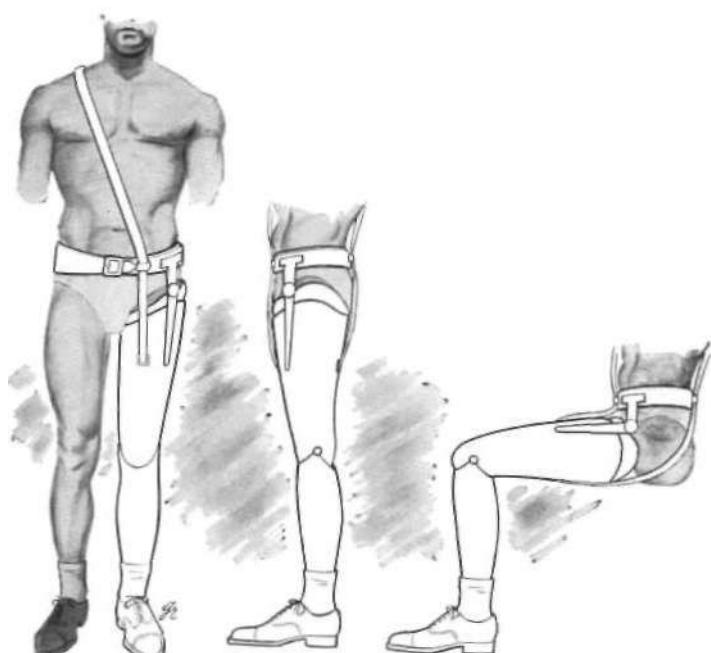


Fig. 1. Saucer-type prosthesis for hip disarticulation.

support. Figure 2 shows a typical prosthesis. A socket, usually of leather, is made to fit the stump and attached by a belt around the pelvis and often with a strap over the shoulder. The socket is articulated on the thigh section

with a metal joint lateral to the acetabulum. Again the joint may or may not have a semiautomatic lock. Without a lock, the wearer has little control over the limb, most of the stability during the stance phase being afforded by friction between the socket and the thigh section.

Because it is extremely difficult to make a hip joint strong enough to bear the entire load, contact between the socket and the medial edge of the thigh section is essential in weight-bearing, and this expedient is of course equally important when a lock is used. Figures 3 and 4 illustrate two meth-

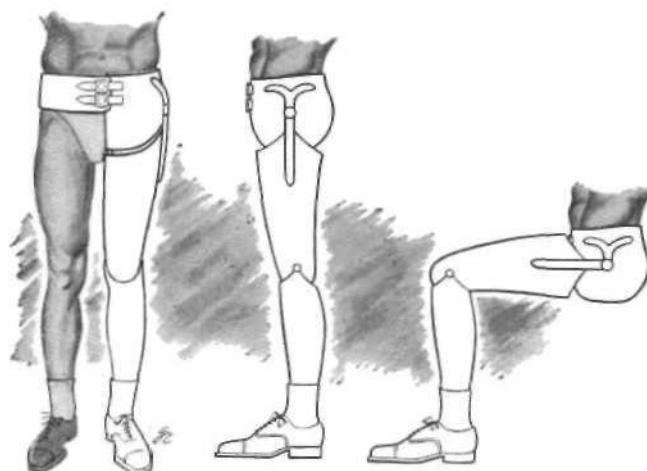


Fig. 2. Tilting-table prosthesis for hip disarticulation, basic design.

ods that have been tried. In Figure 3, a strap is fastened to the socket and passed under rollers attached near the medial brim of the thigh. These rollers also take the downward thrust of the socket, and a metal track may be attached to the socket for the rollers to bear upon. Figure 4 illustrates a dead-center latch mechanism. When the hip joint is fully extended, the latch flips by dead center and secures the socket to the thigh. A hip lock is necessary with this arrangement.

