

# Some Experience with Prosthetic Problems of Above-Knee Amputees

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FOR almost a dozen years the University of California has been active in prosthetics research. On the recommendation of the then Committee on Prosthetic Devices (now the Prosthetics Research Board) of the National Research Council, there was established in 1945, with the cosponsorship of the School of Medicine in San Francisco and the College of Engineering in Berkeley, the Prosthetic Devices Research Project (now the Lower-Extremity Amputee Research Project), a program designed primarily for the purpose of conducting studies in several areas of importance to leg amputees, especially fundamental studies of the processes of human locomotion. Supported on a continuing basis with funds supplied by the Veterans Administration, the work has from the beginning been under the supervision of Howard D. Eberhart, Professor of Civil Engineering, and Verne T. Inman, Professor of Orthopedic Surgery.

In the course of fundamental research, the need for experimental devices required the activation of an engineering design group, and consequently a small staff of design engineers,

draftsmen, and technicians has been active since 1948. This group, working with the fundamental study groups, research prosthetists, and amputee subjects, has designed improved prosthetic devices, developed mechanical aids to fitting and alignment, and assisted in the application of well-known principles of engineering mechanics to the problems of fitting and aligning lower-extremity prostheses.

As correlation of the results of the various fundamental study groups progressed, and as the engineering design group developed improved devices, it became increasingly apparent that, in order to make their results useful to the members of the medical profession and to prosthetists serving amputees, a program of amputee application was indicated. Accordingly, there was organized in the spring of 1953 a Clinical Study aimed at providing increased opportunity for application of research results to the solution of typical prosthetic problems of leg amputees. The work in fundamental research had studied the "man"; the Clinical Study was needed to consider the "man-machine combination." Its objectives were to evaluate current prosthetic practice and to develop improved procedures where needed, to establish basic principles of fit and alignment for all levels of lower-extremity amputation, to evaluate medical and prosthetic factors in the rehabilitation of amputees, and to develop methods for evaluation of lower-extremity amputees and their prostheses.

An immediate outgrowth of the Clinical Study was an increasing awareness of the need for additional research directed toward the solution of the medical problems of the amputee. At the present time, the Medical

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Division of the Lower-Extremity Amputee Research Project, located at the Medical Center in San Francisco, includes groups active in the fields of stump dermatology, amputation surgery, skeletal changes, energy, neuro-anatomy, psychology, and the physiology of pain. The Clinical Study provides an opportunity for the solution of the prosthetic problems associated with the medical studies and also of the purely prosthetics research problems connected with better materials and improved techniques of fitting. To date, most of the experience has been had with above-knee amputees, as here reported, although more than 100 patients, presenting all levels of lower-extremity amputation, are currently under study.

#### PROCEDURES

Each amputee processed through the Clinical Study has certain unique problems, and each must therefore be considered on an individual basis. Initially, it was thought that it would be possible to process amputees in certain rather loosely defined groupings—such as "short-stump above-knee," "long-stump below-knee," and so on. But this procedure has not been found practical since each amputee is referred to the study as his particular problem arises. Largely because of the attendant requirements of time, travel, and inconvenience, it is difficult to induce an amputee to become a research subject when he considers his prosthesis to be comfortable and well fitted. The cases reported here have almost without exception been referred to the Clinical Study as "problem cases" and have had chronic difficulties upon referral. The sample does not, therefore, necessarily indicate a typical cross-section of the amputee population. The prosthetic problems of the group as a whole, however, constitute what we believe to be a rather common group of problems facing above-knee amputees.

Each amputee referred to the Clinical Study is given a preliminary examination for the purpose of obtaining information as to the nature of his problems, if any. The preliminary examination includes:

1. An interview with an amputee specialist (*i.e.*, a trainer). The amputee specialist obtains a brief prosthetic history, explains the research program to the amputee, and records personal data.

2. Medical examination by an orthopedic surgeon. The orthopedic surgeon obtains a brief medical history and endeavors to classify the major complaints of the amputee.

3. Prosthetic evaluation by staff prosthetists and other specialists. A group consisting of three or more people examines the amputee's stump, his prosthesis, and his performance in order to analyze the fit, alignment, and functional behavior of the amputee with his prosthesis.

The results of each of these examinations are recorded in the form of a written memorandum report. Upon completion of the reports, a group discussion is held for the purpose of making recommendations as to the further handling of the case. For example, it may appear on preliminary examination that a particular amputee has a severe skin infection of unknown origin. In such a case, the recommendation might be to refer the patient to the Skin Study Group at the Medical Center in San Francisco before considering any work directed toward improving fit and alignment.

Certain cases considered to be of interest to the research staff as a whole are referred to the Amputee Conference held at the Medical Center, San Francisco, on a regularly scheduled weekly basis. Amputees may be referred to the Amputee Conference by medical study groups as well as by the Clinical Study Group. Attendance at the conference is limited to University of California staff members, and not more than three amputees are presented for discussion at any one session. The Amputee Conference provides an opportunity for presentation of the results of the preliminary examination and, thereafter, a general group discussion. At this time a general plan of treatment, including broad research objectives, is formulated.

If an amputee is accepted by the Clinical Study as a case of research interest, a more complete medical examination is required. Cases referred to the Clinical Study from the medical study groups or the Amputee Conference have usually been examined at the Medical Center prior to referral. The complete medical examination includes routine clinical tests, plus x-rays of the stump and pelvis.

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consisting of an orthopedic surgeon, a prosthetist, an engineer, and an amputee specialist. The team discusses research objectives in detail, writes a prescription for one or more phases of prosthetic treatment, and lays out an estimated schedule. A report is then written summarizing the discussion and recommendations, and the team meets periodically, as necessary, to review progress and to make further recommendations. Each phase of the treatment of the amputee is reported in a memorandum which becomes a written record of progress. Permanent records embrace medical records, including x-rays; evaluation records, including evaluation forms and 16-mm. motion pictures (100 ft. per evaluation); black-and-white still photographs; 35-mm. color transparencies; and memorandum reports on plans and progress.

#### GENERAL PRINCIPLES OF ABOVE-KNEE PROSTHETICS

As already noted, one of the major objectives of the Clinical Study was to provide the means for additional amputee trials of certain principles of fitting and alignment which had been evolved during several years of fundamental research, evaluation of current practices, and amputee trials but which had been developed with a limited number of amputee subjects. The technique of fitting the suction-socket prosthesis to an above-knee amputee has been reported by the University of California in a series of publications (1,3,4,5,7,8,9,10) which have been revised periodically as new knowledge and techniques became available. The latest article (6) stressed the interdependence of the shaping and fitting of the socket and the biomechanics of alignment of the prosthesis. A rational basis for planning and fitting the above-knee prosthesis was presented. All of the patients reported upon in the present paper were fitted in accordance with these principles. It is therefore well to offer here a brief summary of the more important considerations.

The prosthetist is undoubtedly *the* person on the prosthetics team with the heaviest responsibilities. His skill with his hands is largely responsible for the eventual rehabilitation of the amputee. But in carrying out his assignment of providing the amputee with a

satisfactory prosthesis, he is faced with something of a dilemma in the establishment of an order of procedure. In order of importance, he must provide the amputee with, first, comfort; second, function; and third, appearance. It can be argued that he should approach the solution of these problems in reverse order if optimum results are to be achieved. Actually, there are two separate and distinct phases of equal importance in the fitting of a leg prosthesis—the planning phase and the construction phase. It is during the planning phase that the objectives listed above should be considered in the reverse order. One of the principal reasons for failure to achieve optimum results in the fitting of a suction-socket above-knee leg is lack of appreciation of, and hence failure to formulate, a working plan before beginning the construction of the prosthesis.

In order properly to plan the fitting and alignment of a prosthesis, the clinic team must have in mind a rational sequence which will eventually result in a satisfactory fitting for the amputee. The order of the sequence is necessarily dictated by the type of problem to be solved at a particular stage. Let us consider, for example, the case of a typical leg amputee. During the medical and prosthetic examination by members of the clinic team, a careful analysis is made of the patient's potential as a wearer of a prosthesis. This analysis includes classification as to stump type, stump length, activity level, habit patterns, and special medical factors. It dictates in general terms the type of alignment to be incorporated in the amputee's prosthesis (Fig. 1).

The alignment of the prosthesis will in large measure establish the gait pattern of the amputee, assuming of course that he has been trained to use his prosthesis in a manner consistent with its alignment. A leg amputee can walk efficiently with a symmetrical, narrow-based gait only if his prosthesis has been planned and constructed to achieve such a gait pattern. The type of alignment also affects the manner of fitting the socket. An amputee walking with a narrow base may require a distribution of contact forces between stump and socket entirely different from that of an amputee walking with a wide base (*i.e.*, abducted gait).

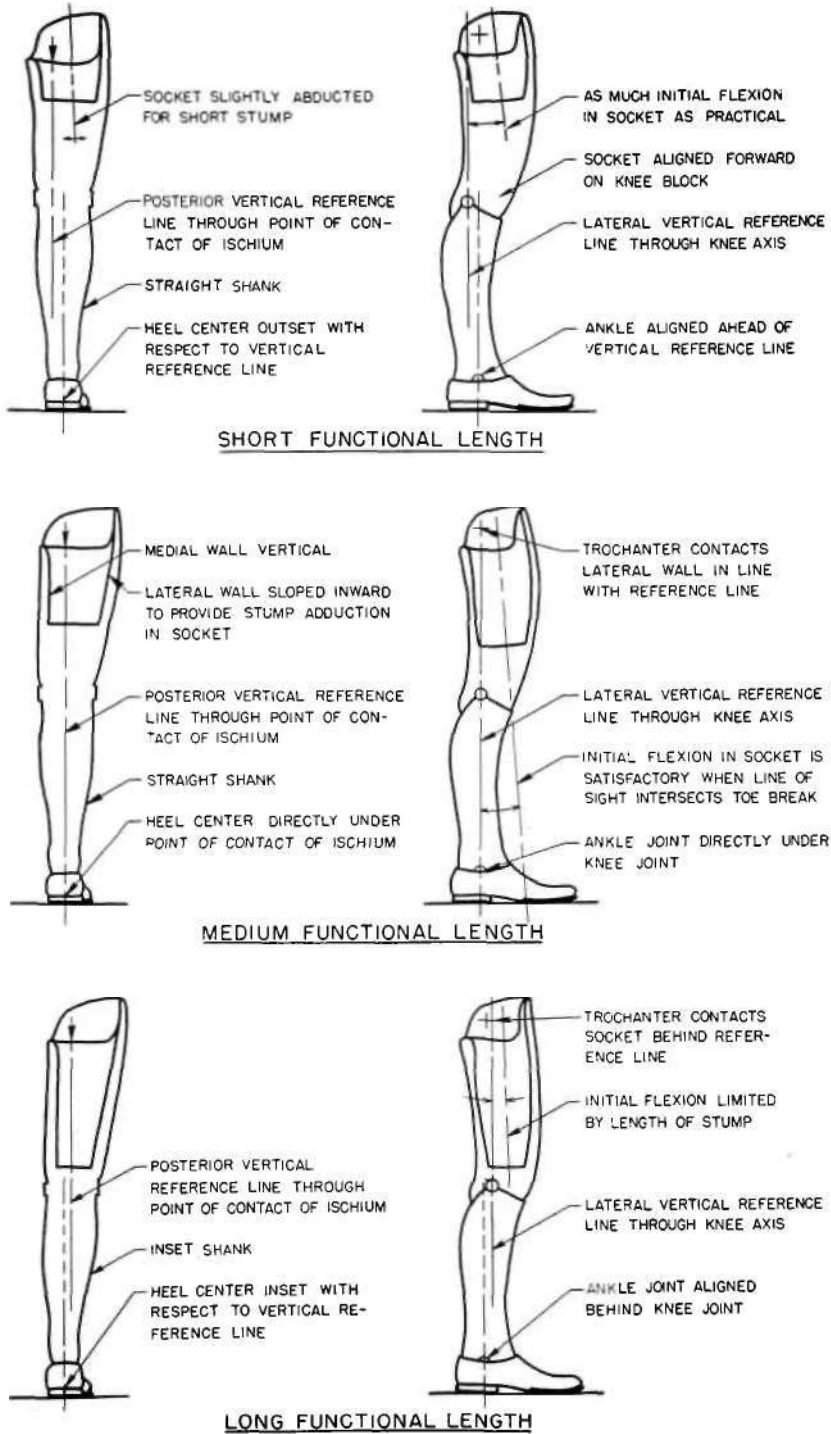


Fig 1. Variations in alignment to accommodate stumps of different functional lengths. With the short stump, the slow or hesitant walker, having limited use of the hip abductors and extensors, needs considerable alignment stability. The moderate walker, with stump of medium functional length, has average use of the hip abductors and extensors. Alignment for the long stump is for an active walker having good use of the hip abductors and extensors. These figures serve as a guide to typical features of alignment once the amputee has been classified After Radcliffe (6).

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The distribution of stump-socket contact forces is determined by the functions the socket must perform, the major functions of a typical above-knee suction socket being as follows:

1. Suspension of the leg in the swing phase of walking. This requirement dictates that an airtight seal be maintained between stump and socket, especially in the proximal third of the stump.

