Status of the Above-Knee Suction Socket in the United States

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1 HE above-knee suction socket constitutes a means of attaching an artificial leg to the stump of an amputee without necessity for the conventional pelvic band, a metal hip joint, or other types of suspension harness (Fig. 1). The leg is held on by the slight vacuum created in the socket each time the leg is lifted from the ground, the pressure usually being controlled by a valve installed in the lower portion of the socket. Accurate functional fit of the socket, as distinguished from the conventional "plug" fit, permits the creation of negative pressure, gives a wider range of muscular control of the leg, and provides comfort while walking or sitting. Because the conventional belt and hinge joint are eliminated, the suction socket gives the above-knee amputee more freedom and less interference with clothing. The leg feels more like an integral part of the body, a feature which tends to decrease the sensation of dead weight and to improve sense of position. Reduced piston action of the stump in the socket results in greater toe clearance during walking. No stump sock is necessary. Any adductor roll is corrected. And finally, active use of the stump muscles causes them to develop instead of becoming atrophied.[3]

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[3] For a complete discussion of the prescription, fabrication, fitting, alignment, and use of the above-knee suction-socket prosthesis, reference may be had to Bechtol (J), to Eberhart and McKennon (5), and to the so-called "suclion-socket brochure" of the University of California ***(19).***

EARLY HISTORY

The earliest known reference to the suction socket is in the form of a patent issued by the United States, February 10, 1863, to Dubois D. Parmelee *(12)* of New York City. Subsequent patents have been issued to George Beacock and Terence Sparham *(2)* of Brockville, Ontario, Canada, in 1885; to Justin K. Toles *(16)* of Stockton, California, in 1911; and to Ernest Walter Underwood *(17)* of Birmingham, England, in 1926. The fundamental principles of the Beacock and Sparham suction socket differed but little from those of the Parmelee method. Toles' description was basically the same but with the addition of a rubber tube and bag lining which could be inflated by air to assist in holding the socket on. The socket described by Under-

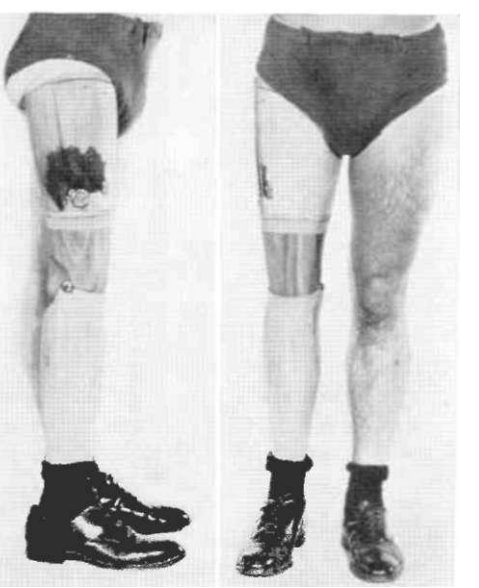


Fig. 1. Typical above-knee suction-socket leg before application of the usual rawhide finish.

wood had smooth helical grooves, which he claimed ventilated the stump as well as assisted in holding the socket in place.

A search of the literature on above-knee suction sockets has revealed only a few articles prior to the last few years. In 1925 Muirhead Little *(9)* of England reported favorably on 11 amputees fitted with the suction socket after the design of Blatchford *(9),* made of metal, and containing a smooth helical groove of a little more than one turn around the circumference of the socket. Some 30 cases were reported as fitted at Roehampton, England, following World War I using a metal socket with a helical groove as described by Blatchford *(9).* It is not known whether these 30 cases included the 11 reported by Muirhead Little, but it is considered doubtful since during this period several different groups were using the suction socket in England. Use of the suction socket has been practically dormant in England since that time, although it has been revived in recent years.

Pfau *(13)* of Berlin says the suction socket has been known in Germany for 30 years but that it was not popularized until Oesterle, in Ulm, started his work in the early '30s. Felix *(6),* a surgeon of Diisseldorf, reported on above-knee sockets in 1941. He stated that the suction socket had been used in Germany to some extent since World War I but that it was not popularized until a satisfactory suction-socket valve had been developed in 1932. After this accomplishment, numerous selected cases were successfully fitted in Germany.

