Some Experience with the Canadian-Type Hip-Disarticulation Prosthesis

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In the year 1953, the Prosthetics Research Group of the then Prosthetic Devices Research Project of the University of California, Berkeley, began a study of fitting and construction techniques for the Canadian-type hip-disarticulation prosthesis. At the time, the device was still undergoing evaluation at the Prosthetic Services Centre at Sunnybrook Hospital in Toronto and seemed to offer definite promise. The group at Berkeley started with attempts to make a prosthesis for a relatively "ideal" case with this type of amputation. As the study progressed, it became increasingly clear that the incidence of this and bordering disabilities was higher than at first had been suspected. As a result, the investigation was expanded to include two more cases for close study, and a number of cases fitted by the limb industry were selected for observation and follow-up.

From this experience, nine cases have been selected for discussion here. Each one highlights some special problem encountered during the study. Although each case is unique in its prosthetic problem, the principles and procedures derived from the cases apply to all cases of similar kind.

CASE DATA

CASE 1

The first case was a young female (age 16 at time of fitting) with a true hip disarticulation. She was strong, athletic, healthy, and willing to devote a considerable amount of time to the study. In addition, she had for a number of years following her amputation used a conventional type of hip-disarticulation prosthesis with excellent results.

Examination showed a stump and pelvis with prominent bony structure and light subcutaneous tissue (Fig. 1), and the weight-bearing area was found to tolerate full body weight without discomfort. The terminal scar extended from a point 3 in. directly below the anterior-superior spine, across the anterior surface of the stump, to a point slightly lateral to and above the perineum. The scar was pressure-sensitive, especially at its lateral end. X-ray showed retarded development of the pelvis on the amputated side and that the ramus sloped downward abnormally from the ischial tuberosity (Fig. 2). The sloping ramus, the sensitive scar tissue, and the rather prominent, lightly padded bony structure were potential sources of difficulty in fitting but served to accentuate the requirements of the fitting procedure for this type of amputation.

From several plaster impressions taken, several plastic sockets were made. The earlier casts of the pelvis and stump were taken with the amputee standing, and the cast was

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Fig. 1. Case 1, anterior view of the stump.

wrapped over the entire pelvis and stump in one operation. No pressure was applied over the weight-bearing area. But this method resulted in sockets so roomy that the bony prominences moved in and out of the recesses

Fig. 2. Case 1, anteroposterior x-ray of the pelvis.

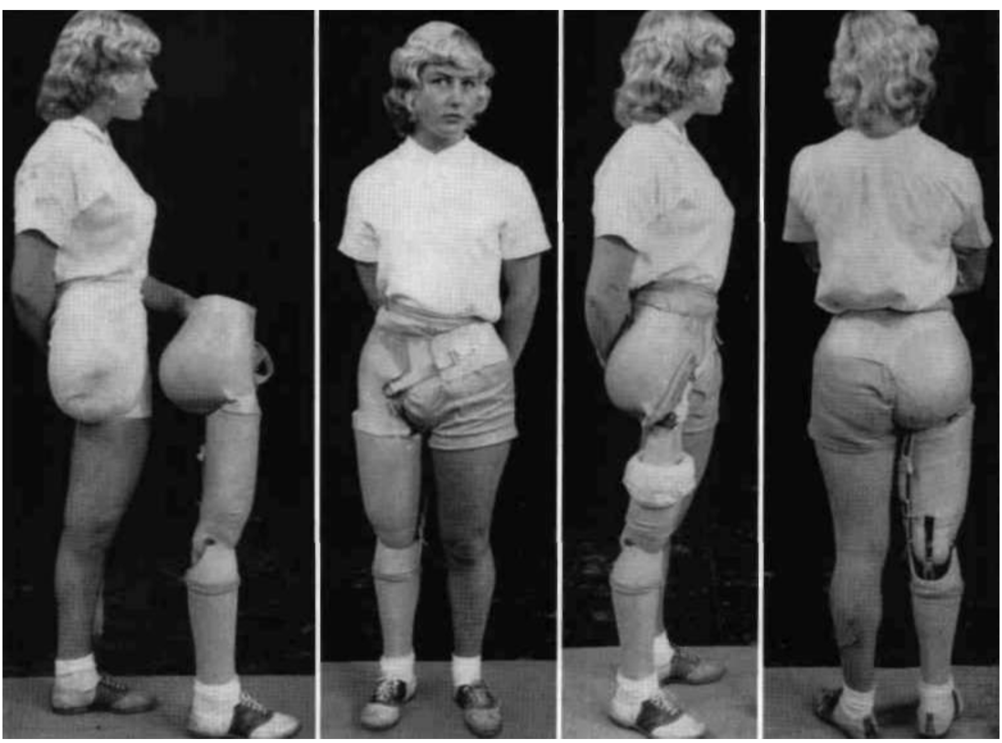


Fig. 3. Case 1, the prosthesis.

provided for them, and the tuberosity moved back and forth over the weight-bearing platform. Finally, the technique outlined in the preceding article (p. 39) was evolved. The cast of the waist area was taken with the amputee supine, the cast of the stump area being taken as a second step and allowed to set with the amputee bearing full weight on it against a hard surface. This procedure aided in keying the body to the socket closely so that relative motion between the body and the socket was minimized.

In order to find the combination of materials that would yield a socket strong enough where stresses were concentrated, yet flexible enough to be put on and removed easily, experiments were made with various combinations of materials. Earlier sockets, using cotton-stockinet reinforcement, were too rigid and bulky and had to be hinged at the back to permit the amputee to don them. As the result of an attempt to achieve flexibility, however, the first flexible socket turned out to be too flexible and sagged in stance phase, thus causing ramus discomfort. Subsequent sockets, made of six layers of dacron tricot and four or more layers of glass cloth to reinforce the general-purpose polyester resin in stressed areas, were successful.

The bony prominences were a problem initially. But through improvement in the cast-taking technique, the relative motion between the socket and the pelvis was reduced and this problem was solved. Once the upper portions of the pelvis were well stabilized in the socket, and once definite ischial-gluteal weight-bearing was established, discomfort of the ramus, discomfort in the area of the scar, and discomfort of the bony prominences were eliminated.

The amputee used the final prosthesis (Fig. 3) only occasionally at first, preferring the greater freedom and mobility she had had with crutches. The tendency for the thigh to flex excessively when sitting in soft seats, as in an automobile, was one feature to which the amputee objected. Gradually, however, she accepted the leg and now uses it extensively.

CASE 2

While the work was in progress on the first amputee, the second, a 56-year-old woman who had recently undergone amputation for a malignancy, was brought into the study. Her general physical condition was satisfactory, but her balance was poor and her activity level low. The stump was extensively scarred in the crotch area and across the anterior surface (Fig. 4). In addition, there were redundant tissue knobs in the same areas. While the bony structure of the pelvis was light, subcutaneous tissue was heavy. X-ray showed an abducted femur which terminated just below the lesser trochanter, well above the perineal level (Fig. 5).