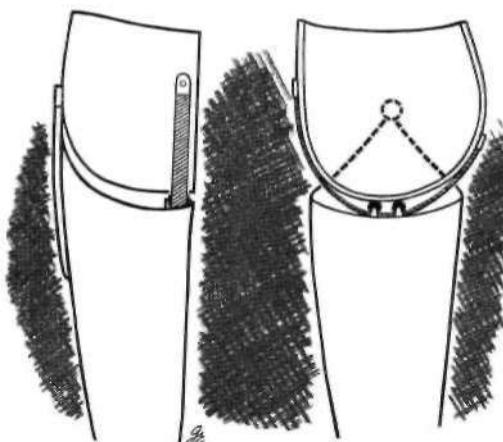


Fig. 3. Variations in tilting-table prostheses: strap-and-roller medial support. Left, anterior view; right, medial view.

Figure 5 illustrates a fairly common departure in design. The walking function is identical, but the hip joint has been lowered to a position beneath the socket where a full-width bearing may be made much lighter. Because of the position of the joint directly below the center of gravity, however, a lock must be used. Along with the usual inconveniences and mechanical difficulties, this type also has distinct disadvantages in sitting. The thigh section is much shorter than normal, and the bulk of the joint raises the socket about an inch above chair height.

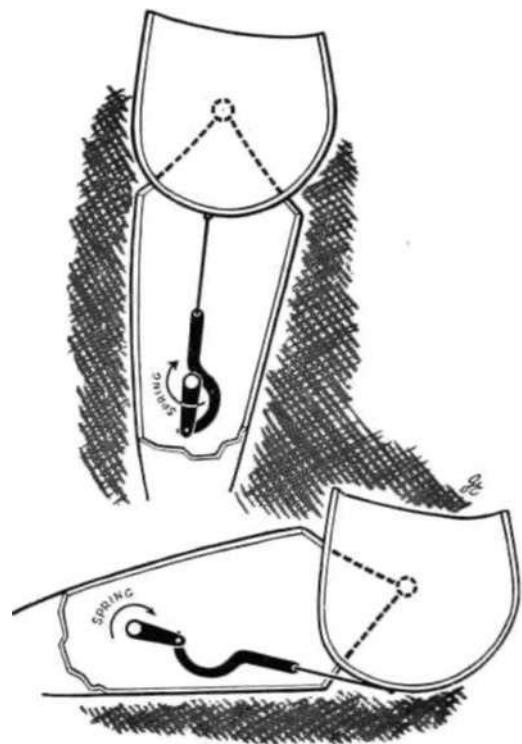


Fig. 4. Variations in tilting-table prostheses: latch-type medial support, cross-sectional view. Above, standing; below, sitting.

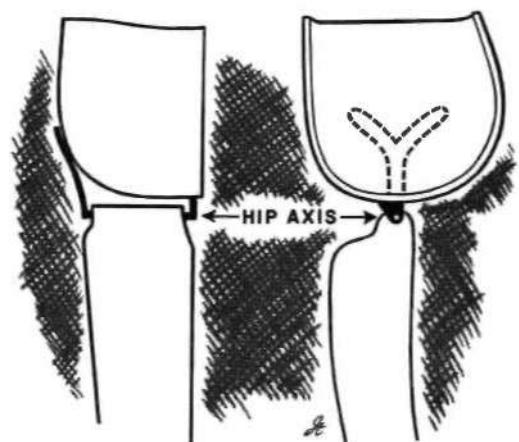


Fig. 5. Variations in tilting-table prostheses: hip joint below socket. Left, anterior view; right, medial view.

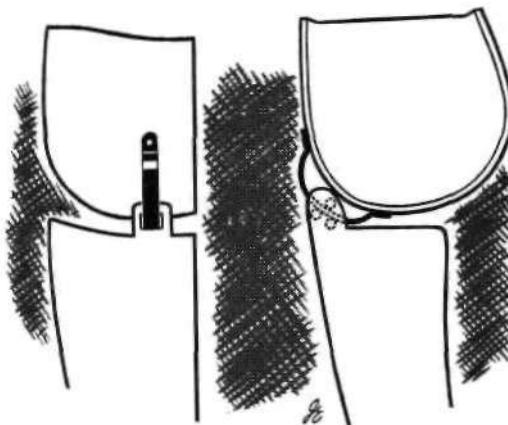


Fig. 6. Variations in tilting-table prostheses: track-and-roller joint. Left, anterior view; right, medial view.