As a result of the apparent reported success with artificial limbs in Germany, early in 1946 the Surgeon General of the United States Army sent to Europe a "Commission on Amputations and Prostheses" to observe foreign practice. One principal item of interest was the successful use in Germany of suction sockets for above-knee prostheses. Because of the favorable report *(21)* issued by the commission, the Advisory Committee on Artificial Limbs instituted, as one activity of its general plan of providing information on the best possible prostheses, a program to determine the possibilities and limitations of the suction-socket type of suspension for the above-knee leg.

CLINICAL RESEARCH IN THE UNITED STATES

After extensive trials and studies in their own laboratory, workers at the University of California, Berkeley, prepared instructional material and started a nation-wide program to determine the feasibility of use of the above-knee suction-socket technique under field conditions in the United States. By September 1947, 52 subjects had been fitted in 10 widely separated localities by local prosthetists in their own shops with materials and devices normally employed but making use of supplementary information and supervision by University personnel.

The success of this program led the Advisory Committee on Artificial Limbs, in October 1947, to recommend to the Veterans Administration the use of the suction-socket technique for above-knee amputees, its use being limited for the time being to further field tests within the VA under the direction of qualified surgeons. The recommendation was accepted and, from December 1947 through January 1949, 20 schools, each of one week duration, were held throughout the country to provide 250 orthopedic surgeons and 200 prosthetists with sufficient knowledge of the fabrication and application of the suction socket to introduce it on an experimental basis.

By October 1949 comprehensive records had been made of over 500 cases, and ACAL felt that sufficient experience had been gained in the use of the suction socket to warrant its general application. Accordingly, a recommendation was made to the Veterans Administration, and the above-knee suction socket has since been in use routinely. The Orthopedic Appliance and Limb Manufacturers Association and the Veterans Administration, in a cooperative effort, have sponsored suction-socket schools from time to time to permit surgeons and limbfitters to gain sufficient knowledge in this field to qualify them to prescribe and fit the suction socket.

SURVEYS or AMPUTEE ACCEPTANCE

The enthusiasm with which the suction-socket above-knee leg has been accepted in the United States is indicated by the results of a number of surveys. Among them are the surveys of selected groups made by Thorndike

and Eberhart *(15)*, by Mazet, McMaster, and Flutter *(10)*, and by Canty and Asbelle *(4)*. Results of three surveys, two by the Orthopedic Appliance and Limb Manufacturers Association, are shown in Table 1. The earliest data are from a University of California report *(18)* of April 1948. The 52 cases reported at that time had been carefully screened, selected, and fitted under the supervision of representatives of the Advisory Committee on Artificial Limbs. The results were carefully recorded. At the termination of this initial experimental program on April 15, 1948, of the 52 subjects fitted, 40 had been wearing their suction-socket legs routinely for 4 to 20 months. All were satisfied and had no intention of returning to the type of prosthesis worn previously. Six of the subjects, owing to improper fittings, nervous disorders, or lack of cooperation, were still alternating between the suction-socket leg and their previous legs. Six had been dropped from the program and were considered as failures.

In February 1949, the Orthopedic Appliance and Limb Manufacturers Association, in an effort to determine the extent of acceptance of the suction-socket leg in the United States, mailed questionnaires to approximately 200 limbshops. Of these, 159 shops reported. Eighty of those reporting had made no suction sockets at all; 79 shops had at that time fitted 1262 men, women, and children, with an amazingly small number of complete failures. A comparatively small group of 46 were converted to pelvic-belt-controlled legs, but many of these continued to use the suction-socket shape and some the suction valve, thus retaining many of the advantages of the suction-socket leg. The 1954 survey, also conducted by OALMA, with 72 firms reporting on 5882 cases, indicates similar conclusions. The 1954 OALMA questionnaire includes those firms reporting as few as three cases fitted and those reporting as many as 500 cases or more.

Table 1

AMPUTEE ACCEPTANCE OF THE ABOVE-KNEE SUCTION SOCKET

Year	1948[a]	1949[b]	1954[c]
Limbshops reporting	10	79	72
Total cases fitted	52	1262	5882
Men	52	1047	4616
Women	—	170	912
Children	—	45	354
Gritti-Stokes	—	112	250
Fitted with auxiliary supports	—	149	1539
Converted to conventional prosthesis	—	46	461
Complete failures	6 (11.5%)	56 (4.4%)	301 (5.1%)

[a] Data from the University of California (*18*).
[b] Data from OALMA's national survey on suction sockets, 1949; reported in *The OALMA Journal* (*11*).
[c] Data from OALMA's 1954 national survey on suction sockets.