As yet the technique for taking the plaster impression had not been defined satisfactorily, and the cast of the entire pelvis was, here again, wrapped in one operation with the amputee standing, and no pressure was applied to the weight-bearing area as the cast hardened. Although not as dramatically as in the previous case (because of the heavier padding of

Fig. 4. Case 2, anterior view of the stump.

Fig. 5. Case 2, anteroposterior x-ray of the pelvis.

subcutaneous tissue over the pelvis), the same difficulties were experienced with bony prominences moving out of the relief pockets. Ramus discomfort was a problem immediately, there was discomfort from stretching of scar tissue in the crotch, and painful pressure was felt on the pubis. These difficulties were alleviated to some extent by building up the weight-bearing area of the socket, especially under the ischial tuberosity, and by trimming material from the edges of the socket.

But this socket was never really successful. Four layers of dacron, and three layers of glass cloth in the weight-bearing areas, had been used to reinforce the polyester resin, and this combination did not provide sufficient reinforcement to prevent the socket from sagging under load. As a result, there was intermittent ramus discomfort and stretching of the scar tissue in the crotch. While all the problems of fit were not resolved, the amputee was sufficiently well fitted to progress in the use of the limb to a remarkable degree considering her poor balance (Fig. 6). After three hours with the socket on the adjustable leg, she was able to walk using a crutch on one side and the walking rail on the other. After six hours of experience, she was able to walk using a cane, with some support from the trainer. Two more hours enabled her, though with considerable tension, to manage with one cane. With a total of 15 hours' experience, obtained over a three-month period, the amputee could manage stairs and ramps as well as level walking using one cane. At this time the leg was delivered, although proficiency on it was not considered good. Use of the leg at home over the next four months resulted in some improvement, although the patient never became fully independent. About this time medical complications terminated the study.

Fig. 6. Case 2, the prosthesis.

Although the patient was tense and had poor balance, some of the difficulties she experienced on the limb were due to other factors. Partly because of the socket construction, partly because of the scar tissue in the crotch, at no time was the socket really comfortable. In addition, because the shank was too light, and because the hip-flexion control strap restricted knee flexion, it was difficult for her to swing the shank through.

CASE 3

About the time that the technique for taking the plaster impression in two steps had been outlined, the Prosthetics Research Group, cooperating with a local limbshop, helped to fit a 30-year-old housewife with a Canadian-type hip-disarticulation prosthesis. Originally, she was dissatisfied with the Canadian type of prosthesis. The motion at the hip, in addition to poor foot function, was a source of insecurity. But she soon adapted and now much prefers this type of limb to the conventional hip-disarticulation prosthesis. She has worn the prosthesis successfully for three years. During this time she became pregnant. By loosening up the corset as the fetus grew, she was able to wear the prosthesis throughout her term. She wore it to the hospital for her delivery and put it on again five days later to go home. In her daily routine, she cares for her growing family unaided.

The first Canadian-type prosthesis for this patient was provided with a wooden foot with plantar-dorsiflexion ankle and with a 2-in. Cuban heel. But she experienced several falls until the foot was changed to a lower heel (Fig. 7). She has since been provided with a new Canadian-type limb with a high-heel SACH foot and has found the knee stable, even descending a 7- to 8-deg. incline (Fig. 8).

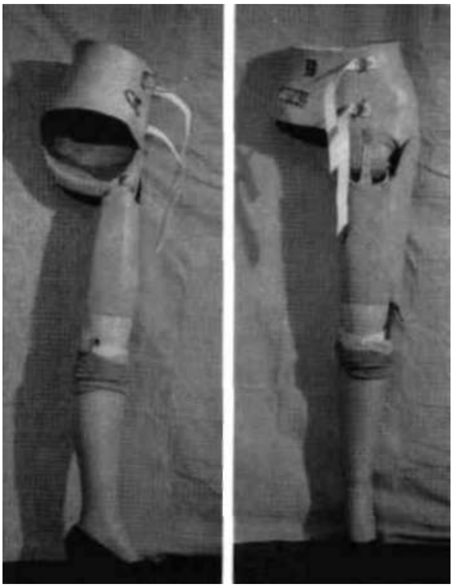


Fig. 8. Case 3, second Canadian-type hip-disarticulation prosthesis provided (with high-heel SACH foot).

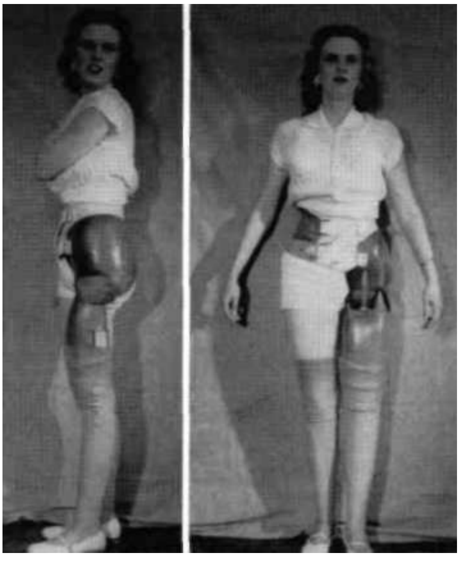


Fig. 7. Case 3, first Canadian-type hip-disarticulation prosthesis provided (after change to low heel).

This circumstance would indicate that the instability on the original limb was due to factors other than the height of the heel, probably to limited range of plantar flexion. One problem the patient reports is that, where an open or projecting type of stair construction is encountered, the prosthetic toe catches under the step. Catching occurs because the leg swings forward from the hip joint when the leg is lifted toward the next step. To prevent catching, the patient restrains the prosthesis manually.

CASE 4

The next two cases were fitted with Canadian-type hip-disarticulation prostheses at about the same time. Case 4, a 15-year-old female, was fitted by the Prosthetics Research Group. Case 5, a 16-year-old male, was fitted by a local limbshop.

Case 4 came to the Prosthetics Research Group three weeks after disarticulation at the right hip had been performed for bone tumor (Fig. 9). In order to enhance this amputee's quick adjustment to the prosthesis and to

Fig. 9. Case 4, anterior view of the stump.

Fig. 10. Case 4, anteroposterior x-ray of the pelvis.