Figure 6 shows a rather interesting deviation. This design uses a track-and-roller mechanism in which the center of rotation is a few inches lower and anterior to the acetabulum. The actual model seen by the writer was heavy and crude in construction so that binding of the rollers on the tracks prevented free motion, but it is worth noting since in principle it is almost identical to the present Canadian type, and it seems to be designed with a view toward improving function.

THE U. S. NAVY HYDRAULIC PROSTHESIS

At the close of World War II, the U. S. Navy designed and fitted an hydraulic prosthesis with the primary purpose of improving function. Figure 7 illustrates the main features of the device. The very large ball-bearing hip joint was made strong enough to bear all the weight, thus obtaining a free joint. An extension controlled the motion about the knee joint. The cylinder in turn was controlled by a valve which was either automatically or manually actuated. Normal motion about the hip joint allowed the piston to move slowly, as in an automobile shock absorber, and the knee joint was thus permitted to flex and extend with some damping. But fast rotation about the hip joint (as in stumbling) caused the valve to close and thus stabilized the knee. The manual control also closed the

valve and locked the knee in any position. There were two disadvantages of this device—cost and weight. In addition, the application of hydraulics to prosthetics usually introduces problems of noise, leakage, and occasional erratic behavior.

THE INFLUENCE OF MATERIALS

A review of prosthetics practice in the hip-disarticulation case would be incomplete without reference to materials. The shank and thigh members are usually of wood covered with rawhide as in standard above-knee legs, but because of the saving in weight aluminum-alloy members are preferable when available. Steel is the almost exclusive medium for hip joints and locks, but in the Navy hydraulic prosthesis aluminum alloy was used to save weight. Sockets are usually made of two layers of leather, with Celastic core for stiffness. Aluminum alloy and monel (an alloy of copper and nickel) have been quite successful. They are usually lighter, more sanitary, and easier to attach to the joints. Plastic laminates are light, strong, sanitary, and easily molded to complex shapes, and it is not surprising to find them successfully used in hip-disarticulation sockets. It was the ease

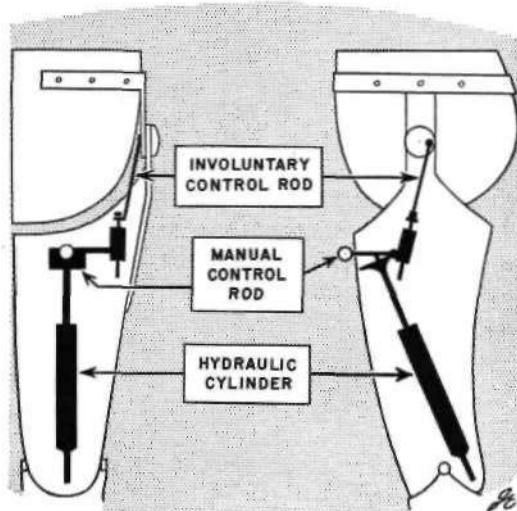


Fig. 7. Navy hydraulic prosthesis for hip disarticulation, schematic.

of fabrication that made possible the plastic socket with the wrap-around pelvic band (page 33).

Generally speaking, the materials and the mechanical designs were chosen with a view toward solving the mechanical problems, and it was with this thought in mind that design study was begun at Sunnybrook Hospital in Toronto. The highlights of this study are worth noting as an illustration of how an indirect approach to a problem can achieve results.

EVOLUTION OF THE CANADIAN DESIGN

The primary objective at Sunnybrook was to construct a hip-disarticulation prosthesis that would avoid the stress concentrations in conventional locks and to provide a simple method for releasing the locks. The first experimental prosthesis employed a four-link mechanism, as shown in Figure 8. The links were about 4 in. wide to provide adequate lateral strength. The socket was plastic and the thigh section aluminum alloy. It was intended that a posterior strap be used to lock the leg in full extension, but initial trials indicated adequate stability without a lock owing to the fact that at or near full extension the effective hip center was well forward of the center of gravity and because the posterior brim of the thigh prevented hyperextension. In order to achieve simplicity in assembly and to increase mechanical rigidity, the forward link was lengthened and made strong enough to support all the main loads (Fig. 9). The rear link thus acted only as a guide and could be made light and adjustable.