Many of the limbshops reporting in both the 1949 and the 1954 OALMA questionnaires indicate that they have adopted the suction-socket method of fitting (that is, ischial bearing) as standard practice even though the amputee cannot actually wear the suction socket as such. Auxiliary supports, such as the Silesian bandage (Fig. 2), are used almost routinely by some limbshops. One of the most widely known and reputable shops in the United States reports the use of auxiliary supports on 300 out of 322 cases fitted. Another reports auxiliary supports applied in 300 out of 373 cases fitted. Another highly successful shop, in fitting 181 cases (of which 91 were children), used auxiliary supports on 90 cases. It is interesting to note that the firms reporting the largest number of cases also report the largest percentage of cases fitted with auxiliary supports.

The surveys indicate that over 96 percent of all suction sockets fitted since the introduction of the program were fitted to stumps over 3 in. long. In the one shop that reported 90 children fitted, not a single one was fitted with a stump shorter than 3 in. It is to be noted that most of those fitted with the stump shorter than 3 in. were women; and some reported that, although they did not believe the fitting of a stump shorter than 3 in. to be practical, they were almost forced at least to attempt it because of pregnancy, a condition which precludes wearing the conventional pelvic belt.

It may therefore be assumed that, except in very rare instances, generally it is impractical to prescribe the suction socket for stumps less than 3 in. long. A further observation is that of the large number of apparently quite successful cases of Gritti-Stokes amputations fitted, no failures whatever being reported in the case of amputation at this level.

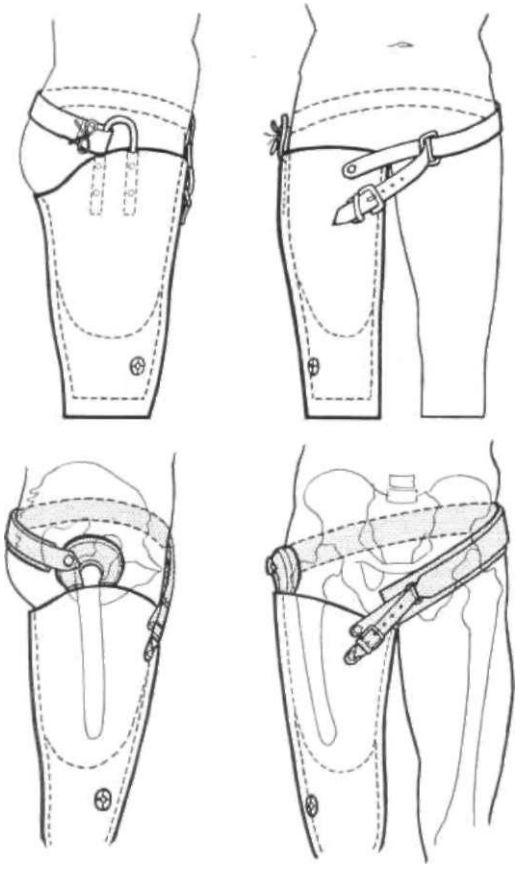


Fig. 2. Two forms of the Silesian bandage commonly used as an auxiliary support for the suction-socket leg, both in the United States and in Europe, particularly in Germany, where, according to Pfau, Hepp, and others ***(13),*** it is used almost routinely.

Another interesting feature brought out is that, while in 13 percent of the cases reported edema was present in the early stages of fitting, in only two cases did the edema persist and become a contributing cause of failure of the suction-socket leg. It is obvious from these data that, while edema may be common, it need not be considered a serious problem.

An effort was made to determine the number of bilateral above-knee amputees fitted successfully with suction sockets, but reliable data were not obtained on this question. From the information received in the survey, however, it is believed that the number will probably be about 100, the percentage of failures being approximately the same as in the case of unilaterals.