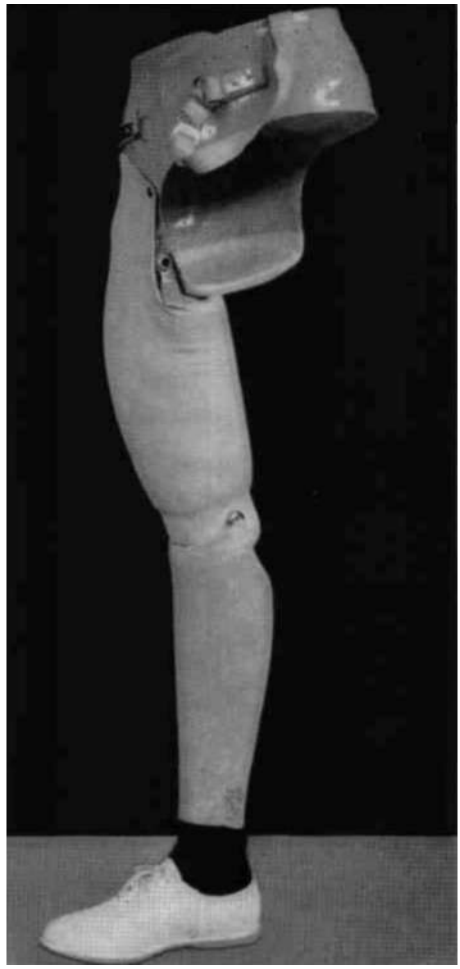
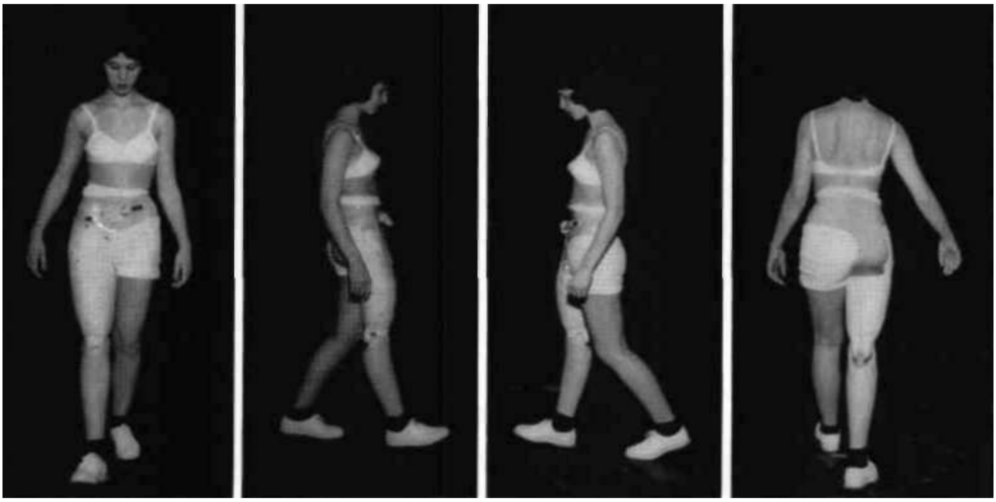


Fig. 11. Case 4, finished prosthesis.

forestall atrophy of the back and abdominal muscles, it had been decided to put her on a prosthesis as soon as the stump would permit. At the time of the initial examination, there was no edema and only limited sensitivity. There was fairly heavy subcutaneous tissue, the bony structure of the pelvis was not prominent (Fig. 10), and muscle padding was substantial. The amputation scar extended from the anterior-superior spine diagonally downward to a point just lateral to and 2 in. below the perineum.

Treatment started a week after examination. The cast and socket were constructed as outlined in the foregoing article (p. 39), considerable tension being applied to the plaster bandage during cast-taking in anticipation of stump shrinkage. It was thought by the study group that performance on a limb of the Canadian type might be more a function of the prosthesis than of the wearer. Little training was given in order to check that hypothesis. After 33 hours of fitting time over a month's period, the prosthesis was finished (Fig. 11) and delivered in time for the summer vacation. During the summer the patient experienced few walking problems and adjusted very quickly (Fig. 12). After vacation, she attended high school fairly regularly throughout the first term and attended her usual social functions, including dancing. By the New Year, medical complications were in evidence, and the study ended a few months later.



CASE 5

Six months after he had undergone amputation following an injury received in a motorboat accident, Case 5 was observed by the Prosthetics Research Group in connection with the Industry Participation Program. The socket had already been made, and the unfinished components were ready for assembly. The stump, in good condition, tolerated full weight-bearing without discomfort (Fig. 13). The short residual femur, which did not extend to the perineal level, was abducted (Fig. 14). Subcutaneous tissue was light, and the bony structure was not unduly prominent.

The plaster cast (Figs. 15 and 16) had been wrapped with the amputee standing, and no pressure had been applied to the weight-bearing area while the cast hardened. The male model of the impression had been taken from the unmodified female cast. On the model, leather spots had been applied over bony prominences, including the iliac crests. The resulting socket, made of semiflexible polyester resin reinforced with glass cloth and cotton stockinet, was attached to the unfinished components of the leg for alignment and adjustments to socket fit.

The residual femur was not a fitting problem and gave no trouble in orienting the hip joint. Up-and-down motion in the socket between weight-bearing and non-weight-bearing resulted in the bony prominences moving in and out of the relief spaces, so that there was discomfort. As the socket was built up over the weight-bearing area, this movement was reduced, and there was a corresponding increase in comfort. No training was given, but the amputee adapted readily.

Because of stump shrinkage, the prosthesis became increasingly uncomfortable over the next six months, and a new leg was required. The new prosthesis (Fig. 17) has a leather-covered plastic socket, a friction-stabilized knee, and a SACH foot. The hip-flexion control strap is attached at either end with machine screws through ball-bearing races. Screw holes at 1/2-in. intervals on the thigh piece allow adjustment of the length of the strap. Up-and-down movement in the socket between weight-bearing and non-weight-bearing is very small—under 1/2 in.

It is of special interest that this prosthesis was suspended not by hooking over the iliac crests but by clamping the socket to the pelvis

Fig. 13. Case 5, anterior view of the stump.

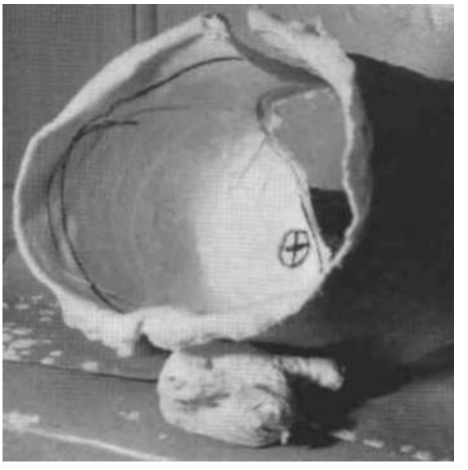


Fig. 15. Case 5, cast from plaster wrap.

Fig. 14. Case 5, anteroposterior x-ray of the pelvis.