2. Vertical support of body weight in the stance phase. The only efficient areas of an above-knee stump for weight-bearing are the ischial tuberosity and the gluteus maximus. Attempts to use for weight-bearing in a suction socket the attachments of the adductor musculature in the perineal area have been unsuccessful. Almost without exception this procedure leads either to painful pressure on the pubic ramus or to skin irritation where there exists a definite roll of adductor musculature over the medial brim of the socket.

3. Stabilization of the ischial tuberosity on the posterior brim (ischial seat) of the socket. Failure to provide stabilization of the tuberosity will allow the pelvis to slide forward and down into the socket, a circumstance which causes chafing and irritation of the skin under the ischial tuberosity and, in addition, is a major source of crotch discomfort.

4. Provision of effective stump reaction points for utilization of hip musculature on the side of the amputation. Any attempt to use the hip musculature either for control of the torso above the hip joints or for control of knee-joint movements below the hip joint will require that the stump transmit a moment, or torque. For lateral stabilization of the torso, there is required a pair of mediolateral reaction forces equal in magnitude but opposite in direction—one acting on the lateral side of the stump, concentrated in the lower third, and a second acting horizontally against the medial side of the stump in the upper third. During those times when the stump acts to maintain knee stability by active stump extension, the reaction points are against the posterodistal and the anteroproximal areas of the stump.

On the basis of these functional requirements, the quadrilateral shape of suction socket shown in Figure 2 has been developed. It not only conforms to the anatomical skeleton and musculature but also provides the four functions already listed—suspension, support, ischial stabilization, and torque reaction points.

Thus far the objectives of appearance and function have been accounted for. It has been

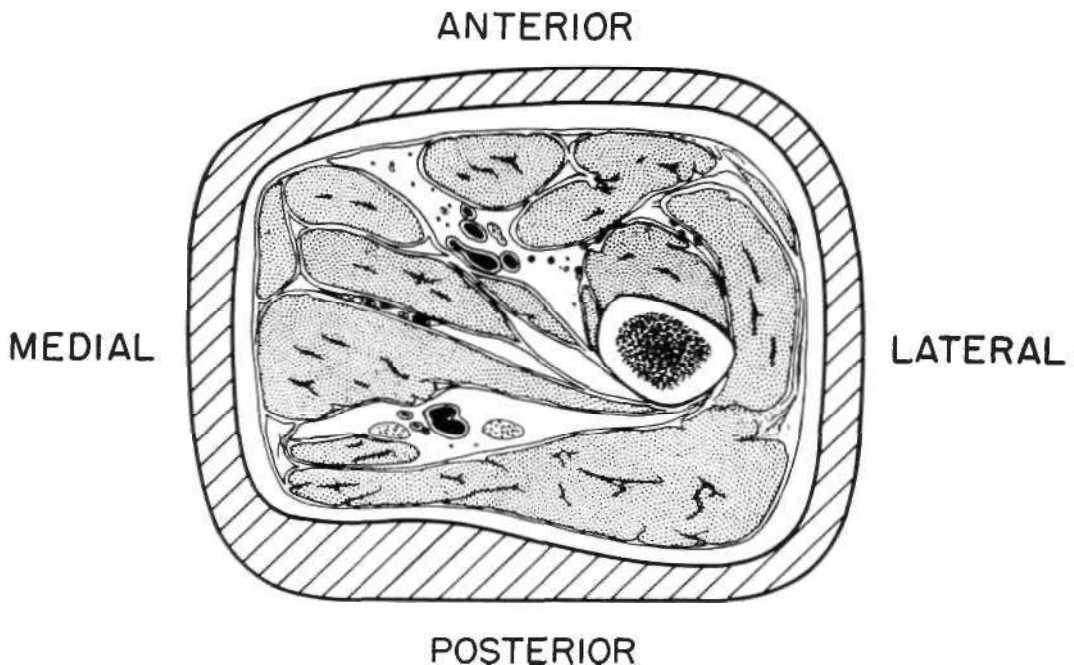


Fig. 2. Quadrilateral shape of suction socket, as developed at the University of California, showing anatomical features of an above-knee stump in weight-bearing. Cross-section 1/2 in. below ischial level. After Radcliffe (6).

stated that appearance is determined by proper alignment and use of the prosthesis and that function is dictated by proper alignment accompanied by a rational design of socket to provide the necessary accommodation of stump-socket forces. These concepts can be restated in the following two principles:

1. Gait and alignment establish a definite pattern of stump-socket forces.
2. The force pattern, in combination with anatomical proportions, dictates a rational design of socket of a generally quadrilateral shape.

The third objective is to provide a completely comfortable socket which will be consistent with the functional requirements and yet allow the amputee to use his prosthesis for long periods. Comfort is achieved by application of three additional principles:

1. Relative motion or rubbing between stump and socket should be held to a minimum.
2. Stump-socket contact forces can never be eliminated. Contact forces can be tolerated most comfortably if distributed over a large skin area.
3. Where a contact force must be transmitted in an area of the stump involving both soft and firm tissues, a uniform distribution of the contact pressure is accomplished by a proportionately greater distortion of the softer tissues.

Application of the three principles relating to comfort have resulted in four features of socket shape at the brim that are of particular importance:

1. The anteroposterior dimension of the socket must be determined with considerable accuracy from skeletal measurements. Any error in this dimension will be reflected in improper placement of the ischial tuberosity on the posterior brim of the socket.
2. To ensure distribution of vertical support over the entire posterior brim (*i.e.*, to achieve ischial-gluteal weight-bearing), a rather flat posterior contour with a flare in the gluteal area is required.
3. An anterior wall extending into the inguinal area (the high front), when used with the proper anatomical dimension, is extremely efficient in stabilization of the ischium on the ischial seat.
4. A definite protuberance into Scarpa's triangle (the adductor area extending downward into the socket), accompanied by a channel to fit the belly of the rectus femoris, is necessary to ensure a uniform pressure distribution and an airtight seal across the anterior brim of the socket.

The following cases have been selected as illustrative of typical problem cases and as

being informative to others engaged in the rehabilitation of above-knee amputees. Treatment was not completed in all cases because considerable improvement over the previous condition sometimes caused the individual to believe the optimum had been reached and to be reluctant to devote additional time. The cases are in general indicative of the kind of results that can be obtained under the team approach to the problem of amputee rehabilitation.

#### SOME ABOVE-KNEE CASES

##### CASE 1, LOWER THIRD OF THIGH

###### *History*

Case 1, a male, was 32 years of age, measured 5 ft. 8-1/2 in., and weighed 190 lb. His left leg had been amputated above the knee in October 1944 as the result of a wound. He was employed as a civil engineer. For two years after the amputation, he received intermittent physical therapy and exercise before being fitted with a conventional prosthesis with pelvic belt. The patient's second and third prostheses were similar. His fourth prosthesis, also a pelvic-belt leg, was worn with fair results for 18 months. It was then converted to suction suspension in an unsuccessful attempt to increase comfort. The fifth prosthesis, also suspended by suction, was worn for a year with continuous stump trouble before the amputee was finally hospitalized.

The patient was referred to the clinical-study program in November 1953 following hospitalization for severe edema precipitated by his suction-socket prosthesis. Treatment consisted of remaining off the prosthesis during and immediately following hospitalization.

###### *Examination and Evaluation*

The stump was 12 in. long, with limited tolerance to weight-bearing on the end. Subcutaneous tissue was light and musculature soft, with some bunching of the hamstrings and slight atrophy at the distal end. X-ray showed a healed but laterally displaced fracture of the distal 5-1/2 in. of the femur. The end of the femur was slightly rounded, was closed with new bone growth, and had a small medial spur. Approximately half an inch of muscle padding

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lay over the end of the femur. The ischial tuberosity was well padded, and the general health of the amputee was excellent.

When the patient was admitted to the hospital, the end of his stump was severely edematous, open, and weeping. At the time of entrance to the study program, there was still some weeping and edema, and the end of the stump was discolored (Fig. 3).



Fig. 3. Case 1. Condition of the distal end of the stump on referral.

Follicular lesions were apparent in the area of the inguinal crease and of the crotch, and a small, healing abscess existed on the anteromedial portion of the stump 5 in. below the groin. Some rawness and irritation were still apparent in the crotch area. The distal area of the posterior aspect of the stump was tender, and there was a moderate adductor roll.

Examination of the socket fit showed constriction of the stump, especially in the upper third. Weight was carried on a flesh roll at the brim of the socket (Figs. 4 and 5).

#### Treatment

Interest in the case centered around the edema, roll formation, and skin problems, including discomfort in the crotch. Ischial-gluteal weight-bearing, with increased area of support at the anterior wall, particularly in the upper third, was expected to eliminate crotch discomfort, skin lesions and irritation, roll formation, and constriction of the proximal portion of the stump. A snug fit of the socket in the upper third was required to reduce the adductor roll, and a close fit of the distal two thirds of the stump was required to reduce remaining edema and to maintain fit as the edema subsided.

The amputee was provided with a suction-socket prosthesis using a Navy above-knee set-up (11,12), including the variable-cadence knee, the functional ankle, and the sponge-rubber toe. The socket was made of willow wood reinforced with rawhide and finished

inside with cellulose acetate lacquer, and an automatic expulsion valve with standard spring was used. A flat, leather-covered, sponge-rubber pressure pad was placed in the bottom of the socket to provide back-pressure on the edematous tissue at the end of the stump.

No special provision was made for relief of the adductor roll. The anterior wall provided no protuberance over the femoral triangle, and there was no special relief for the displaced section of the femur. The perimeter of the socket was 2-1/4 in. less than that of the stump

at the proximal end, 3/4 in. less at the mid-stump level, and equal to that of the stump at the end. The distance from the channel for the tendon of the adductor longus to the ischial seat was 4-1/2 in., the corresponding anatomical dimension being 3-3/4 in. This difference between medial socket width and anatomical measurement was subsequently found to be a major source of difficulty. Current practice is to have the medial width of the socket compare very closely with the anatomical measurement.

Prosthetic evaluation showed some instability of the knee in ramp descent owing to reduced range of plantar flexion. Although there was drop-off at the end of the stance phase because of the soft dorsiflexion stop and the soft, sponge-rubber toe, the amputee's performance was excellent.



Fig. 4. Case 1. Prosthesis worn prior to referral.



Fig. 5. Case 1. Shape of socket of prosthesis worn prior to referral.

During the final fitting, the end of the stump turned red, but a sponge-rubber pad placed in the bottom of the socket improved stump color markedly within two hours. One week after delivery of the prosthesis, the edema was reduced; three weeks after, there was no edema; nine months after fitting, some edema was evident at the distal end of the stump.

Evaluation indicated that the ischial tuberosity was sliding anteriorly off the ischial seat so that the stump was settling deeper into the socket, with increased constriction at the proximal end. Several factors were involved. The stump had shrunk, and the anteroposterior dimension of the socket, especially in the medial third, which had been too great initially, had been increased in an unsuccessful attempt to relieve discomfort in the inguinal crease and in the weight-bearing area of the stump. The edema was confined to the areas of the stump which extruded into the valve recess and into the gap between the pad and the socket walls. The valve recess was lowered, the pad was refitted so that more weight was carried on the end of the stump, and the space between the pad and socket walls was eliminated. The edema cleared up.

Roll formation over the anterior brim of the socket was eliminated through extension of the anterior wall of the socket above the level of the ischial seat. The adductor roll was completely contained within the socket. Tightness of fit in the upper third was a source of minor discomfort immediately, but this problem decreased with reduction of the roll, which was complete within six months (Fig. 6).

Follicular lesions in the area of the crotch and the inguinal crease quickly cleared up with reduced forces from the socket brim and elimination of roll formation over the brim. One year after treatment began, the discoloration at the end of the stump was markedly decreased. Irritation of the skin over the posterior brim was a persistent problem directly related to decreased effectiveness of ischial-gluteal weight-bearing and wedging of the posterior aspect of the stump against the inside edge of the posterior brim of the socket. Attempts to increase weight-bearing on the distal end of the stump showed that the amputee preferred

ischial-gluteal weight-bearing because of discomfort experienced on the stump end with prolonged support of body weight.

Reduced support on the ischial tuberosity followed stump and socket changes and caused discomfort on the ramus. The medial brim of the socket was lowered to provide relief. This expedient was partially successful, but the stump sank deeper into the socket after wear, and ramus discomfort has recurred.

### Summary

The problems of edema, roll formation, skin lesions, and discomfort in the crotch were studied. Edema was originally caused by a tight fit of the stump with constriction of the proximal end. Definite ischial-gluteal weight-bearing, with increased area of anterior support, was the primary factor in clearing up the edema. A pressure pad under the end of the stump helped to reduce the edema. Stump and socket changes which allowed the ischial tuberosity to slide into the socket, with wedging of the stump proximally, caused edema to recur. Improved fit of the pressure pad, with increased end-bearing, cleared up the edema. The adductor roll was brought about by weight-bearing in the crotch on the tight socket. Ischial-gluteal support, adduction of the femur in the socket with relaxation of the adductors, and extension of the medial brim to the level of the ischial seat, without provision of a relief pocket, eliminated the adductor roll. Discomfort due to tightness of fit for adductor-roll reduction decreased as the roll reduced. The high anterior wall eliminated roll formation over the anterior brim of the socket. Skin lesions and irritation were caused by high force concentrations on the stump. Ischial-



Fig. 6. Case 1. Present prosthesis.