The overwhelming reason given for failure in the use of the suction socket comes under personality factors. An effort has been made in the surveys to obtain reliable data as to the definite reasons for failure. Personality factors are found to be predominant, with physical factors next in line, the condition of the stump third, and social and economic considerations fourth in importance. Thus tabulated, the causes of failure look about like this:

1. *Personality Factors*
- Unfavorable temperament
- Poor cooperation
- Inability to adjust
- Discouragement
- Lack of interest
- Low order of intelligence
- Insecurity

2. General Physical Factors
- Skin trouble
- Age
- Change in weight
- Circulatory difficulties
- Inability to bear weight on ischium
- Buerger's disease
- Ovenveight
- Perspiration
- Allergy
- General weakness
- Loose abduction
- Unsocial noises

3. *Slump Characteristics*
- Inadequate length
- Bone spurs
- Interfering scars
- Undue length

4. *Social and Economic Considerations*
- Insufficient time for proper fitting
- Excessive distance from shop
- Undue sales influence
- Employer disapproval
- Occupational requirement

Another question asked the reporting firms was: "What percentage of above-knee amputees could, in your opinion, be fitted with a suction socket?". While the answers to this question range from a low of 30 percent of all amputees to as high as 100 percent, the average is 73 percent, a figure thought, in the opinion of the authors, to represent a realistic approach.

Another question, asked because of the unusual amount of interest in children and the older age group on the part of the Committee on Artificial Limbs, was: "Is the socket suitable for amputees under five and over

seventy?". Almost without exception the suction socket was said not to be suitable for the very young or the very old.

Again, the question was asked: "When is the suction socket a practical approach to prosthetic fitting?". The following list of conditions, in the order of frequency with which they were mentioned, indicates the thinking prevalent among the reporting firms on this particular question:

Right personality factors and willingness to cooperate
Healthy, unscarred stump over 3 in. long
Under 65 years of age
New amputees not conditioned to suspenders or pelvic control
Easy access to facility
Good muscular reaction
Patient's enthusiasm
Good circulation
Good balance and coordination
Available training and therapy
Reasonable occupational demands

FACTORS IN SUCTION-SOCKET TECHNIQUE

Accumulated experience with fitting the suction-socket above-knee prosthesis over a period of seven years has clearly demonstrated its many advantages and its desirability over the conventional belt- or shoulder-suspended leg. On the other hand, the experience of the authors during the same period has convinced them that the suction socket is not suited for all above-knee amputees. This belief has been confirmed further by reports of survey studies previously conducted by others and by the results of the surveys reported here. In our opinion, there is considerable question as to the validity of the statement made by some to the effect that the suction socket can be used profitably by any thigh amputee who can wear the conventional type of prosthesis successfully. Experience has shown that there are certain amputees who cannot wear a suction-socket prosthesis successfully. If failures are to be avoided, all cases should be studied and screened carefully before a suction socket is prescribed.

The factors to be considered are divided roughly into two groups, each often affecting the other—those relating to characteristics of the prosthesis itself, and those relating to the characteristics of the amputee. Chief among the mechanical considerations of the leg are alignment and socket shape. Factors relating to the amputee are the general physical and mental condition, the condition of the stump, and the condition of the opposite extremity.

FACTORS RELATING TO THE ARTIFICIAL LEG

Alignment

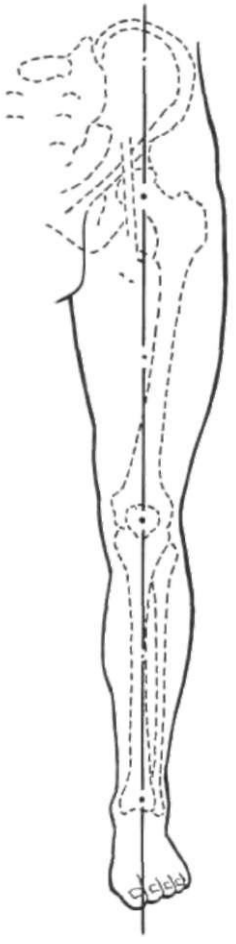
With the suction-socket leg, which is controlled entirely by the stump muscles, alignment becomes much more critical than in the case of the pelvic-band suspension and therefore must be correct for proper control and comfort. If alignment is incorrect, there is a definite whip or rotation of the prosthesis during the swing phase. The problem of alignment has not yet been solved completely, and opinions differ a little as to what constitutes the ideal alignment of the prosthesis. Theoretically, it is desirable to incorporate as much adduction of the stump within the socket as is possible mechanically, since to do so tends to suppress body sway and to place the iliotibial band (or that portion of it which may remain intact) under tension.