Fig. 16. Case 5, plaster trial socket.

between the iliac crests and the greater trochanter. Since the pelvis of a true hip disarticulation narrows below the crest of the ilium, it is necessary to suspend the prosthesis from the iliac crest on the side of the amputation. Where the greater trochanter is present, however, as it is in this case, it projects beyond the iliac crest. The resulting outward pelvic flare from the crest of the ilium to the trochanter makes it possible to suspend the prosthesis between the crests and trochanters. Besides offering effective suspension of the prosthesis, this method reduces confinement of the pelvic area. It may thus be suggested that wherever possible the surgeon should consider leaving some femur in the stump for purposes of suspension.

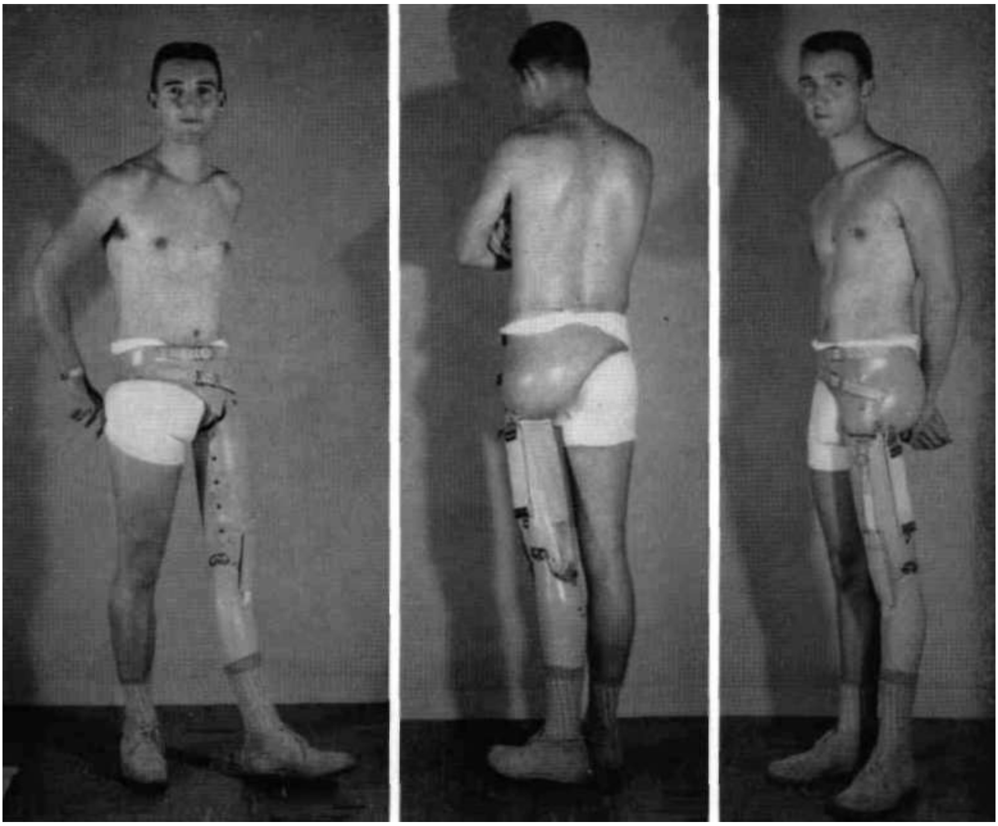


Fig. 17. Case 5, the prosthesis.

CASE 6

The next case, observed in a local limbshop, was a young man 32 years of age whose amputation had left a residual femur extending to just below the lesser trochanter, the distal end almost level with the perineum (Figs. 18 and 19). The femur was abducted 20 to 30 deg. Near the end of the femur the stump was pressure-sensitive and had a superficial trigger point. The femur length and the trigger point presented fitting problems. With sufficient room allowed in the socket for the femur in a relaxed position, and with added space to ensure relief for the trigger point, there was difficulty in locating the joint so that the prosthetic knee would be even with the normal knee in the sitting position. Had the femur been flexed, and the soft tissue in the area under the joint distorted upward, joint placement would have been less of a problem.

The amputee had worn the conventional type of hip-disarticulation prosthesis successfully for 10 years. His first reaction to the Canadian type was one of criticism. He objected to the unyielding nature of the socket around his body and to having the prosthetic knee somewhat farther out and higher than the normal knee in sitting. After a short time on the new prosthesis in the fitting stage, however, he felt much more secure on the new limb than he had on the conventional one. He was impressed by the very positive suspension afforded by the molded plastic socket.

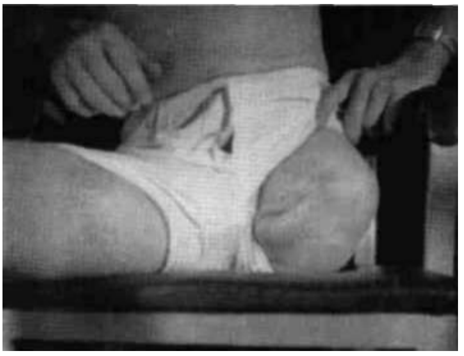


Fig. 18. Case 6, anterior view of the stump.

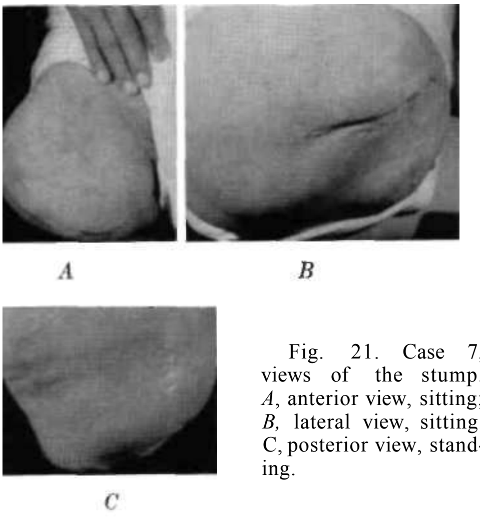
Fig. 19. Case 6, anteroposterior x-ray of the pelvis.

CASE 7

The longest residual femur that the Prosthetics Research Group attempted to fit with the Canadian-type hip-disarticulation prosthesis was in a 37-year-old male. It extended 1 1/2 below the perineum (Fig. 20). Failure to fit this amputee successfully with an above-knee type of prosthesis led to his referral by the Veterans Administration.

The stump was very short and powerful with a sensitive scar in the crotch area (Fig. 21). A trigger point on the anterodistal aspect made weight-bearing intolerable on the end of the stump, and there was a considerable volume change between flexion and contraction of the muscles. On the normal leg the knee was weak and buckled frequently, and a triple arthrodesis had been performed on the ankle joint.

Fig. 20. Case 7, anteroposterior x-ray of the pelvis.



A B C

Fig. 21. Case 7, views of the stump. *A*, anterior view, sitting; *B*, lateral view, sitting; C, posterior view, standing.