One difficulty remained—there was a chopping action between the top of the thigh and the socket such that serious pinching could result. Owing to the geometry of the linkage system, the gap between the thigh and the socket was present whenever the thigh was neither fully flexed nor fully extended.

The next step in the evolution was to extend the front link to include the knee joint and to replace the rear link with a simple rubber stop to prevent hyperextension. This final configuration, shown in Figure 10, permitted the use of a single broad joint without

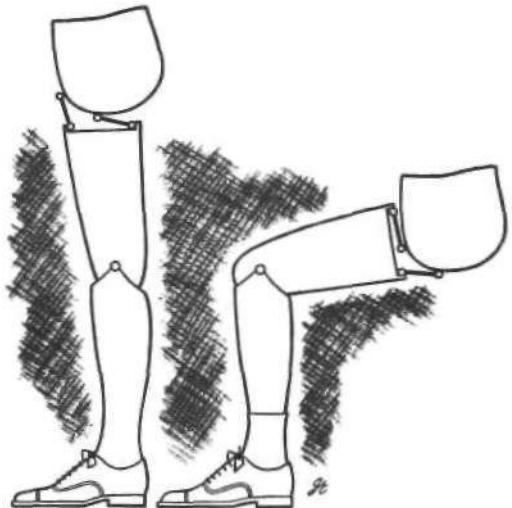


Fig. 8. Steps in the evolution of the Canadian-type hip-disarticulation prosthesis: four-link mechanism.

locks. At first it was felt that the position of the stop would be critical, and accordingly the first unit included a stop that could easily be adjusted by the amputee. It was soon found that this feature was not critical and

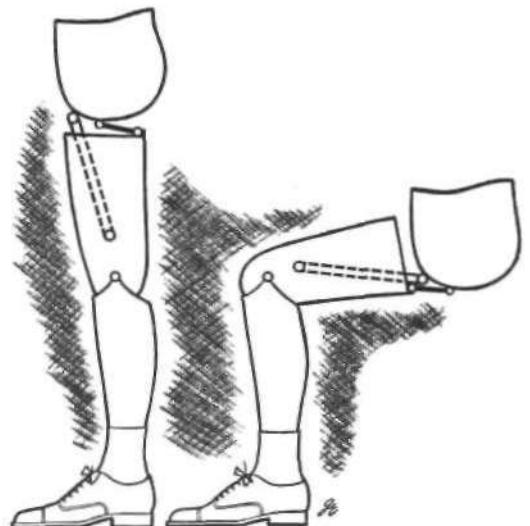


Fig. 9. Steps in the evolution of the Canadian-type hip-disarticulation prosthesis: modified four-link mechanism.

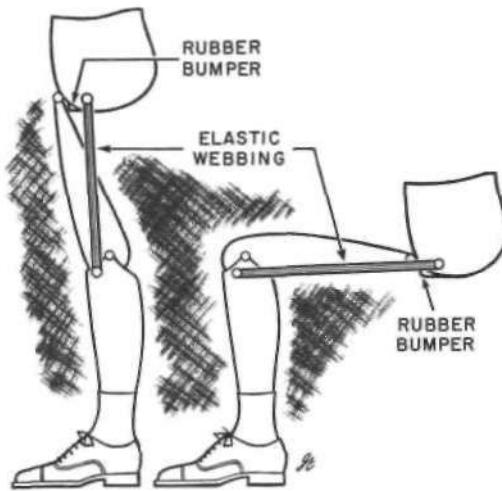


Fig. 10. Steps in the evolution of the Canadian-type hip-disarticulation prosthesis: final design.

that initial adjustment by shimming or grinding was adequate. The most apparent difficulty was the tendency for too long and too slow a stride, and thus the elastic webbing was added to restrain hip flexion. Cosmetic appearance was improved by a floating thigh cover (Fig. 11) made of horsehide and attached to the socket only. A foam-rubber

liner was glued to the horsehide to give it stiffness.