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gluteal weight-bearing, with increased area of anterior support, eliminated irritation and follicular lesions in the area of the crotch and the inguinal crease. Ramus discomfort following stump and socket changes was a sign of reduced effectiveness of ischial-gluteal weight-bearing, which allowed the stump to sink deeper into the socket. Discomfort in the weight-bearing area posteriorly was caused by wedging of the stump against the posterior brim of the socket as the tuberosity slid inside the socket.

## CASE 2, MID-THIGH

*History*

Case 2, another male, was 57 years of age, measured 6 ft., and weighed 187 lb. He was employed as a district manager for an insurance company. Amputation was through the right femur following a railway accident at the age of 17. He was referred to the clinical study in November 1953 by a local limbshop because of a history of problems. These included skin infections and irritations, fatigue, and low back pains which had persisted since amputation. At the time, the amputee considered his prosthesis satisfactory. The first prosthesis, with shoulder-harness suspension, was fitted in 1913 and worn until 1928. Prostheses with shoulder-harness suspension were worn until 1943, when a change was made to pelvic-belt suspension. The pelvic belt was uncomfortable and aggravated the back pains, and prior to referral the prosthesis was converted to suction suspension.

*Examination and Evaluation*

General health and physical condition were good. The stump was 10 in. long and cylindrical, with light subcutaneous tissue and average musculature except for moderately prominent hamstrings. There was a lateral-distal bone spur, a mass of redundant tissue at the lateral-posterior end of the stump, and sensitive scar tissue which was adherent to the femur. Perspiration level was high. Skin irritations were present in the area of the crotch and the inguinal crease, and hard skin nodules existed in the ischial-gluteal area (Fig. 7).

The prosthesis did not provide ischial-gluteal weight-bearing, and the tuberosity of

the ischium was sliding inside the socket during weight-bearing. This set of circumstances resulted in painful pressure on the ramus and wedging of the proximal portion of the stump against the anterior and posterior brims of the socket, with a high concentration of forces at the brim level. The medial brim had been lowered a half inch below the level of the ischial seat in an unsuccessful attempt to relieve the discomfort at the ramus. Walking with a narrow base increased the ramus discomfort because the femur was not adducted in the socket for stabilization of the pelvis. There was roll formation over the low anterior brim. Knee stability at the end of the stance phase was excessive owing to a long forefoot and posterior placement of the knee joint, which further increased the force concentrations at the socket brim. Insufficient security at heel contact was due to stiff plantar-flexion action. A pelvic hike on the side of the amputation in the swing phase was noticeable, probably because of experience with shoulder-harness and pelvic-belt suspension.

*Treatment*

Problems of interest included skin lesions, horny nodules, ramus discomfort, fatigue, and backaches. It was decided that relatively standard procedures, including ischial-gluteal weight-bearing with increased support from the anterior wall, would be effective in eliminating roll formation and in reducing pressure concentrations on the stump, especially in the crotch, in the inguinal crease, and in the ischial-gluteal area. Further reduction of vertical forces in the region of the crotch could



Fig. 7. Case 2. Lateral view of patient standing. Note scar on distal portion of stump over lateral and posterior aspects.

be achieved by adduction of the femur in the socket, thus eliminating pelvic drop in the stance phase.

The amputee was provided with a suction-socket prosthesis which included a single-axis constant-friction knee, a plantar-dorsiflexion ankle, and a foot with single toe-break. Segments of the prosthesis were willow wood reinforced with rawhide. The socket interior was finished with cellulose acetate lacquer, and use was made of an automatic expulsion valve with standard spring.

Since the ischial tuberosity was not adapted to weight-bearing, the gluteal channel was held shallow to increase gluteal support. In addition, this arrangement offered increased sitting comfort by allowing a thinner posterior wall. Definite hamstring relief was provided by channeling the posteromedial apex of the socket (Fig. 8). The medial brim was approximately 1/4 in. lower than the posterior brim to provide clearance for the ramus. The medial socket width was 4-3/4 in. as compared to an anatomical measurement of 3-3/4 in., a difference subsequently found to be a major source of difficulty. As already mentioned, current practice is to have the medial width of the socket compare very closely with the anatomical measurement. The anterior wall was extended 2 in. above the level of the ischial seat and was relieved slightly over the femoral triangle. But this idea, which was tried for fear that pressure in the femoral triangle would interfere with circulation, has since been abandoned in favor of a definite protuberance into this area. Such a shape gives considerable distributed anterior support.

The socket was placed well forward on the knee block to allow initial flexion of the femur in the socket for increased voluntary control,

reduced energy requirements, and decreased lordosis of the lumbar portion of the spine. Prosthetic evaluation indicated that there was



Fig. 8. Case 2. Socket shape of prosthesis worn at present.

excessive stability at the end of the stance phase owing to a long forefoot and the posterior location of the knee axis, the long forefoot having been dictated by the large foot size. In the swing phase, there was some whip, which was not removed during alignment trials on the adjustable leg (3,4,5), but the gait was markedly improved on the new prosthesis. There was no ramus discomfort, no irritation, and no roll formation in the crotch or inguinal crease. The ischial tuberosity was close to the inside edge of the socket, so that the medial wall had to be lowered to prevent ramus discomfort.

After stump shrinkage, ramus discomfort recurred. The medial brim was lowered, but this measure provided only temporary relief as the stump settled deeper into the socket. Skin irritations from the anterior brim were reduced but persisted, since wedging occurred owing to inefficient ischial weight-bearing. Force concentration at the anterior brim was reduced somewhat by extension of the brim 2 in. above the level of the ischial seat. Undercut of the anterior wall over the femoral triangle reduced the effective area of anterior support.

Skin lesions in the crotch cleared up initially but recurred with failure of ischial weight-bearing. Formation of horny nodules in the weight-bearing areas was unchanged because poor ischial support allowed the tuberosity to move in and out of the socket over the inside edge of the posterior wall, thus creating abrasive and wedging action. Excessive perspiration was considered a factor both in the formation of horny nodules and in stump irritation because of the deteriorating effect it had on the inside finish of the socket.

Although the anterior and posterior brims were rolled and adjusted periodically to reduce discomfort from skin irritations in the inguinal crease and from nodules in the weight-bearing areas, this expedient provided only temporary relief, since the forces involved were either unchanged or increased. Reduced alignment stability, with increased flexion of the stump in the socket, did not relieve the backache. Activity level was not noticeably changed, and fatigue also remained unchanged.

In the course of treatment, redundant tissue at the lateral-distal portion of the stump was a

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problem in fitting because of the sensitivity of the adherent scar tissue. A large pocket was provided to give relief. Doing so reduced the effective length of the femur available for stabilization of the pelvis.

### Summary

Failure of ischial-gluteal weight-bearing resulted in ramus discomfort and skin lesions. Lowering the medial brim provided only temporary relief, since the stump settled further into the socket. With recurrence of vertical pressure in the crotch, skin lesions were again a problem. The need for effective anterior stabilization to maintain the ischial tuberosity on the ischial seal was definitely indicated.

The high anterior wall eliminated roll formation and reduced skin infections in the inguinal crease. Undercut of the anterior wall over the femoral triangle reduced the anterior support area and increased the force concentration at the brim. Modifications of the anterior wall and of the posterior brim reduced discomfort temporarily only, since the force pattern was unchanged.

Placement of the prosthetic toe-break at the shoe crease provided excessive knee stability at the end of the stance phase. This result suggested that the conventional location of the toe-break was too far forward.

### CASE 3, MID-THIGH

#### History

Case 3 was another male, age 51, height 6 ft., weight 180 lb. He lost his left leg above the knee at the age of 17 after an injury sustained in a baseball game. Since his original surgery, he had had no further revision. For the first five years after amputation, he used crutches without a prosthesis. He had since worn three prostheses during his 34 years as an amputee. The first leg had a shoulder-harness suspension. The leg worn upon his acceptance as a research patient had been converted in 1952 from an aluminum socket, pelvic-belt leg to a wooden suction-socket prosthesis a year and nine months previously. He was employed as an expeditor in a shipyard, and the nature of his employment was such as to involve consider-

able standing and moving about over short distances. His chief complaint was concerned with persistent edema of the stump since conversion to suction suspension, and this was the reason for his referral to the clinical-study program by a local limbshop in November 1952. The patient complained of occasional phantom pain but had no persistent local pain.

#### Examination and Evaluation

The patient was in good general health, with normal reflexes and above-average musculature. The stump was cylindrical, with 6-1/2 in. of femur below the perineum and 2-1/2 in. of soft tissue over the end of the femur (Fig. 9). Stump musculature was not abnormally prominent, and subcutaneous tissue was light. On contraction of the muscles, the redundant tissue pulled upward without bunching. A large scar, adherent to the distal end of the femur, extended 6 in. up the lateral side of the stump (Fig. 10). There was severe, nonpitting edema in the redundant tissue. The skin in the edematous area was without hair, distended, discolored, and scaly, with an orange-peel

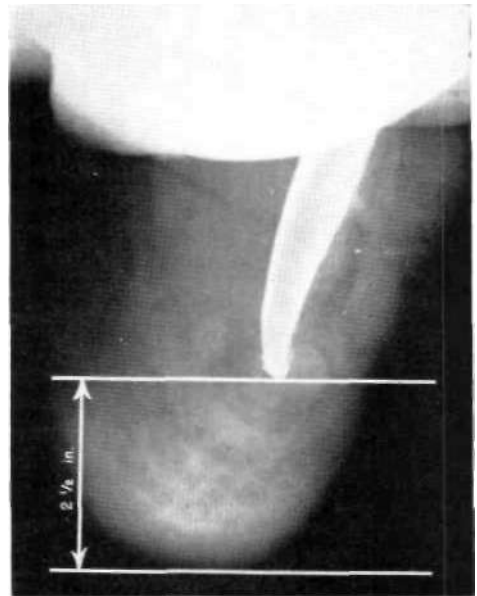


Fig. 9- Case 3. X-ray of stump, mediolateral view.

texture. Small cysts and horny nodules were evident in this region as well as in the inguinal area and in the crotch. The patient said that these cysts frequently enlarged and broke down, producing a pinkish-yellow discharge.

X-ray revealed the usual finding that there was lessened bone density on the amputated side and that the femur tapered and curved medially toward the distal end, which appeared to be closed. Comparison of socket and stump perimeters showed the socket smaller than the stump by 1-1/4 to 2 in. at corresponding levels. The distance from the tendon of the adductor longus to the ischial tuberosity was 3-1/2 in., as compared to the corresponding socket measurement of 5 in.

The suction socket the patient was wearing, although of the ischial-bearing type, did not achieve ischial bearing. The anteroposterior dimension was too large, the mediolateral dimension too small (Fig. 11). The socket was too tight, especially in the distal half, and the proximal end of the stump was constricted because of a wedging action precipitated by failure to establish ischial-gluteal bearing. Weight was borne on the medial brim of the socket, which was 3/8 in. below the level of the ischial seat and generously flared. There was a small adductor roll, and the anterior brim of the socket was level with the posterior brim, with some roll formation in the area of the inguinal crease. The anterior wall was undercut, a feature that caused localized high pressure on the stump at the anterior brim. The patient was well adapted to the use of the prosthesis, although a number of undesirable characteristics of gait were apparent, including a 7-in. walking base, considerable sidesway, and exaggerated arm swing on the side of the amputation.

#### Treatment

This patient's chief problem was the severe edema. It was felt that this disorder, as well as the skin lesions, could probably be controlled adequately by proper fit and alignment. The question of prime interest to the study group was whether or not suction suspension was the cause of the edema in this case.

Fig. 10. Case 3. Lateral view of stump. Note large, adherent scar.



The amputee was provided with a suction-socket prosthesis with conventional components, including a single-axis constant-friction knee, a plantar-dorsiflexion ankle, and a foot with a single toe-break. Segments were made of wood and reinforced with rawhide. An automatic expulsion valve with a strong spring was used to increase positive pressure in the socket during the stance phase.

The socket perimeters were 1-1/2 in. less than corresponding stump dimensions in the top third and equal to stump dimensions below that.

The distance from the tendon of the adductor longus to the ischial tuberosity was 3-1/2 in., and the corresponding socket dimension was 4 in. The anterior wall was relieved to avoid pressure in the area contacting the femoral triangle (Fig. 12), and a flat sponge-rubber pad covered with soft leather was placed in the bottom of the socket to provide back-pressure on the edematous tissue.

After the patient had worn the prosthesis for six weeks, the edema in the redundant tissue had decreased markedly. The improvement was maintained over a nine-month period, although at no time was the condition completely eliminated. About the ninth month, there was a sudden increase in the amount of edema. Three factors seemed to be involved. There was increased activity. A weaker valve spring had been installed to reduce loss of suction. And there had been stump shrinkage, as indicated by the experience of ramus discomfort. The thickness of the control pad was

## SOME ABOVE KNEE CASES

increased, but doing so did not alter the condition. Next, a stronger valve spring was provided to increase the positive pressure in the stance phase, and there was then a marked and immediate improvement in the edematous condition of the stump. To provide increased ischial weight-bearing by reducing the antero-posterior dimensions of the socket, liners were added in the area of the socket contacting the femoral triangle. Although ischial weight-bearing was improved, as evidenced by the elimination of ramus discomfort, there was no change in the edema.

The decision was then made to provide the amputee with a socket that would make total contact with the stump end, thus exerting greater back-pressure on the edematous tissue. After a four-day trial period, the patient found



Fig. 11, Case 3. Socket shape of prosthesis worn on referral.