Two possibilities for fitting this short stump were considered—suction-suspension above-knee prosthesis and Canadian-type hip-disarticulation prosthesis. Of the two, the suction-suspension method seemed to offer the greater challenge because on the medial side there were only 1 1/2 to 2 in. of stump available for effecting a suction seal. The scar tissue on the crotch was a potential source of discomfort, and the large volume change between tense and relaxed states might make it difficult to maintain a suction seal. Were a Canadian-type prosthesis to be used, the amputee would lose the function of his hip on the side of the amputation. Furthermore, since the patient lived in a very warm summer climate, the enclosing socket of the hip-disarticulation prosthesis might be a trial to wear.

The amputee was first fitted with a plaster socket for the Canadian-type prosthesis as in the method already outlined, the cast being molded with the stump in full flexion. The tissues under the stump, from the gluteal fold out to within about an inch of the end of the femur, were pushed up, thus immobilizing the femur to prevent any rubbing on the trigger point at the end of the stump,[3] and the patient used the resulting check socket comfortably with a peg leg for about two hours. It was clear that this type of prosthesis had possibilities, but one objectionable feature would have been the unnatural appearance of the anterior protuberance for the flexed stump.

Along with evaluation of the Canadian-type prosthesis, a suction-socket above-knee prosthesis also was made and evaluated. Although because of previous disappointing experience with suction sockets the patient had been convinced that suction suspension would fail and had strongly favored the Canadian-type prosthesis, the suction-socket prosthesis was immediately successful and proved a more satisfactory means of treating this case. Confirmation was seen in the patient's increasing activity on the leg over a period of a year.

[3] This indentation in the bottom of the socket would have allowed convenient installation of the hip joint.

CASE 8

During 1957, two hemipelvectomy amputees have been observed in local limbshops. The first was a young woman, 22 years old, whose amputation for a sarcoma removed all of the left portion of the pelvis with the exception of part of the iliac crest (Figs. 22, 23, and 24). Nearly two years after amputation she was fitted with a prosthesis. It is made according to the Canadian design, but the socket is of molded leather with Celastic for reinforcement. The socket is high, embracing the lower portions of the thoracic cage, and laces anteriorly (Fig. 25). The hip joint, 2 in. wide instead of the 3 1/2 in. reported here, is set 2 in. lateral to the medial edge of the socket, a feature which allows it to be positioned farther back toward the weight line, so that in walking over the leg the motion in the hip joint is continuous and smooth.

Weight is carried on the rib cage, the sacrum, and the compressed soft tissues of the amputated side. Up-and-down movement in the socket, approximately 1 1/2 in. between weight-bearing and non-weight-bearing, gives the

Fig. 22. Case 8, anteroposterior x-ray of the pelvis.

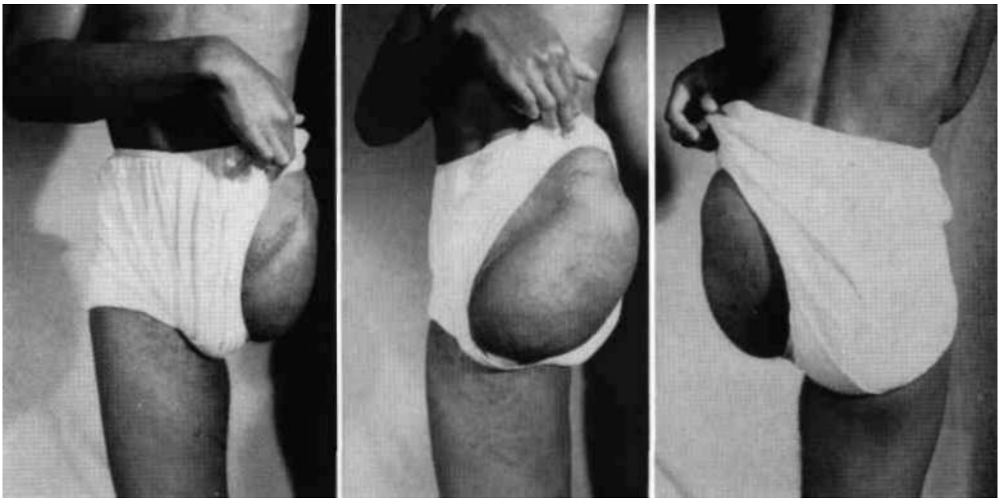


Fig. 23. Case 8, views of the stump.

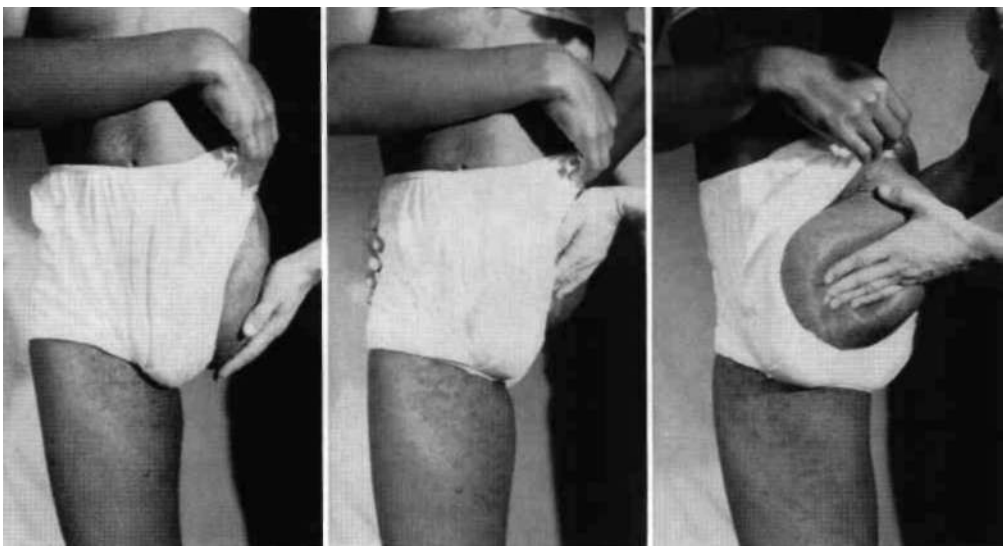


Fig. 24. Case 8, showing gross displacement of soft tissues of stump upon application of pressure. Lack of underlying bony structure prevents satisfactory weight-bearing in the stump area.

amputee the impression that the leg is heavy. But sitting and turning can be accomplished without difficulty (Figs. 26 and 27).

Before amputation this young woman was very active physically. Now she tires easily. Bearing weight on the rib cage greatly restricts her body motion and also limits the amount of food she can eat at any one time. Heat dissipation and perspiration are real problems, so that after only three months of use the leather socket, with its odor, is becoming a hygienic nuisance.