Apart from the mechanical simplicity of the new prosthesis, functional advantages soon became apparent. Little effort was required in the swing phase, and a full stride was easily obtained. Previously, with a locked hip joint, hip flexion was simulated either by pelvic rotation or by motion of the socket on the stump. The resultant gait was usually jerky and tiring, although some amputees had learned to walk surprisingly well. Since the amputee is actually "sitting" in the socket, complaints of discomfort were not common, but obtaining adequate security in the socket was a different matter.

Too seldom have the bony prominences of the ilium been used for secure fitting. Usually a broad, leather pelvic belt, as in Figure 2, was used for lateral support and a shoulder strap was added to prevent the socket from dropping down during the swing phase. The excessive weight of many prostheses necessitated the shoulder strap. The ischial seat is nearly always available for direct weight-bearing, and the areas for taking pressure elsewhere are large. If the socket is extended in the form of a band across the back of the pelvis and around to the opposite iliac crest, then three points of the innominate bones are firmly gripped, as shown in Figure 12. Since

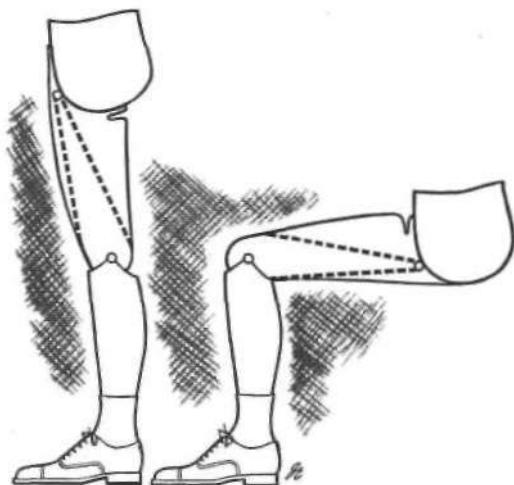


Fig. 11. Steps in the evolution of the Canadian-type hip-disarticulation prosthesis: floating thigh cover for cosmesis.

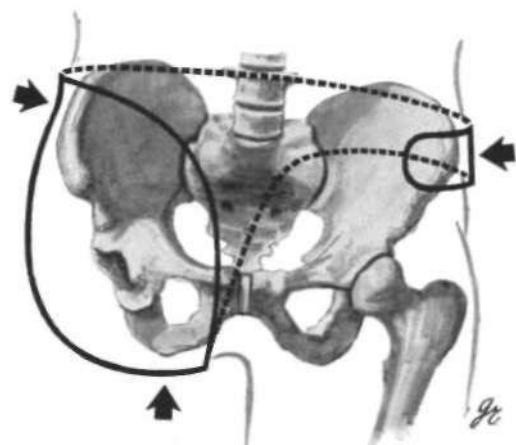


Fig. 12. Anterior view of socket-waistband showing three points where the skeletal structure is firmly gripped.

these three points are well spaced, excellent lateral stability is obtained. It is undesirable to have the socket extend above the iliac crests since doing so causes restriction and discomfort. Adequate vertical support can be obtained by ensuring a close fit in the area between the crests and the anterior-superior spine of each ilium.

CONCLUSION

The Canadian-type prosthesis has been fitted to many amputees at various centers and over a period of several years. Stability with the free hip and knee joints is adequate if correct alignment is attained and if some gait training is provided. In a fall, the prosthesis is usually safer, since the joints collapse and prevent vaulting. One amputee has sustained several falls without injury to himself or the prosthesis. There are, however, several

improvements possible in walking characteristics of the prosthesis. The elastic check-strap prevents excessive hip flexion, but some means should be provided for cadence control. Without restraining forces at the knee and hip, the leg tends to walk at its own pace as determined by its pendulum properties. Correctly applied friction or hydraulic devices could enhance the swing characteristics so that various speeds and strides could easily be attained. Furthermore, stability at the knee joint depends upon hyperextension. This means that knee flexion requires effort. A knee which would provide adequate stability at heel contact and yet flex easily when required would offer a big advantage. No doubt several years hence the present device will seem crude and clumsy; in the meantime it provides a light, strong, and relatively efficient prosthesis.