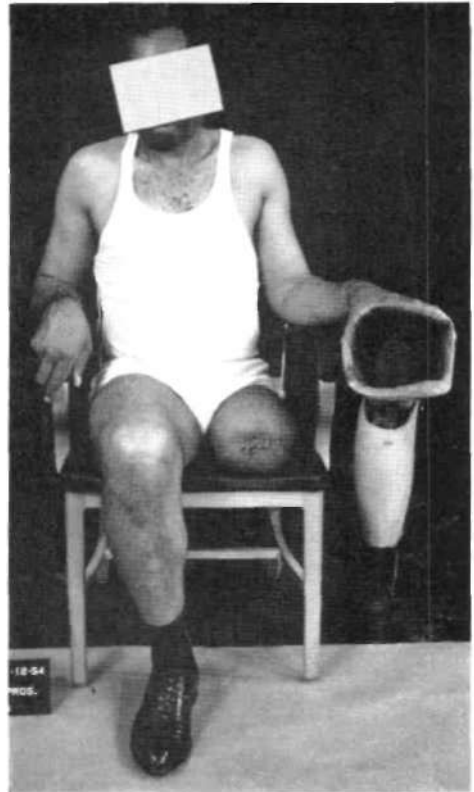


Fig 12 Case 3 Socket shape, present prosthesis

that accumulated perspiration irritated the stump acutely, and the socket had to be discarded. At present the amputee continues to wear the first prosthesis provided and still has moderate edema.

Skin infections initially present in the crotch area were cleared with provision of ischial-gluteal weight-bearing, but with stump shrinkage the condition recurred because of decreased effectiveness of such weight-bearing. Provision of liners over the area of the socket contacting the femoral triangle increased the effectiveness of ischial-gluteal weight-bearing and reduced the skin problems. Throughout treatment, there was irritation on the weight-bearing area of the stump, especially around the ischial tuberosity. Provision of a section of nylon stocking, fastened to the outside of the socket and draped anteriorly over the weight-bearing area, improved comfort considerably by reducing shear between the skin and the socket. The

skin irritations were due primarily to excessive anteroposterior socket dimensions, especially along the medial wall. This situation allowed the tuberosity to slip into the socket and the entire stump to settle deeper, with consequent wedging of the stump against the posterior brim and the anterior wall, thus creating a high force concentration on the ischial tuberosity. A pressure pad was found very helpful in controlling edema when other elements of the fit were satisfactory.

Minor skin irritations resulted from deterioration of the inside finish of the socket, but refinishing the socket cleared them.

### Summary

Although treatment was never completely successful in eliminating this patient's edema, function and comfort were markedly improved, and the course of his prosthetic treatment served to demonstrate several principles. Provision of ischial-gluteal weight-bearing eliminated ramus discomfort, reduced edema, and cleared skin infections anteriorly and medially where the stump contacted the socket brim. The posterior brim caused irritation of the stump when ischial-bearing was indefinite, with the tuberosity near the inside edge of the socket, or when the radius of curvature over the inside edge was too small, or when the ischial area was not conditioned for weight-bearing. Use of liners to decrease the anteroposterior dimension increased comfort. When there was stump shrinkage and decreased ischial support, edema increased, and a pressure pad alone was not successful in controlling it. Use of a stronger valve spring, to increase the positive pressure, decreased edema. In spite of the failure to control the edema completely, the patient was able to perform at a high level of activity.

### CASE 6, LOWER THIRD OF THIGH

#### History

Case 6, male, was 56 years old, stood 6 ft. 2 in. tall, and weighed 142 lb. He lost his right leg above the knee as a result of a motor-coach accident when he was 47. The patient's first prosthesis, fitted six months after amputation,

used shoulder-harness suspension. It was worn for two years. The next prosthesis provided pelvic-belt suspension. It was being worn when he entered the Clinical Study in November 1953 (Fig. 13). Complaints included tightness of the socket, discomfort due to abrasion of the hip by the belt on the side of the amputation, and irritation in the distal-lateral area of the stump. The prosthesis was in a state of general disrepair.

#### Examination and Evaluation

General health was good, and activity level was high both at home and at work. The stump was conical, with light subcutaneous tissue and very light musculature, muscular atrophy having been brought about by stump inactivity in the walking cycle. Tissue over the end of the stump was very thin. The lateral-distal portion of the stump was scarred, and the ischial tuberosity was small, sharp, and lightly padded. Scars in the crotch area indicated periodic folliculitis and boil formation, and there was local pain posterodistally.

A number of points were of interest in this case. They included a heavy adductor roll due to abducted gait and the plug fit; inexperience with suction suspension and ischial-gluteal weight-bearing; gait faults, including the abducted gait and pelvic hike on the side of the amputation; and the history of boils and folliculitis in the crotch due to weight-bearing in that area (Figs 14, 15, and 16).

#### Treatment

The amputee was provided with a suction-



Fig 13 Case 6 Original prosthesis. Weight carried on adductor roll

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Fig. 14. Case 6. Relaxed position of stump prior to treatment.



Fig. 15. Case 6. Adductor roll prior to treatment.

socket prosthesis which included a single-axis knee with constant-friction swing-phase control, a plantar-dorsiflexion ankle, and a foot with a single toe-break. Segments were willow wood reinforced with rawhide (Figs. 17 and 18).

Since the gluteus maximus was atrophied, the extensor channel and gluteal flare were fitted closely. No relief was provided for the heavy adductor roll, which was drawn completely into the socket as a part of the process of reduction. The socket perimeters at the brim of the socket were 3 in. less than stump dimensions. Two inches below the level of the ischial seat, socket perimeters were approximately half an inch less than stump dimensions. At the lower levels, socket and stump perimeters were identical. The distance from the ischial seat to the channel for the tendon of the adductor longus was 3-3/4 in., the corresponding anatomical measurement being 3 in.

Adduction of the femur in the socket relaxed the adductors and permitted inclusion of the roll in the socket with less difficulty (Fig. 19). Initially a safety belt was provided to increase

the amputee's sense of security, since he had a fear of losing the leg.

For the first three months of treatment the prosthesis was worn three hours a day. During the next six months use of the prosthesis was increased to all day, the extended period of adaptation to use of the prosthesis being due to discomfort at the ischial tuberosity. After nine months there was marked increase in comfort, a circumstance which induced the amputee to discard the cane he had theretofore used regularly. A soft pad over the ischial seat reduced discomfort but was discontinued after two weeks in the expectation that adaptation would be accelerated.

Tight fit of the proximal third of the stump for reduction of the adductor roll resulted in edema in the distal portion of the stump. But



Fig. 16. Case 6. Triangular shape of original socket.

when the socket perimeters in the upper third were increased to reduce constriction, the edema cleared up. Two weeks later the adductor roll had shrunk, and there was loss of suction. A new socket was made and modified with liners at intervals for a period of a month as shrinkage continued. By this time, the perimeter of the stump at the perineum had been reduced 2-1/2 in., so that a new socket was required. The dimension of this socket from the ischial seat to the channel for the tendon of the adductor longus was reduced by half an inch, and a protuberance was provided over the area contacting the femoral triangle.

Edema recurred after six months, and examination of fit showed considerable development of the hamstring muscles. Accordingly, the socket was opened at the posterior wall starting 2 in. below the ischial-seat level; the edema cleared up.



Fig. 17. Case 6. New prosthesis, with ischial-gluteal weight-bearing.

Further development of stump musculature resulted in edema at the end of the stump during the ninth month of treatment. Increased hamstring relief was provided, a stronger valve spring was installed, and a sponge-rubber pad was placed in the bottom of the socket to increase back-pressure on the end of the stump. Again the edema cleared up.

Training was provided for a period of one hour a day for six weeks. Gait was excellent under observation, although there was some reversion to old habits when the amputee was not under supervision. Pelvic hike was particularly per-

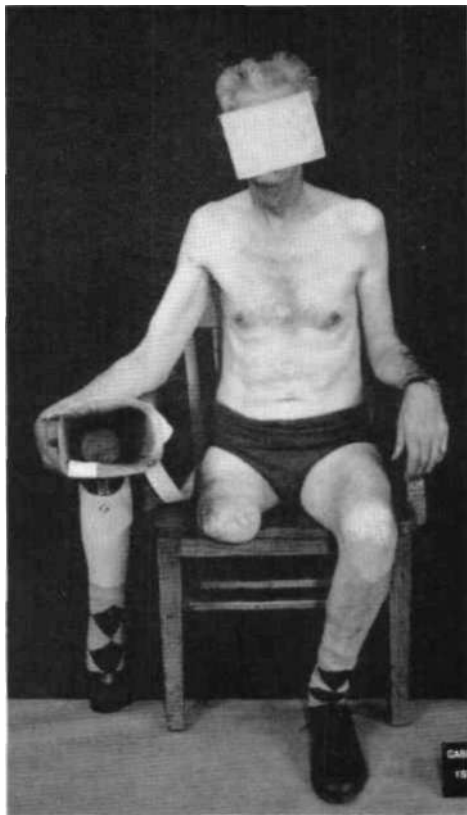


Fig. 18. Case 6. Shape of socket of new prosthesis

sistent. Those habits which were dependent on fit and alignment, including abducted gait, were gradually eliminated.

#### Summary

Problems studied included stump changes, particularly at the large adductor roll, adaptation to suction suspension, adaptation to ischial weight-bearing, and gait faults. Boils and folliculitis did not recur during the process of treatment.

Reduction of the large adductor roll formed in five years of weight-bearing in the crotch with abducted gait required six months of treatment. During this period there was some edema owing to constriction of the proximal third of the stump. Edema was reduced by increasing the perimeters of the socket in this region. Edema resulted again owing to constriction following hamstring hypertrophy.



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Relief for this development, the use of a stiffer valve spring for increased positive pressure in the stance phase, and a sponge-rubber pad in the bottom of the socket cleared up the edema.

There was periodic loss of suction following stump shrinkage. The light subcutaneous tissue could be distorted very little. As a result, slight stump changes led to loss of suction.

Initially some lateral instability and reduced control of the prosthesis, probably resulting from weakness of the gluteus medius, was experienced. With adaptation to suction suspension, there was increased stability and control as the gluteus medius became stronger. Adaptation was completed within the nine months required to stabilize the stump. The ischial tuberosity took more than nine months to condition for weight-bearing, chiefly because of the lack of previous experience, the light padding over the tuberosity, and the especially sharp configuration of the bone.

## CASE 8, MID-THIGH

*History*

Case 8, another male, was 42 years old, measured 6 ft., and weighed 175 lb. His right leg was amputated above the knee in December 1949 after a shotgun wound received in a hunting accident approximately a year previously. He had had only one prosthesis since amputation and was wearing it at the time he was accepted by the Clinical Study in January 1954. Although the prosthesis provided suction suspension, the components were conventional. The patient was dissatisfied with the prosthesis primarily on the basis of poor fit, but he felt that the alignment could be improved and that such improvement might give him more comfort and better function. He also complained of needlelike phantom pains in the ball or sole of the "foot," with persistent tingling.

*Examination and Evaluation*

General physical examination was normal. The stump was conical (Fig. 20), approximately 9 in. of femur remained below the perineum, and about an inch of tissue covered the end of the femur. Musculature of the stump was firm, but there was retracted muscle on

the lateral side about 2-1/2 in. from the tip of the femur. There was little subcutaneous fat. On the posterior aspect of the stump at the distal end was an inverted T-shaped scar, and the distal end of the femur was sensitive to pressure. X-ray showed a medioposterior spur arising from the end of the femur, curving upward, and tapering. There was edema and brown discoloration at the end of the stump (Fig. 21), and small follicular lesions were evident in the areas contacting the anterior and medial brims of the socket.

The prosthesis had a wooden socket reinforced with rawhide, a single-axis knee with constant friction for swing-phase control, an ankle providing plantar-dorsiflexion action, and a foot with a single toe-break 5 in. anterior

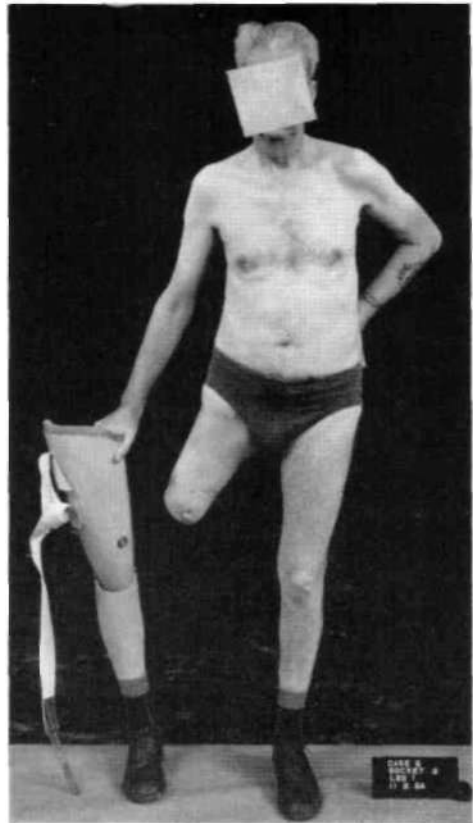


Fig. 19. Case 6. Condition of subject one year after application of new prosthesis. Note reduced adductor roll.