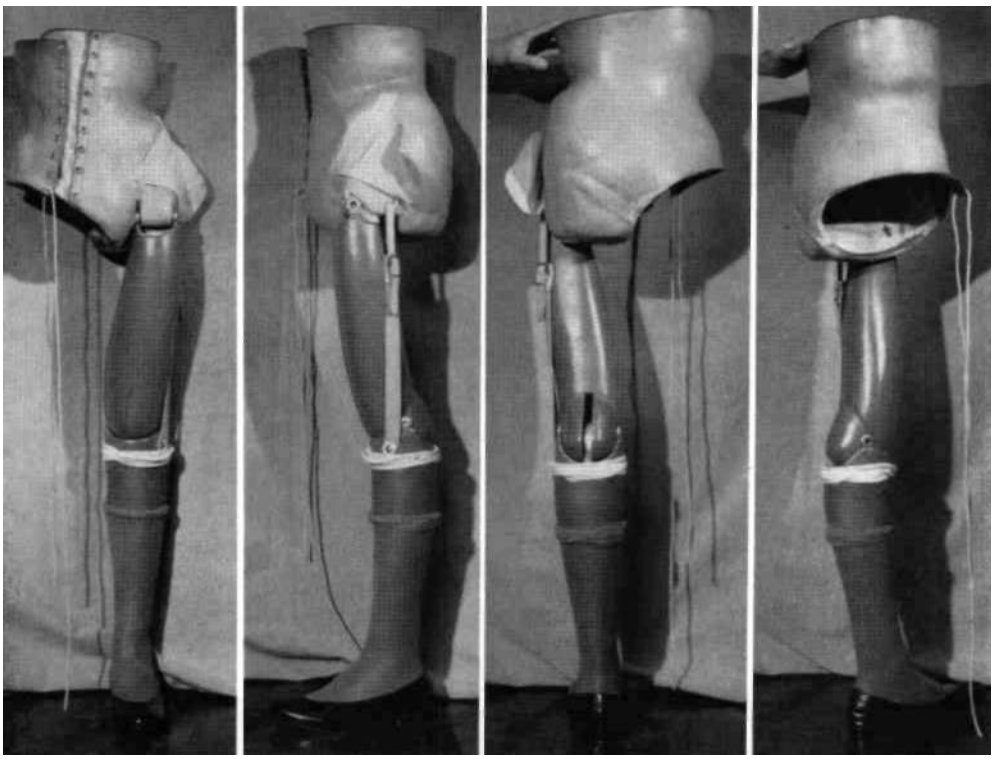


Fig. 25. Case 8, the prosthesis.

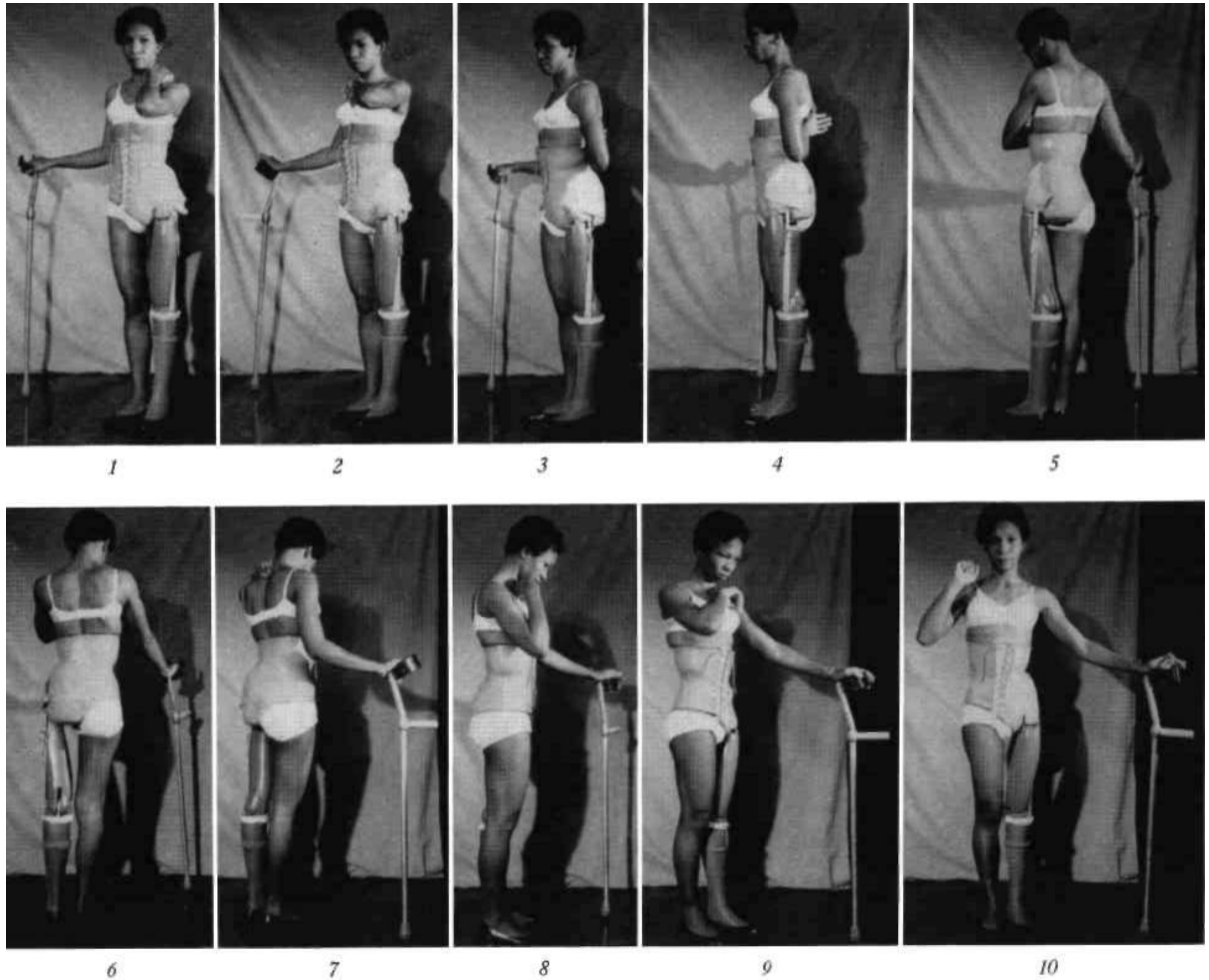
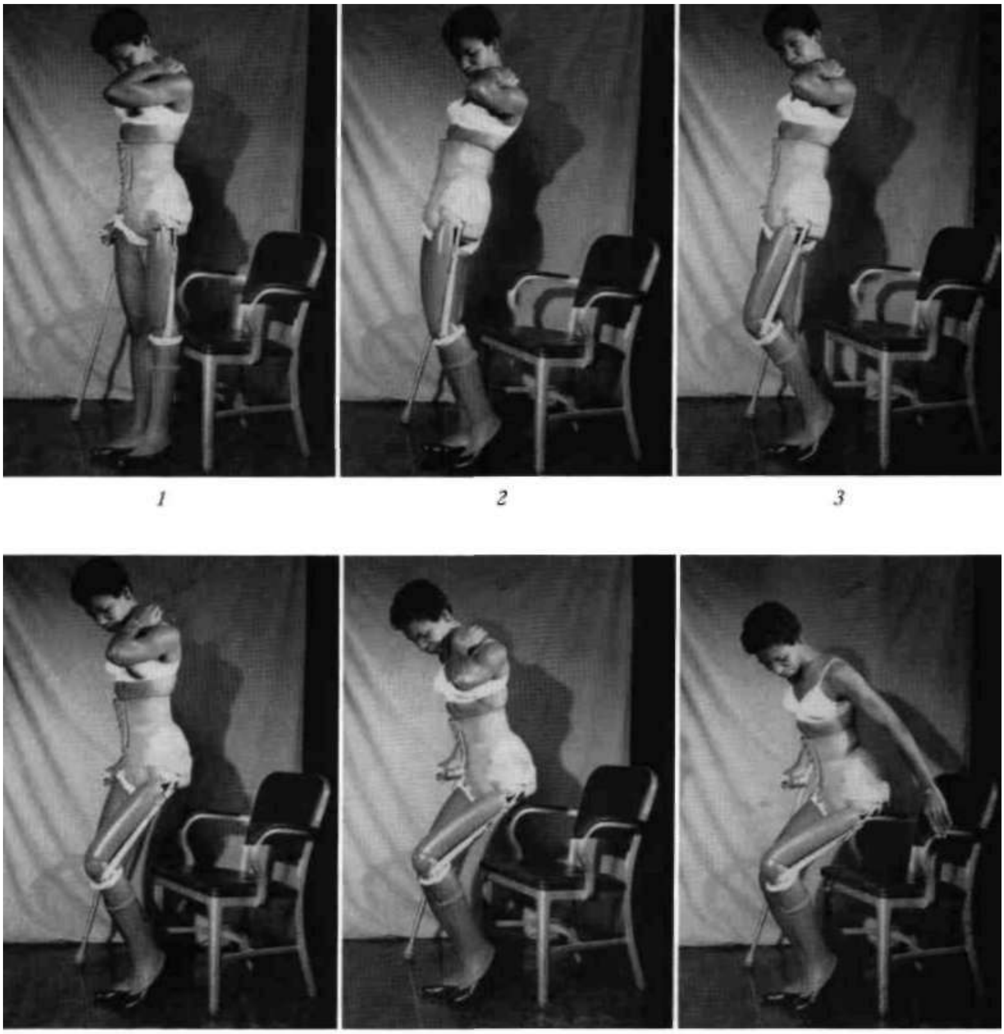