Fig. 20. Case 8 Stump molded by tight fit.

to the ankle axis. Weight was carried through a roll of flesh at the brim of the socket (Fig. 22), and the amputee walked with a wide-based gait owing to crotch discomfort and out-set of the foot. Knee stability was excessive because of the long forefoot and the posterior position of the knee axis, which fell approximately 1 in. posterior to the trochanter-ankle reference

line. The prosthesis was short, but this detail was not too apparent since the ischial tuberosity was 1-1/2 in. above the posterior brim of the socket. Because of insufficient knee friction and excessive kicker action, there was heavy impact at the end of the swing phase, and there



Fig. 21. Case 8. Socket shape of original prosthesis. Note edema and brown discoloration at the end of the stump.

was whip during the swing phase, probably owing to muscle activity within the socket and to the vigorous stump action required to break the prosthetic knee at the end of the stance phase. Rotation at heel contact was due to excessive stiffness of the plantar-flexion bumper.

Problems of interest to the Clinical Study included the edema encountered with use of suction suspension, skin infections, the adductor roll, the time and circumstances involved in conditioning the amputee to ischial-gluteal weight-bearing, and gait training.

#### Treatment

Reduction of the edema required reduced constriction of the proximal third of the stump through provision of ischial-gluteal weight-bearing, extension of the anterior wall above the level of the ischial seat, and close fit of the distal two thirds of the stump. Reduction of pressure on the proximal end of the stump from the superior brim of the socket was required to clear up skin infections. At the same time, snug fit, with adduction of the femur in the socket to relax the adductors, was required



Fig. 22. Case 8. Original prosthesis. Plug fit, with roll formation over the socket brim.

for reduction of the adductor roll. Improved fit and alignment, with training, were planned to correct gait faults.

The amputee was provided with a suction-socket prosthesis which included a single-axis knee with constant-friction swing-phase control, a plantar-dorsiflexion ankle, and a foot with a single toe-break. Segments were of wood,

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reinforced with plastic laminate. The extensor channel was held shallow and flared minimally at the brim to increase gluteal weight-bearing, since the amputee was not accustomed to ischial weight-bearing. No relief was provided for the adductor roll. The anterior wall of the socket was slightly relieved over the area contacting the femoral triangle (Fig. 23). The toe-break was cut 5 in. anterior to the ankle axis so as to coincide with the normal break of the shoe. To increase knee stability in the initial phase of the fitting, the knee axis was placed  $3/4$  in. behind the trochanter-ankle reference line. Socket perimeters were  $1-1/4$  in. under stump perimeters at the proximal end and equal to stump perimeters at the level of the distal two thirds. The distance between the ischial tuberosity and the adductor longus tendon was  $3-3/4$  in., the corresponding socket dimension being  $4-1/2$  in.

Evaluation following delivery of the prosthesis indicated that knee stability was excessive owing to the long forefoot and the posterior position of the knee axis. Training was required to improve balance and cadence

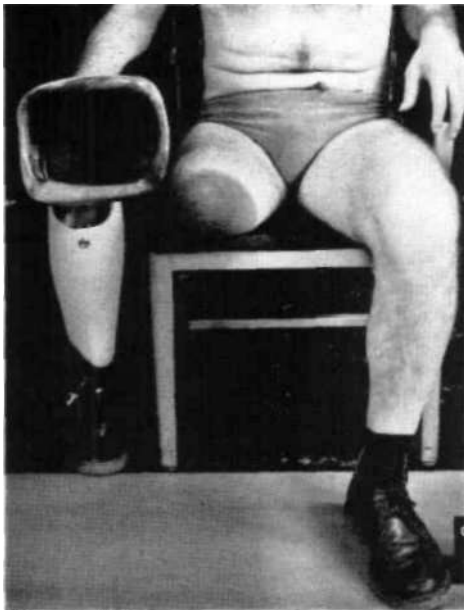


Fig. 23. Case 8 Socket shape, new prosthesis



Fig. 24 Case 8. New prosthesis. Note elimination of roll formation over the brim of the socket.

symmetry and to overcome the vaulting as well as to reduce the width of the walking base. The ischial tuberosity was on the seat, and there was no ramus contact with the medial brim of the socket. The adductor roll was contained in the socket. Roll formation over the anterior brim of the socket was eliminated (Fig. 24).

Initially there was some edema at the distal end of the stump owing to constriction proximally. As the flesh roll reduced, constriction and edema decreased, and finally the edema cleared up.

After an illness which caused the patient to lose considerable weight, the stump settled deeper into the socket as the ischial tuberosity slipped inside. This circumstance allowed the ramus to contact the medial brim and caused the anterior and posterior brims to constrict the stump. But because the somewhat conical shape of both stump and socket maintained the snug fit over the entire stump as the latter settled down into the socket, and because, consequently, the pressure differential between the proximal and distal portions of the stump was not increased sufficiently, edema did not recur. Nevertheless, ramus discomfort decreased activity on the prosthesis. The problem was eliminated with provision of a new socket.

Follicular lesions cleared up with effective ischial-gluteal weight-bearing but recurred when ischial support was decreased following

loss of weight. Provision of a new socket with ischial-gluteal weight-bearing again cleared up the skin condition. With the first socket, poor stabilization of the ischial tuberosity on the seat contributed to skin irritation and to the formation of horny nodules in the weight-bearing area. Comfort was greatly improved by reduced anteroposterior dimensions, with improved anterior support by provision of a protuberance on the anterior wall over the area contacting the femoral triangle.

Gait training improved walking habits but focused attention on deficiencies of fit by forcing the amputee to walk according to a preconceived pattern rather than one that provided maximum comfort. Sixteen months after training was complete, evaluation indicated that, because of discomfort from loss of fit, gait was somewhat worse than before training. Since in any case the amputee adapted his gait pattern to provide maximum comfort, training was of doubtful value as compared with good prosthetic treatment. With the first prosthesis, excessive knee stability detracted from naturalness of gait, and this condition also was a factor in causing the discomfort in the ischial-gluteal area and at the end of the femur anteriorly, where the stump showed the results of the force required to break the knee. Subsequent fit and alignment corrected these problems and greatly improved comfort. The length of the forefoot was reduced to approximately 3-1/2 in. to decrease knee stability, and the knee axis was placed on the ankle-trochanter reference line.

#### *Summary*

The patient's edema on the prosthesis worn at the time of referral was apparently caused by constriction of the stump in the socket, especially in the proximal third. A contributing factor was weight-bearing on the adductor roll over the medial brim. Provision of ischial-gluteal weight-bearing, with wide distribution of the pressure on the anterior aspect of the stump, had a number of consequences. The edema disappeared with the reduction of the adductor and anterior rolls and recurred only when fit and ischial support were lost with loss of weight from illness. Skin irritations in the crotch, along the gluteal fold, and around the

ischial tuberosity were cleared up by reduction of shearing forces when positive support was provided. Reduction of alignment stability by shortening the toe-break length and by moving the knee axis forward cleared up the skin irritation on the anterodistal aspect of the stump by reducing the force required to break the knee at toe-off. Training appeared to have far less effect on symmetry of gait than did fit and alignment. When the patient was able to walk symmetrically with comfort, he did so. When last seen, the amputee reported a general increase in comfort and a corresponding increase in his level of activity.

#### CASE 9, BILATERAL ABOVE-KNEE, UPPER THIRD OF THIGHS

##### *History*

Case 9, male, 27 years of age, weight 100 lb., underwent amputation at the age of eight as a result of crushing injuries to both legs sustained in a truck accident. He had had six pairs of legs since his amputation, the first pair having been fitted four months after surgery, without preliminary conditioning therapy or exercise. That pair, employing shoulder-harness suspension, was worn for four years. Between that time and 1948, he had had three sets of legs, all employing pelvic-belt suspension and using conventional components. In 1948 he was fitted at the University of California with suction suspension. The prostheses were worn for two years and then discarded because of disrepair. New suction sockets, provided in 1950, were worn for two years. These were uncomfortable owing to tightness of fit. In 1953 a local limbshop fitted the patient with the suction-socket prostheses he was wearing when referred to the Clinical Study in September 1953. The complaints included skin irritation with folliculitis, boils, and abrasion on areas of the stump contacting the socket brim; crotch discomfort; and edema in the ends of the stumps. Although working at essentially a sedentary occupation, he did a great deal of walking around his office.

##### *Examination and Evaluation*

There were no significant physical findings except as pertaining to the amputations. This

## SOME ABOVE-KNEE CASES

young man was well nourished, healthy, and of average intelligence. The stumps were almost identical. They were approximately 6 in. long, measured from the perineum, and cylindrical, with approximately 2 in. of tissue over the distal ends of the femurs (Fig. 25). Hygiene of the stumps and prostheses was poor, perspiration level high. There were boils, folliculitis, and abrasions on the stumps and the crotch areas, with boils and folliculitis in the inguinal creases. Both stumps had heavy, nonpitting edema and petechiae at the distal ends. The stumps were held in 28 deg. of abduction, but ranges of motion and muscle power were normal and equal. X-ray showed medial curvatures of both femurs distally. The medullary cavities appeared to be closed, and there were no sensitive areas.

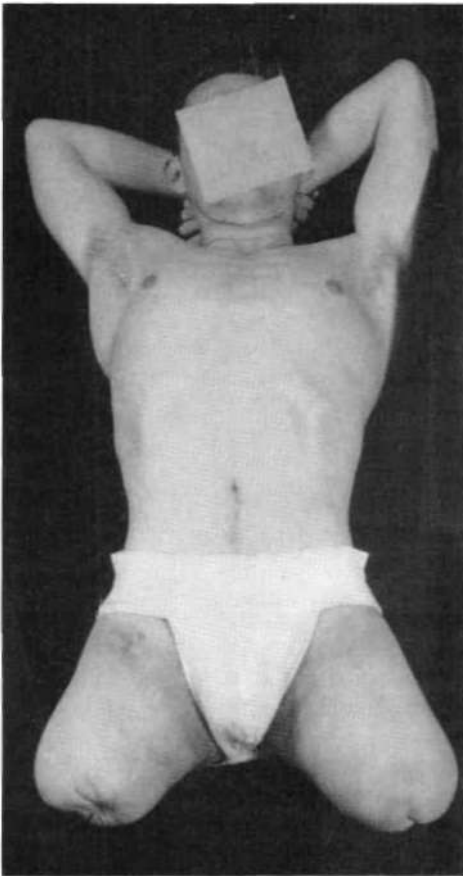


Fig. 25. Case 9. Stumps relaxed.

The prostheses (Figs. 26, 27, and 28) had rectangular suction sockets on single-axis knees with constant-friction swing-phase control, plantar-dorsiflexion ankles, and wooden feet with single toe-breaks. Segments of the prostheses were made of willow reinforced with rawhide. No auxiliary suspension or control straps were used. Although the sockets were intended to provide ischial-gluteal weight-bearing, the ischial tuberosities were down inside the sockets so that weight was carried on the medial brims, which had been lowered in an unsuccessful attempt to provide relief, with severe wedging of the stumps against the anterior and posterior brims. This situation was a cause of irritation and infection of the stumps in the areas contacting the medial and posterior brims of the sockets and promoted edema by restriction of circulation. Excessive alignment stability due to posterior placement of the knee axes increased forces on the posterior aspects of the stumps as the amputee attempted to break the knees to initiate swing phase.

The patient walked with a wide-based gait, at least partially because of the abducted position of his stumps. He customarily used a cane but was able to walk without it. Because the amount of friction in the swing-phase-control units was adjusted to provide minimum resistance to rotation, there was impact at the end of the swing phase. Rotation at heel contact was due to excessive stiffness of the heel bumper of the left prosthesis. Torso and pelvic list were due to shortness of the right prosthesis.

#### *Treatment*

The objectives of treatment in this instance were:

1. Elimination of crotch discomfort and skin problems by providing definite ischial-gluteal weight-bearing;
2. Elimination of irritation and follicular lesions in the inguinal areas by reducing force concentrations in these areas through use of high anterior walls and definite ischial-gluteal weight-bearing;
3. Reduced wedging of the stumps proximally through provision of definite ischial-gluteal weight-bearing and high anterior walls for increased area of support;

4. Close fit of the slumps along their entire lengths, with decreased wedging of the stumps proximally, for reduction of the edema;

5. Reduction in energy consumption by providing increased voluntary control with flexion of the stumps in the sockets and reduced alignment stability; and

6. Study of the effect of narrow- and wide-base alignment on lateral stability, within the limits imposed by the abducted positions of the stumps.

In March 1954, the patient was provided with two suction-socket prostheses (Fig. 29). A light webbing belt was furnished to aid suspension. Single-axis constant-friction knees, plantar-dorsiflexion ankles, and wooden feet with rocker toe-breaks and foam crepe shoe-sole material in the toes were used. The prostheses were reinforced with rawhide, the inside surfaces of the sockets were finished with cellulose acetate lacquer, and automatic expulsion valves with standard springs were used. For knee stability, the reference line joining the ankle axis to the point of contact of the greater trochanter passed 1 in. ahead of the knee axis on both prostheses. The ankles were provided with stiff plantar-flexion bumpers to increase anteroposterior stability.

Within approximately a month from the time of fitting the initial prostheses, there was substantial improvement in comfort and skin problems in the crotch areas. The medial brims were not appreciably lower than the

posterior brims. Skin problems in the inguinal creases were relieved by ischial-gluteal weight-bearing, by high anterior walls, and by provision of a protuberance over the region of the femoral triangle (Figs. 30 and 31).

Provision of ischial-gluteal weight-bearing and increased anterior support resulted in reduced wedging of the stumps proximally, and a close fit of the stumps over their entire length produced a prompt and marked reduction in edema. Irritation in the weight-bearing area was a persistent problem in the early stages of fitting. At one point, the amputee had the sockets modified in a commercial limbshop in an attempt to relieve this discomfort. But these changes increased the anteroposterior

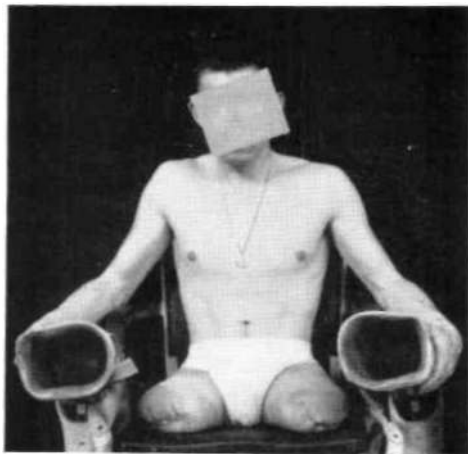


Fig. 26. Case 9. Socket shape of prostheses worn at time of referral, medial walls nearest patient's hands.

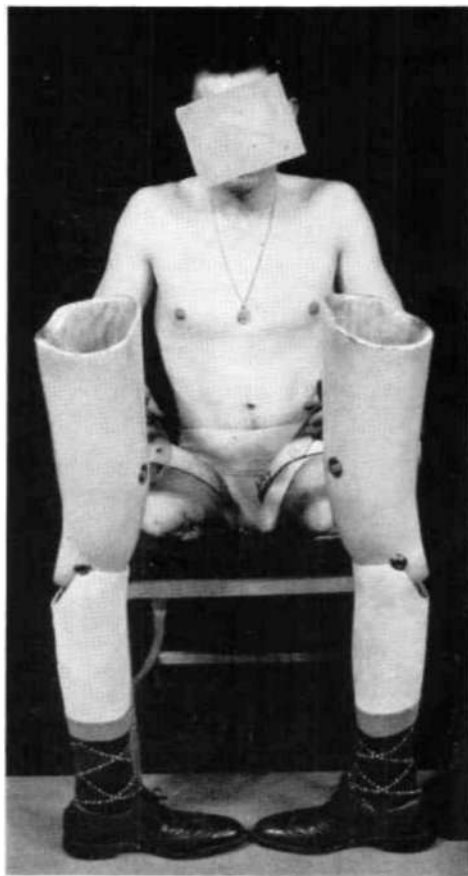


Fig. 27. Case 9. Prostheses worn at time of referral, medial view.

## SOME ABOVE-KNEE CASES

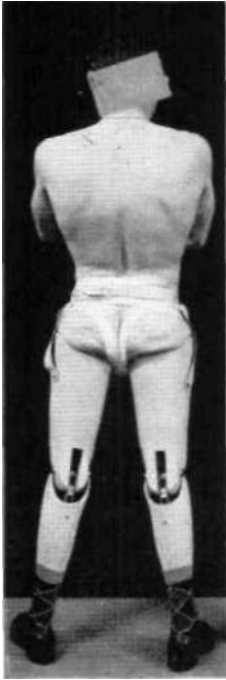


Fig. 28. Case 9. Prostheses worn at time of referral. posterior view.

dimensions of the sockets medially in the upper third. The tuberosities slipped into the sockets, and edema recurred. New sockets were fitted to re-establish ischial support. Irritation and discomfort in the area of the tuberosities disappeared after approximately two months of conditioning.

Ischial - gluteal weight-bearing raised the stumps in the sockets and decreased voluntary control, but after four months the patient became

adjusted to this change. It was found that he could walk with adequate control and stability when using stiff plantar-flexion bumpers, with the ischial seats well behind the projected lines through the ankle and knee axes, and with initial flexion of the stumps for voluntary control (Fig. 31). Because of long-established habits of abduction, it was necessary to provide wide-base alignment of the second pair of prostheses. At the time of the final evaluation, the stumps were in excellent condition.



Fig. 29. Case 9. Present prostheses.

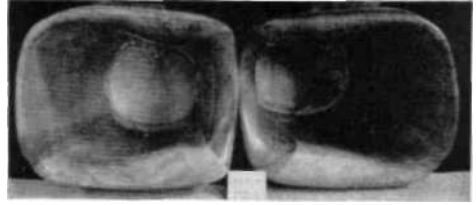


Fig. 30. Case 9. Socket shape, present prostheses. Ischial seats are at bottom center.

### Summary

The patient's problems of edema and skin irritation in the areas of the crotch, the inguinal creases, and the gluteal folds responded well to the standard principles of fitting. Irritation in the weight-bearing area was a temporary problem which cleared up with tissue conditioning. A wide walking base was required in this case for lateral stability. The stiff plantar-flexion bumpers provided antero-posterior stability both standing and walking. Placement of the sockets well forward on the knees provided adequate security.

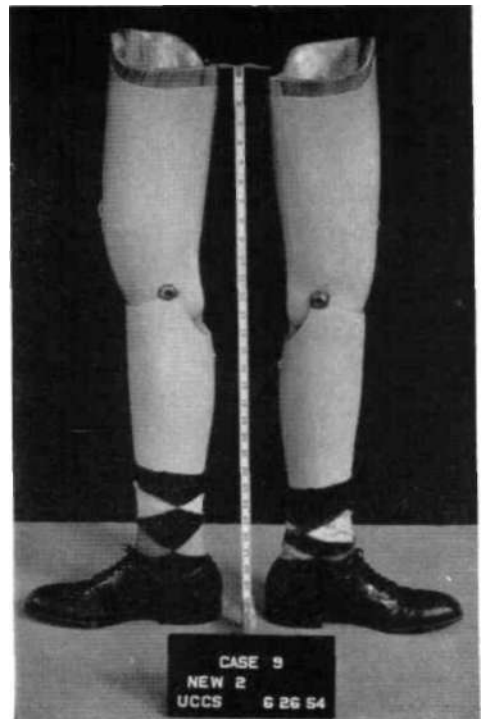


Fig. 31. Case 9. Present prostheses, medial view.

## CASE 10, VERY SHORT ABOVE-KNEE

*History*

Case 10, male, was 51 years of age, weighed 150 lb., and was 5 ft. 7 in. tall. Amputation was through the left femur in the upper third. The original amputation had been carried out in December 1952 as a result of arteriosclerosis, and the stump had been revised in August 1953.

This patient was referred by a local limbshop that was in the process of fitting him with a pelvic-belt prosthesis converted from a suction socket because of failure to maintain suction. He was pessimistic about the use of suction suspension and was unwilling to attempt it except for the benefit of the research group. Because of pressure in the groin, insecurity at the knee, toe-scuffing in the swing phase, and stump withdrawal when sitting, he was dissatisfied with the leg being fitted by the local shop.

*Examination and Evaluation*

Physiologically, the patient appeared older than his age, but he was alert and cooperative. The abdomen was severely scarred from surgical incisions for appendectomy and double sympathectomy, and scars also extended from the distal end of the stump up the antero-medial aspect to mid-groin. The medial scars were deeply adhered to underlying tissue. Subcutaneous fat was moderate and musculature firm, with prominent adductors and gluteus maximus. There were no sensitive areas. Skin was normal. The femur extended 1-1/2 in. below the perineum and 7 in. below the great trochanter (Figs. 32 and 33). A spur extended upward on the medial side, and the stump showed some abduction contracture.

This patient was of interest primarily because of the very short stump. Also of interest was the patient's inexperience, which offered an opportunity to study problems of adaptation and stump changes. Experience in prosthetic treatment of cases with circulatory impairment was also desired.

*Treatment*

The patient was provided with a suction-socket prosthesis. At first a single-axis knee

with constant-friction swing-phase control, a plantar-dorsiflexion ankle, and a foot with single toe-break were used. Segments were of wood, reinforced with plastic laminate. Later the knee was changed to a friction-stabilized type. The final socket was made of plastic laminate, and a SACH foot (solid ankle, cushioned heel) was used instead of the conventional foot.

Two sockets were fitted within the first two months. With the second socket, all requirements for the successful application of suction suspension had been met, but, because of obscuring factors related to the amputee's attitude, this condition was not altogether understood at the time. A remolding process had brought about elongation of the stump, a feature which made suction easier to maintain.

Successful application of suction suspension depended upon undercutting the posterior, medial, and anterior walls of the socket below the ischial-seat level, maintaining the lateral wall above the level of the ischial seat, and holding the fit close in the proximal part of the stump. Because of the undercut medial wall, bunching of the adductors did not break the suction. Suspension aids, valuable in providing increased sense of security in the initial phase of treatment, were unnecessary once the amputee was adapted to the use of his prosthesis. Because of the limited amount of femur available, and also because of the abducted position of the stump, no attempt was made to adduct the femur in the socket. Flexion of the stump in the socket was designed



Fig. 32. Case 10. Lateral view of the stump in the hanging position.



## SOME ABOVE-KNEE CASES

to meet the natural requirements of the stump and spine rather than to provide voluntary control of the knee, since stump power was limited and undercutting of the anterior and posterior walls of the socket reduced the effectiveness of the stump in controlling the knee (Fig. 34).

Initially the patient was provided with a conventional single-axis knee with adequate knee stability. Fear of falling and buckling of the prosthetic knee due to weakness of the normal leg, inexperience, and other factors, however, led to use of a friction-stabilized knee. But aligning the friction-stabilized knee in accordance with the rules for the single-axis conventional knee resulted in excess stability at the end of the stance phase. Accordingly,



Fig. 33. Case 10. Stump in 90 deg. of flexion.



Fig. 34. Case 10. Rectangular socket provided for patient.

Fig. 35. Case 10. New prosthesis, posterior view.

the knee was later aligned to provide decreased alignment stability with greater reliance on the friction mechanism.

Although narrow-based gait was not anticipated in the alignment of the limb, the amputee was able to walk with a 4- to 6-in. base. The prosthesis was made about 1-1/2 in. shorter than the normal limb (Fig. 35) because the amputee found that the shorter prosthesis permitted better control. Before prosthetic treatment started, the patient had back pains, and it was anticipated that the shorter leg might lead to recurrence. As a matter of fact, he had some recurrence of the back pains early in the fitting when a webbing belt was tried as a supplement to suction suspension. But this problem disappeared when use of the belt was discontinued.

Stump changes during the study were minimal. In the first two and a half months, stump shrinkage occurred, but the stump remained stable throughout the following two years of observation. After the patient had worn the first suction-socket prosthesis a short time, the tissue of the stump started to extend, so that by the time the stump had stabilized there was an increase from 1-1/2 in. to 3 in. of tissue available below the perineum for effecting a suction seal. At no time was there more than a reddening of the stump in the weight-bearing area, and, as the tissue became conditioned, the skin became dark and tough. There was no edema.

#### Summary

The problem in this case was to attempt application of suction suspension to a very



short, heavy, above-knee stump. Suction proved to be a practical means of suspension. All walls were concave, and relief was provided for bunching adductors to prevent the stump from being forced away from the socket in the medial apexes with consequent failure of the suction seal. For increased control and reduced effort, the amputee preferred the prosthesis approximately 1-1/2 in. shorter than the normal leg. There were no back pains. The stump shrank slightly during the first two months, and there was elongation of the stump, particularly on the medial side. Because of insufficient knowledge for adequate prosthetic treatment of the patient, and because of the poor adjustment of the patient to his amputation and physical condition, rehabilitation was a lengthy process. Once the patient was successfully treated, no changes in fit and alignment were required over a two-year period.

#### CASE 24, LOWER THIRD OF THIGH

##### *History*

Case 24, female, was 41 years of age, stood 5 ft. 2 in. tall, and weighed 126 lb. She had undergone amputation at the level of the lower third of the left femur. There had been a congenital lymphangioma involving the tissues of the left leg from the knee down. Infection developed in the soft tissues over the anterior portion of the tibia, and subsequently there was an osteomyelitis of the tibia. Later a mass, which was diagnosed as carcinoma, appeared in the ankle. Amputation was performed in May 1954.

The amputee had had only one prosthesis since amputation. It consisted of conventional components and a molded leather socket laced anteriorly (Fig. 36). When she entered the study program in January 1955, complaints included skin irritation and infection, with discomfort in the crotch, discomfort and restriction from the corset used to suspend the prosthesis, right-sided backache, and excessive wear of hosiery.

##### *Examination and Evaluation*

Normally a very active person, the patient had a rather low activity level owing to



Fig. 36. Case 24. Prosthesis worn on referral. Note lateral displacement of the socket on the stump.

limitations imposed by her prosthesis. General physical condition was good, except for very flabby abdominal musculature, but the patient experienced phantom sensations as though the "leg" were "falling asleep." Phantom pains in the form of cramps in the "calf" and shooting pains on the medial side of the "ankle" also were present. They lasted only a few seconds and were less frequent since she had been fitted with a prosthesis.

The stump was cylindrical and 9 in. long measured from the perineum, including approximately 2 in. of redundant tissue over the end of the femur. Subcutaneous tissue was heavy but firm. Musculature was of average strength, with no group particularly prominent. There was no significant edema or skin problem in the distal end of the stump, but follicular lesions existed in the crotch, and areas of irritation were present on the torso from pinching and bruising by the corset stays.