Fig. 26. Case 8, turning sequence.



1 2 3

4 5 6

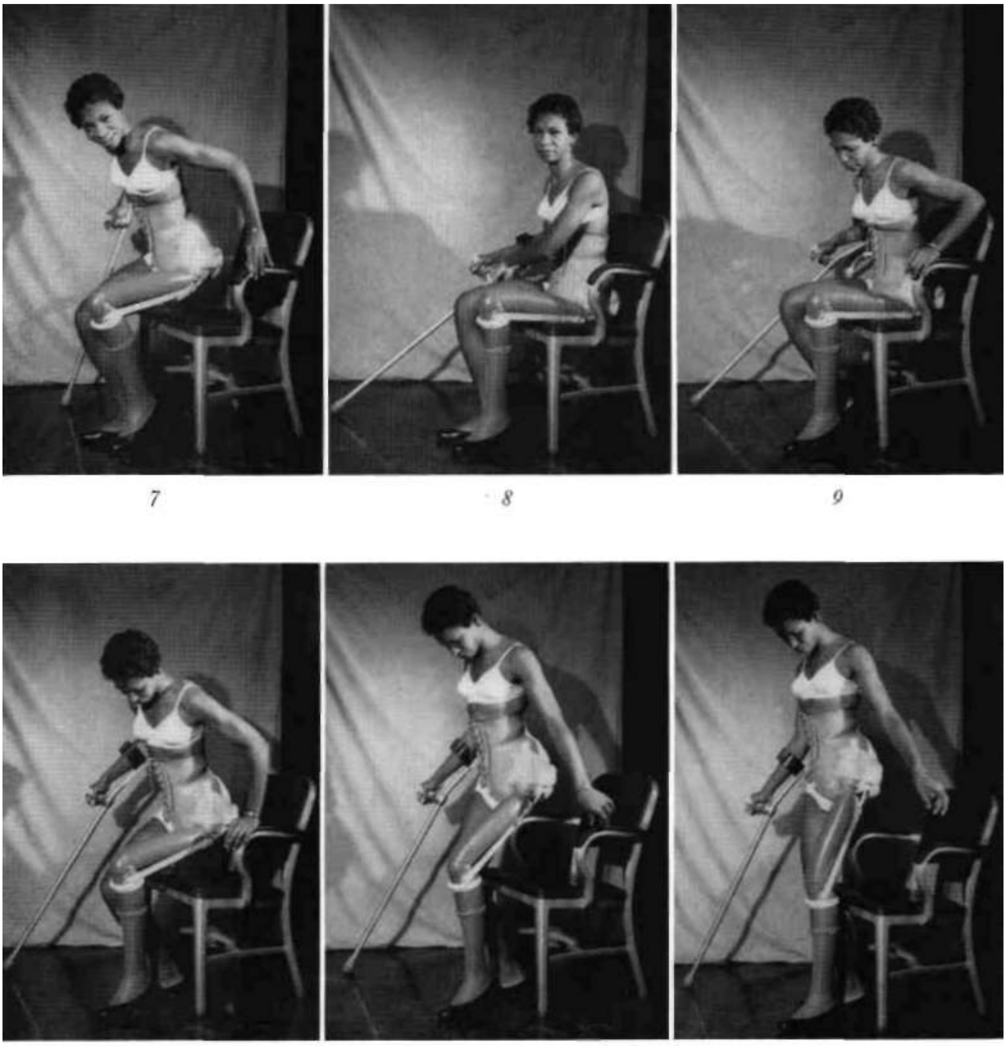
Fig. 27. Case 8, sitting and rising sequence.

CASE 9

The second hemipelvectomy was in a small, agile, and active man of 38, who underwent amputation in January 1957 for a malignancy (Fig. 28). In this amputation the pelvis was disarticulated at the sacroiliac joint (Fig. 29). A Canadian-type prosthesis was made for the patient in May 1957 by a local limbshop and the Prosthetics Research Group cooperatively.

The wrapping for the cast was made with the amputee standing, and pressure was applied by hand under the remaining ischial tuberosity. Although it was planned to put the weight-bearing on the tuberosity if possible, there was no assurance that it could be done. Accordingly, the wrapping was continued well up on to the rib cage.