The prosthesis provided weight-bearing on a flesh roll around the brim of the socket, in the crotch, and against the side walls of the socket (Figs. 37 and 38). A pressure pad in the bottom of the socket did not provide appreciable support, and the patient walked with a wide base and with torso and pelvic list owing to excessive length of the prosthesis, wide-base alignment, and discomfort in the crotch. Stride length, cadence, and arm attitude were unsymmetrical because of excessive stability of the prosthetic knee.

This amputee presented several problems of interest to the study group. They included

skin infections, the relationship between redundant tissue at the end of the stump and edema with suction suspension, factors involved in changeover from corset to suction suspension, factors involved in changeover to ischial-gluteal weight-bearing, stump changes, the cosmetic problems of a female amputee, and use of the SACH foot with high-heeled shoes.

#### *Treatment*

In September 1955, the patient was provided with a suction-socket prosthesis consisting of a single-axis constant-friction knee, a SACH foot made for a high-heeled shoe, and wooden segments reinforced with plastic laminate. An automatic expulsion valve with standard spring was used, and the inside surface of the socket was finished with phenolic resin varnish. A polyvinyl chloride-acetate cosmetic cover was provided for the shank. Since the amputee was unaccustomed to ischial weight-bearing, and also in order to increase sitting comfort, the gluteal flare and the extensor channel were fitted closely to provide increased gluteal support. The lateral wall was closed in over the stump above the ischial-seat level, and the anterolateral apex was closed to reduce conspicuousness of the brim of the socket under the clothing.

This socket was worn on the adjustable leg (4) for approximately a month and was then installed in a finished prosthesis. After a week, the redundant tissue at the end of the stump was moderately edematous. The only known difference between the prosthesis with the adjustable leg and the finished prosthesis was that the latter had five coats of "Platon" varnish on the inside of the socket. There were three possibilities related to the finish of the socket interior. The stump worked down into the socket through weight-bearing, with increased effect of muscle activity on negative

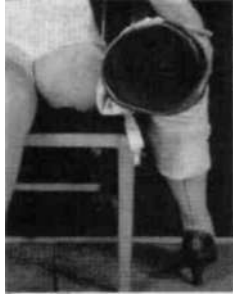


Fig. 37. Case 24. Socket shape at the brim, prosthesis worn on referral.

pressure and reduced positive pressure in the stance phase owing to reduced excursion of the stump in the socket. There was adherence of the stump to the walls of the socket and, hence, reduced massaging action at the distal end. Vacuum seal was improved so that negative pressure was maintained, especially during sitting.

The edema cleared up after provision of a pressure pad in the bottom of the socket and after atrophy of the stump, which reduced constriction proximally. In addition there was, as a result of aging and lubrication of the surface finish by body oils, decreased adherence of the stump to the socket. Addition of liners to compensate for shrinkage did not cause edema with this socket.

A second prosthesis was supplied in December 1955, the socket of this limb being fitted snugly in anticipation of further shrinkage of the stump. Six weeks after delivery of the prosthesis, examination showed edema at the end of the stump. A pressure pad was provided, but there was no reduction in the edema during the next two months. Pad thickness was then increased. When the amputee was examined next, six weeks later, the pad had been discarded owing to ineffectiveness in controlling the edema. Edema was reduced, and the stump had atrophied further. This development had reduced constriction of the proximal



Fig. 38. Case 24. Lateral view of the stump in the hanging position.

portion of the stump without reducing the effectiveness of ischial support, thus indicating that edema was caused by constriction of the proximal area and that the pressure pad was ineffective in reducing it so long as constriction persisted proximally. Six weeks later there was no edema, and the socket was looser. Liners were installed over the anterior and posterior walls to decrease perimeters of the socket in the upper third by one inch. Edema did not recur. Socket perimeters proximally were reduced another inch two months later as a result of stump atrophy. There was no edema before or after addition of the liners, and at no time was there failure of ischial support.

The patient adapted very well to the change-over from corset to suction suspension and appreciated the comfort and freedom that resulted. Control of the prosthesis was excellent. Adaptation to ischial-gluteal weight-bearing was immediate, and skin lesions and discomfort in the crotch cleared up quickly. The shallow gluteal flare and extensor channel, with relief for hamstring attachments at the ischial tuberosity, provided sitting comfort. As the stump atrophied, proper weight-bearing was maintained effectively by the addition of liners to the anterior and posterior walls of the socket as necessary (Fig. 39).

Stump atrophy due to heavy subcutaneous tissue was a problem, and the stump had not stabilized at the end of a year. It was found that initial fitting of the socket snugly, in anticipation of shrinkage, was satisfactory practice and did not produce a serious amount of edema. Such edema as was produced subsided as stump atrophy proceeded. As further shrinkage occurred, liners were added without complications.

Closing the lateral wall over the stump above the ischial-seat level and curving the anterolateral apex im-



Fig. 39. Case 24. Socket shape, new prosthesis. Note liners added for shrinkage adjustment.

Fig. 40. Case 24. Anterior view of new prosthesis with cosmetic covering.



proved appearance of the prosthesis under clothing. The SACH foot provided a good cosmetic junction between the shank and the foot and permitted use of high-heeled shoes. The polyvinyl acetate cosmetic covers used were sufficiently durable (Fig. 40) and were acceptable in appearance until they become discolored. Staining was objectionable within about six months.

Although the cosmetic effect of the SACH foot was appreciated by the amputee, there was objection to the decreased plantar-flexion action and to the damage this caused to spike-heeled shoes. As a result, the patient requested a foot with an articulated ankle. It was found that the decreased plantar-flexion action was a problem down ramps only.

#### Summary

In spite of the excessive amount of redundant tissue at the distal end of the stump, it was possible to use successfully suction suspension embodying the principles and techniques previously outlined. Problems of edema, skin changes, and loss of suction that occurred during fitting and wearing of the prosthesis were successfully treated by controlling the fit and alignment. Proper fit and alignment were instrumental in promoting stump reduction to a more firm and functional state and in eliminating skin lesions and discomfort in the crotch due to the heavy subcutaneous tissue and steady stump reduction. With a properly fitted suction-socket prosthesis, the patient was able to assume a more satisfactory level of activity without discomfort, and it was possible without difficulty to adapt this type of prosthesis to the require-

## SOME ABOVE-KNEE CASES

ments of cosmetic appearance. Foot and ankle function were suitable for use with high-heeled shoes, but frequent examinations and modifications to socket fit were required to maintain comfort.

## CASE 28, LOWER THIRD OF THIGH

*History*

Case 28, male, age 62, height 5 ft. 11 in., weight 121 lb., underwent amputation in the lower third of the left femur in June 1955 following circulatory failure. When he entered the Clinical Study in August 1955, he was wearing a plaster socket on a peg leg with shoulder-harness suspension. He disliked the peg leg because of its appearance and because of discomfort in the crotch. Activity level postoperatively was very much less than prior to amputation and was a matter of great concern to the amputee, who had just retired to a small farm.

*Examination and Evaluation*

The amputee's physiological age was in advance of his chronological age. The stump was 11 in. long and cylindrical, with light subcutaneous tissue, average musculature considering the age of the patient, and full range of motion at the hip (Fig. 41). The end of the femur was adequately covered and tolerated considerable pressure. At the end of the stump there was persistent, mild pain not related to use of the temporary prosthesis, and there were diminishing shooting phantom pains. X-ray showed a spur on the lateral-distal end of the femur. Postoperative edema was slight.

The plaster socket on the pylon leg had been furnished to aid in reducing the stump. As shrinkage proceeded, the number of stump socks used had been increased to adjust for it. Considerable stump shrinkage had occurred, a circumstance which, despite the added stump socks, allowed the stump to drop into the



Fig. 41. Case 28. Stump in abduction, slack tissue on medial side.

socket. Severe crotch discomfort was present, since ischial weight-bearing was not used. The amputee walked with a circumducting gait, stride length on the prosthesis was shorter than that on the normal side, there was rotation around the pylon in stance phase, gait was abducted, and one cane was used.

Of interest to the research group were the effects of the temporary plaster socket and the peg leg, stump changes, the rate of rehabilitation of the amputee, and evaluation of suction suspension on an elderly amputee with circulatory deficiency.

*Treatment*

The patient was provided with a suction-socket prosthesis which included a willow socket, a variable-cadence friction-controlled knee, a willow shank, and a SACH foot (Figs. 42 and 43). Wooden segments were reinforced with plastic laminate, and the socket was finished inside with a phenolic varnish. The extensor channel was shallow, and there was minimal gluteal flare to ensure as much gluteal support as possible (Fig. 44). The anterior wall protruded over the area contacting the femoral triangle starting at the anterior brim and extending downward to a point one third the distance down into the socket. Evaluation of the finished prosthesis indicated that the forefoot was too long and that there was insufficient initial flexion of the stump in the socket.

At first the amputee found it difficult to don the prosthesis, partly because of his age and partly because of the snugness of fit, which was intended to aid in stump reduction. The difficulty decreased as the patient became more accustomed to the limb and as snugness was reduced with stump shrinkage. Because of the patient's age and physical condition, it was necessary to maintain a comparatively low activity level during fitting and training, a matter which resulted in minimum discomfort or abrasion of the skin from impact between the stump and socket. The single-axis knee offered sufficient stability under normal circumstances, but the amputee felt insecure at such activities as gardening. As a result, he was provided with a friction-stabilized knee, and alignment stability was reduced. Initial

Fig. 42. Case 28. Lateral view of new prosthesis. Note amount of initial flexion of the stump, as indicated by the angle between the shank and thigh sections. Note also extension of the gluteus maximus over the brim of the socket, indicating weight-bearing on the tendinous hamstring attachments.



indications were that the friction-stabilized knee was an advantage, especially at heel contact. More supervision during fitting and training was required than is usually the case with younger amputees. Suction suspension offered good control, but had the patient been weaker this method of suspension might not have been practical because of the difficulty of putting the leg on.

Gait evaluation showed two faults. One, circumduction of the prosthesis, was probably carried over from the peg leg. The other, which consisted of stepping from the prosthesis to the normal leg as soon as the resistance of the prosthetic forefoot was felt, may also have been related to the use of the pylon. Training reduced but did not eliminate these characteristics of nonsymmetrical gait.

There was consistent stump shrinkage over the first six months of treatment. The initially snug fit of the socket was of limited significance since shrinkage was extensive. Addition of liners as the stump shrank was a successful means of maintaining fit, although it eventually affected alignment. Most extensive shrinkage occurred in the proximal third of the stump. Postoperative edema was not a significant factor, nor was stump hypertrophy. To avoid excessive enlargement of the socket during adjustments, it was necessary to apply a shrinker bandage before prosthetic treatment was started.

There were no fitting problems related to the limited time lapse between amputation

and prosthetic treatment. Adaptation was rapid, and the cane used with the plaster pylon was discarded before delivery of the permanent prosthesis. Use of the prosthesis as part of the reduction treatment introduced the difficulty of frequent examinations and adjustments but was less troublesome and more effective than applying the shrinker, especially at the proximal end of the stump, which the amputee found difficult to wrap properly.

At no time were there skin or circulatory problems with suction suspension, but initially there was moderate discoloration at the distal end of the stump owing to the snugness of fit at the proximal end. Loss of suction, a matter related to the lightness of the subcutaneous tissue, was a frequent problem. Only a small amount of stump shrinkage produced loss of suction, since the amount of tissue distortion possible prior to shrinkage was limited, which is to say that stump fit had to be maintained close to optimal at all times.

Some end-bearing was provided on a pad of foam crepe shoe-sole material in the bottom of the socket. When end-bearing was increased periodically as the stump dropped deeper into the socket with stump shrinkage, the stump end became sensitive and even painful.

#### Summary

Problems studied with this amputee included those involving his age, his experience on the peg leg, stump changes, rate of rehabilitation, use of suction suspension where there had been circulatory impairment, and training. Prosthetics treatment was more time-

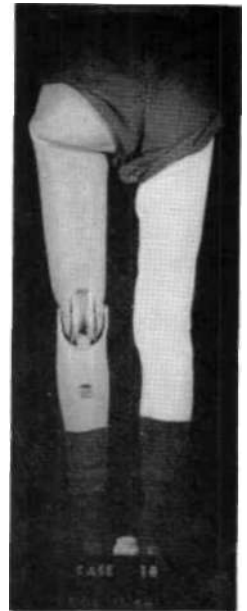


Fig. 43. Case 28. Posterior view of new prosthesis providing ischial-gluteal weight-bearing and narrow-based alignment. Knee is friction-stabilized.



Fig. 44. Case 28. View of the crotch area of the stump and of the socket brim of the new prosthesis. Note the distance between the level of the ischial tuberosity and the very prominent tendon of the adductor longus. Note also the corresponding socket dimension.

consuming, but stump discomfort was not a problem since activity level was low. At first the patient found the leg hard to put on, but this problem was overcome with practice. Fitting and training schedules were less strenuous than would be followed with a younger amputee. Use of the friction-stabilized knee increased the amputee's confidence, and voluntary control was thus improved because it was possible to provide more flexion of the stump in the socket. Use of the temporary prosthesis with plaster socket and peg-leg attachment introduced gait problems which could not be eliminated entirely, but the plaster socket was effective as a means of reducing postoperative edema. There was, for example, almost no postoperative edema when treatment was started. It was therefore not a problem. Suction suspension caused no circulatory difficulties,

#### CASE 37, VERY SHORT ABOVE-KNEE

##### History

Case 37, male, age 39, height 5 ft. 11 in., weight 180 lb., underwent amputation through the right femur, 1-1/2 in. below the perineum, as a result of an injury sustained in World War II. At various times, but without success, attempts had been made to fit him with above-knee prostheses, including suction (Fig. 45) and belt suspension. These circumstances led to a proposal by the referring agency to

have the patient fitted as a hip-disarticulation case using the Canadian type of prosthesis (2). A plaster-cast check socket had been fitted as a preliminary, with apparent success.

##### Examination and Evaluation

The stump, though short, was powerful, and the end of the femur was covered by approximately 1 in. of muscle padding. Subcutaneous tissue was fairly heavy. The ischial tuberosity was broad and well padded, but there was pressure-sensitive scar tissue on the lateral side of the stump and in the crotch (Figs. 46, 47, and 48). The distal end of the stump tolerated considerable pressure but, because of a trigger point on the anterodistal aspect, it was unsatisfactory for end-bearing. Abduction and flexion contracture of the hip was typical of an above-knee amputee with a short stump. Because of the habit of extending the knee when crutch-walking, a practice which had reduced extensor control at the knee, the normal knee buckled occasionally under load in the flexed position. A triple arthrodesis of the normal ankle was an additional complication.

##### Treatment

The problem presented was how to fit an amputee who was on the borderline between the above-knee case and the hip-disarticulation.

Were the patient fitted as a hip-disarticulation, there would be loss of stump function, and, since the amputee lived in a hot-summer climate, the socket would present a particularly acute heat problem. Joint placement with the hip-disarticulation prosthesis would also be a problem, since, when the stump was flexed, it extended 2



Fig. 45. Case 37. Unsuccessful suction socket worn on referral.

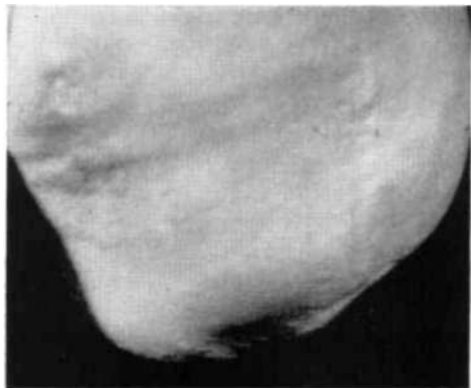


Fig. 46. Case 37. Posterior view of stump. Note scar on posterolateral apex.

in. ahead of the usual anterior contour for a hip-disarticulation amputee.

An above-knee type of prosthesis offered the advantage of preserving stump function, particularly where suction suspension could be used effectively, since with the use of suction there is reduced excursion and piston action of the stump in the socket. At the same time, the shortness of the stump, with the reduced area for effecting a suction seal, and the large volume change in the stump between the relaxed and the tensed states, accompanied by prominent bunching of the adductors, could cause difficulty in achieving a reliable suction seal. Moreover, the possibility existed that the close fit required could cause discomfort to the sensitive scar tissue in the crotch.

It was decided to treat this patient simultaneously as an above-knee and as a hip-disarticulation amputee, first to check the possibilities of using suction suspension on such a short stump and, second, to check the Canadian hip-disarticulation prosthesis as a method of treating very short above-knee stumps. The amputee was successfully fitted with a plaster hip-disarticulation check socket and walked for two hours with a peg leg attached. The socket constructed from this check socket would have provided sufficient clearance for installation of the hip joint, but the hip-disarticulation fitting was discontinued

at this stage because of success achieved with suction suspension.

Within five days of the beginning of treatment the subject walked successfully on the adjustable leg using suction suspension. The first socket failed from loss of suction through the posterolateral apex because the socket had been enlarged in this area in an attempt to compensate for the action of the gluteus maximus, which tended to force the stump away from the socket. The second socket, modified in view of lessons learned from the first, held suction and was comfortable (Fig. 49). It was provided in a finished prosthesis. A short-above-knee pelvic harness, as designed at the University of California (Fig. 50), was added to assist in swing-phase control and to maintain the prosthesis on the stump in the sitting position.

Components incorporated into the finished prosthesis included a SACH foot, a wooden shank reinforced with plastic laminate, a friction-stabilized knee, and a wooden socket providing definite ischial-gluteal weight-bearing. The tuberosity was located on the posterior edge of the seat, so that considerable weight was carried on the tendinous hamstring

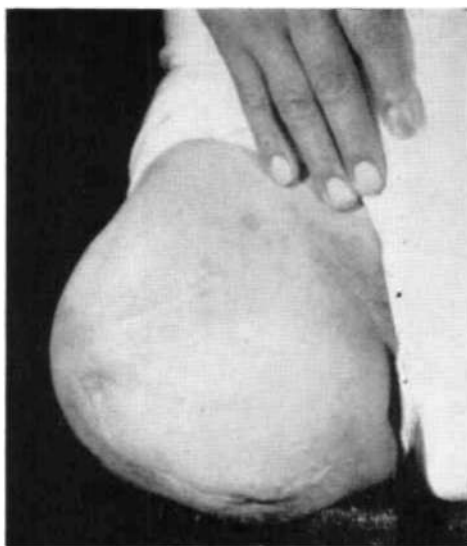


Fig. 47. Case 37. Anterior view of stump. Note scars in crotch and on lateral side of anterior aspect.



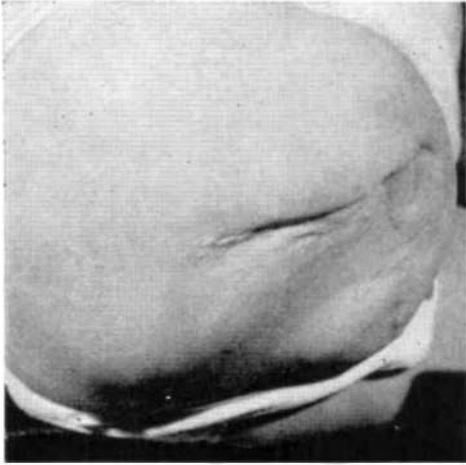


Fig. 48. Case 37. Lateral view- of stump in maximum flexion.

attachments, and the gluteal flare was fitted close to provide some gluteal support and to ensure a suction seal. The medial brim was held level with the posterior brim, while the anterior brim extended 2-1/2 in. above the ischial-seat level. The socket protuberance into the area of the femoral triangle did not extend below the level of the ischial seat, and the lateral brim was held at the same level as the anterior brim. To aid in effecting a suction seal, the perimeter of the socket was enlarged below the brim level. The concavity of the anterior wall started 1 in. above the level of the ischial seat and extended downward, while the concavity of the lateral wall was above the ischial-seat level. Concavity of the medial wall below the brim provided room for the prominent adductors, so that suction was not lost when the stump was tensed. At the brim, the socket perimeter was approximately 3 in. less than the stump perimeter. Alignment stability was reduced, inasmuch as a friction-stabilized knee was provided.

The short-stump harness was successful in preventing loss of suction during sitting, the leg adhered firmly with tensing of stump musculature when the amputee walked, and there was no ramus discomfort. The scar in the crotch proved to be no problem in fitting

and was not a source of discomfort. Except for a mild discomfort in sitting, which resulted in stretching of the skin, especially while sitting in soft seats, there was no discomfort from the posterior brim of the socket. Gait was satisfactory using one cane.

Examination one month after treatment. was begun showed little change in the stump since the initial examination; it had simply elongated about 1/2 in. on the medial side. The ischial tuberosity tolerated weight-bearing without difficulty, and the skin over that area was somewhat toughened. No edema, skin abrasion, or skin infection was evident. Six weeks after treatment started the amputee used the leg all day with one cane, but at a low activity level. Buckling of the normal knee was reduced as a problem when use of the knee increased with improved physical condition.

Five months after treatment started the amputee wore the prosthesis from rising to retiring, and the stump was in excellent condition. Activity level was average, considering the level of amputation. One cane was used, although the patient was able to walk without it. There was some brownish discoloration in the weight-bearing area. Stump shrinkage was not noticeable, and there was no further elongation of the stump. The tuberosity was firmly supported on the ischial seat, and there was no crotch discomfort, although there was slight skin irritation in the crotch due to roughness of the socket finish. The amputee

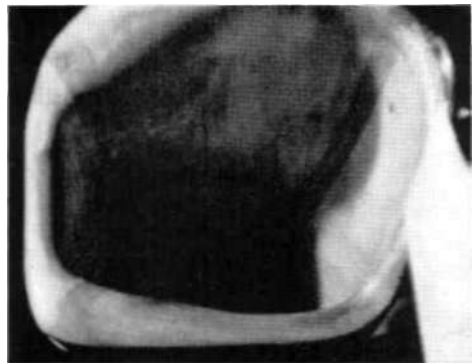


Fig. 49. Case 37 Successful suction socket.

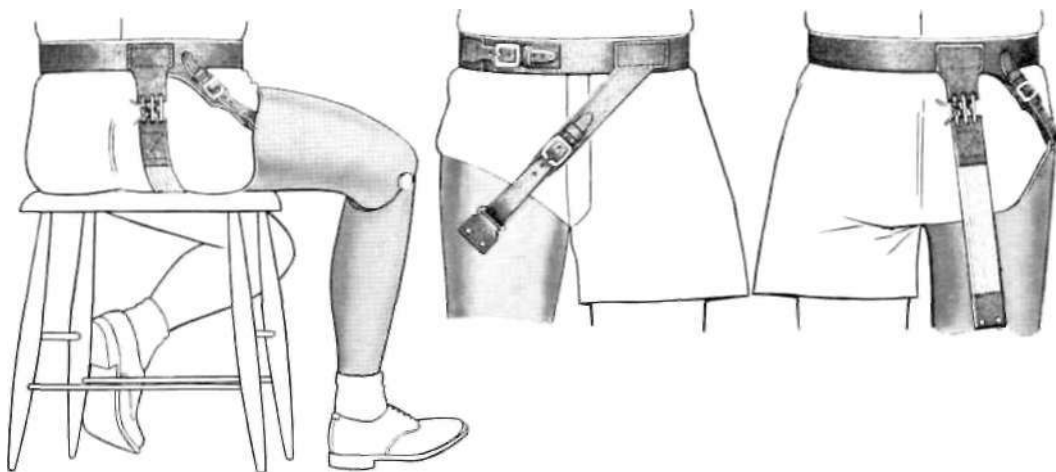


Fig. 50. Auxiliary suspension for short-stump above-knee amputee (modified Silesian belt), as designed at the University of California.

considered the socket comfortable but wanted the leg lengthened. The rough area on the medial brim was covered with "Teflon" tape in an attempt to reduce friction. Elongation of the prosthesis by 5/8 in. resulted in an improved gait appearance.

#### *Summary*

The problem in this case was to define prosthetic requirements correctly. Suction suspension with the above-knee type of prosthesis, in conjunction with the short-stump pelvic harness, was successful and, since it preserved usable function of the stump, seemed to offer for this amputee a method of treatment to be preferred over the hip-disarticulation prosthesis. Difficulties encountered were minimal owing to the previous experience gained with Case 10 (page 64).

Gait, more natural with the use of one cane, improved markedly over the five months of study. Weight-bearing on the gluteus maximus, ischial tuberosity, and tendinous attachments of the hamstring musculature was satisfactory. Use of the high anterior wall, without a protuberance of the socket wall over the area in contact with the femoral triangle, except above the ischial-seat level,

was satisfactory. For retention of suction, it was necessary to make all walls of the socket concave, especially below the medial brim because of bunching of the adductors.

#### CONCLUSION

From working with a group of amputees such as has been reported here, or from work with any similar group, many lessons are to be learned. One of the most obvious is that considerable "tincture of time" is required to solve chronic problems. The hope is that, as a result of the considerable amount of time devoted by a relatively small group of research subjects at the University of California, prosthetics clinic teams will gain some insight into possible methods of solving the problems of many other amputees.

The most common prosthetic problems of above-knee amputees as a group are edema, formation of an adductor roll, discomfort in the perineum (ramus pressure), and skin lesions. It has been found possible to control edema by maintaining a relatively uniform contact pressure between stump and socket. The proximal third of the socket need be fitted only slightly tighter than the more distal areas while still maintaining an airtight

seal. In the case of an edematous stump, it is important to recognize the necessity for skillful application of socket liners to maintain a functional socket fit as the edema is reduced. Such liners are usually applied along the anterior and lateral walls only.

The adductor roll which typically occurs with plug fit requires considerable time before the change can be made to an efficient, well-fitting suction socket. Almost without exception, such a condition requires a second socket to complete the fitting.

Ramus pressure is a thing of the past. Use of the higher anterior brim and the proper anteroposterior dimension from Scarpa's triangle to the posterior brim will eliminate completely this most troublesome complaint of above-knee amputees. No longer need the above-knee amputee suffer in silence because he just naturally expects his leg to be uncomfortable in this area.

Provision of an efficient supporting surface along the posterior brim of the socket and of a proper fitting of the lateral wall of the socket to provide femur stabilization will relieve common areas of skin irritation, such as at the anterior brim, at the ischial seat, at the medial brim, and at the lateral-distal end of the stump. The most common sources of skin difficulties are poor stump hygiene or rubbing and abrasion. Abrasion can be minimized by a functional fitting of the socket.

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