The wrap-cast was made into a check socket, and a peg leg was installed. When the amputee was checked on it, there was at least 1 1/2 in.



7 8 9

10 11 12

Fig. 27. Case 8, sitting and rising sequence, continued.

of up-and-down excursion in the socket between full weight-bearing and non-weight-bearing. To reduce excursion of the torso in the socket, the ischial seat was built up until the iliac crest was against the suspension hook. As walking trials proceeded, the brim of the socket was cut down from the rib cage to slightly above the crest level. Cutting the socket down freed the upper torso and had no apparent effect on stabilization.

A second check socket, this one of plastic laminate, was fabricated and installed on the adjustable leg. In checking the socket on the amputee, it was found that he was comfortable both in walking and in sitting, but adjustments to the weight-bearing platform had left other areas of the stump without support. To check clearance of the bony prominences, and to see just how closely the socket was contacting the stump, about a dozen 1/4 in.

Fig. 28. Case 9, lateral view of the stump.

Fig. 29. Case 9, anteroposterior x-ray of the pelvis.

holes were drilled through the socket in the sacral area and from the level of the iliac crest down. To check effectiveness of the suspension hook, holes were bored in the socket through the area over the normal crest. As much as 1/2 in. of space was found between the socket and the body in the gluteal region.

Then, with the subject standing in the socket but bent slightly forward, thin plaster was poured into the check socket at the depression of the spinal column. When enough plaster had been poured into the socket so that it began to ooze out of the holes, the holes were masked off, and the amputee stood upright until the plaster had hardened. His immediate reaction was that he felt considerably more stable in the socket and that he had better suspension. After an hour's check for walking and sitting comfort, there were no further complaints. On the male mold made from this socket, the brim was undercut all around to increase the flare, which had been insufficient on the plastic check socket.

The final socket was fabricated from five layers of dacron with ten layers of glass cloth for reinforcement, especially across the weight-bearing area. Three layers of glass cloth were extended up to the level of the iliac crest on the side of the amputation, and two layers were brought up around the crest on the sound side. The socket did not overlap in front, but the anterior section was cut out between the mid-line and the crest on the normal side and a leather lacer was substituted. The final prosthesis (Fig. 30) was very satisfactory, and after two hours of walking between the bars the amputee was able to walk on a flat surface without the aid of canes or crutches.

This man reports that he has worn his prosthesis continuously every day for the past six weeks. An expediter for a manufacturing concern, he is required to do much sitting, and

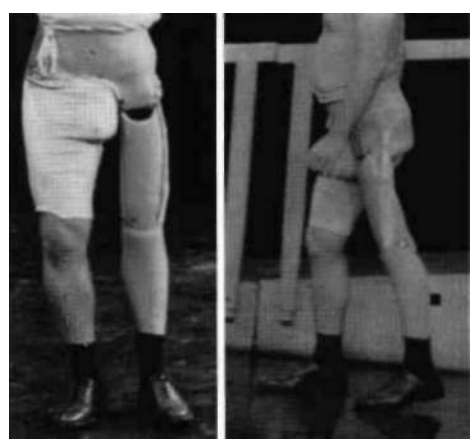


Fig. 30. Case 9, the prosthesis.

he finds that the balancing action of the prosthesis in sitting greatly reduces fatigue.

On the basis of their experience with the case, the prosthetists concerned felt that at another time they would begin the plaster wrapping from the bottom and sit the patient on a solid object shaped to give firm contact under the tuberosity, an expedient which would concentrate the forces there. With the amputee still sitting, the wrapping would be continued upward over the crest of the ilium and around the waist, thus keying the pelvis to the cast.

Making the plastic check socket was considered a very useful part of the procedure because it showed up a number of socket faults not easily found with the plaster-wrap socket and peg. Part of the reason was that using the check socket with the adjustable leg rather than with a peg allowed the socket to be checked under conditions closer to those of the finished prosthesis.

SUMMARY

The experience of the Prosthetics Research Group to date indicates that the Canadian-type hip-disarticulation prosthesis is highly satisfactory. Gait is fairly natural as a result of hip-joint action in the last part of the swing phase and in the first part of the stance phase. Elimination of a hip lock through arrangement of the joints allows the amputee to stoop, squat, and sit voluntarily without reference to manual controls (Fig. 31). The broad hip joint has proved very durable. No cases of hip-joint failure or wear have been seen thus far. The plastic-laminate type of socket has proved durable. Resistance to perspiration and ease of cleansing make the socket odor-free, and the relatively unyielding molded socket allows comfortable, efficient transfer of forces between the torso and the prosthesis.

Disadvantages of the prosthesis include the tendency for the hip to flex excessively when the amputee sits in soft seats and for the prosthetic toe to hook under overhanging steps. Another inherent disadvantage is that the speed with which the amputee can walk is limited by the characteristics of the compound-pendulum system of the leg. Available control mechanisms do not offer substantial improvement. In sitting, hip flexion can be restricted by a stop between the socket and the top of the thigh, although this expedient limits the amputee in such maneuvers as squatting, or the amputee can prevent excessive hip flexion by crossing the prosthetic shank with the normal shank so that the prosthetic forefoot is restrained by the back of the normal shank (Fig. 32).

Fig. 31. Action of the Canadian-type hip joint in sitting and bending.

Fig. 32. Method of preventing excessive hip flexion during sitting. Normal shank restrains artificial shank.

Amputees who are accustomed to using a conventional prosthesis with a hip lock find the sensation of the free hip joint disturbing at first. Adaptation is rather rapid, however, at least for well-coordinated amputees. New cases do not sense the hip joint as a source of insecurity. Adaptation has been very rapid even in cases where a training program has been omitted.

For the hip-disarticulation amputee, the place of the Canadian-type prosthesis has been definitely established. Moreover, indications are that it can be applied successfully to borderline cases in the category "hip disarticulation." The two hemipelvectomy amputees studied have exhibited a degree of insensitivity to socket pressure that would not have been thought possible and have shown an astonishing level of ability on the prosthesis considering the extent of anatomical loss. In the case of the short-stump above-knee amputee, the aim must be to conserve all possible function compatible with making the amputee ambulatory in a comfortable and effective manner. More than 1 1/2 in. of tissue below the perineum would suggest that suction suspension should be attempted. If the stump is flexed, the Canadian-type prosthesis may be used, although remaining function is then sacrificed and cosmetic problems are introduced.

Components used with the Canadian-type hip-disarticulation prosthesis have included both standard and friction-stabilized knees and standard as well as SACH feet. The single-axis knee with friction for swing-phase control has been found satisfactory. Knee stability is adequate at heel contact if the leg is properly aligned, and there is the advantage that the knee can be flexed easily at the beginning of the swing phase. In the last analysis, consideration of biomechanical principles and of individual amputees' requirements serves as the best guide to selection of components.

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