In the normal, the centers of hip, knee, and ankle joints coincide in the frontal plane with the mechanical axis of the lower extremity as a whole (Fig. 3). After amputation through the femur and fitting with a prosthesis, however, the body weight is no longer borne through the center of the hip joint but on the ischial tuberosity, which lies medial to the center of the hip joint. This would indicate, then, that the mechanical axis of the well-aligned above-knee prosthesis would more nearly coincide with a vertical line extending from the ischial tuberosity through the centers of the knee and ankle joints (Figs. 4 and 5).

In the sagittal plane, the weight line in the normal person is a vertical line drawn through the centers of the shoulder, hip, knee, and ankle joints (Fig. 6, left). After amputation and fitting of a prosthesis, however, this vertical weight line must be shifted forward in order to obtain alignment stability (Fig. 7).

If the amputee is young and agile, with no stump deformities and with strong and well-developed muscles in the back of the stump, the dimension *b* in Figure 7 may be reduced to zero. On the other hand, in the presence of flexion contracture in the stump, or weak

musculature, this dimension may have to be increased to give sufficient stability. But to do so may result in the sacrifice of a normal gait and cause a tiring and awkward one. Similarly, postural abnormalities (Fig. 6, center and right) can make proper alignment very difficult to achieve.



Fig, 3. Normal alignment in the frontal plane, showing how centers of hip, knee, and ankle joints coincide with the mechanical axis of the lower extremity as a whole. From Thomas and Haddan ***(14).***

Such deviations in the weight line have upon postural stability and body alignment a biomechanical effect that is obvious. To complicate matters further, the amputee is deprived of a number of those sensory cues upon which every normal human being depends for the autonomous control of posture and motion. These include touch and pressure sensations from the soles of the feet and the never-ending bombardment of proprioceptive impulses that emanate from sensory receptors in the muscles, tendons, and joints of the weight-bearing limbs and sweep upward to the cerebellum. In the aggregate, these physiological and biomechanical deviations from normal appear formidible. Yet with proper fitting and alignment of his prosthesis, and with adequate training in the proper gait and posture, the average amputee can compensate for them to an amazing degree.

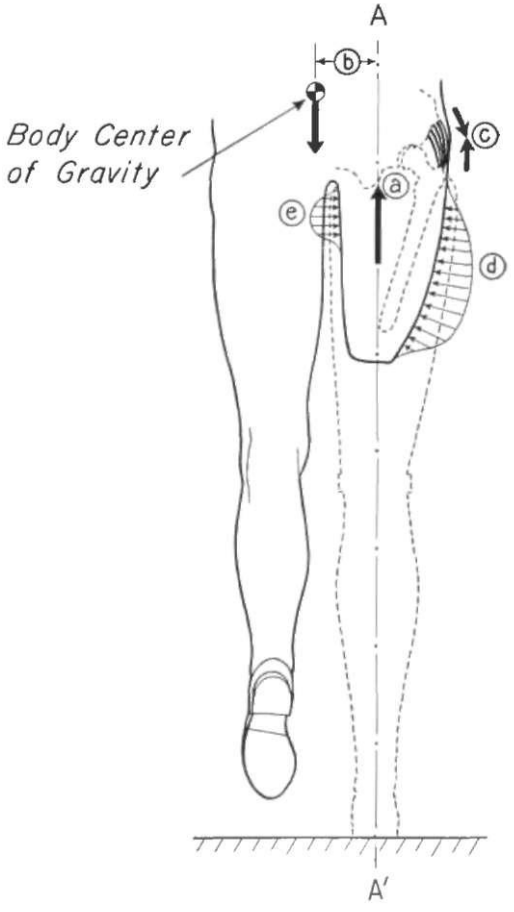


Fig. 4. Forces acting on the stump and pelvis of an above-knee amputee during the stance phase. In the well-aligned prosthesis, the heel of the foot and the center of the knee should fall approximately on a vertical line (A-A') through the point of contact of the ischium (a). The tendency of the pelvis to rotate downward on the normal side owing to the body weight can be reduced by keeping the dimension **(6)** as small as possible. This is accomplished by an upward force through the ischium (a). Lateral rotation of the pelvis and sidesway in the shoulders and torso can both be minimized if the force in the abductor muscles (c) is sufficient to balance the body weight by lever action about the ischial seat *(a).* The stump must be anchored firmly and comfortably by pressure along the entire lateral side *(d).* Failure to do this results in discomfort at the crotch (e). From Haddan («).

Socket Shape

Exactly what constitutes the most successful socket shape has not yet been fully determined owing to the many variables involved in the use of this technique. Several successful designs have been fully described in the literature *(3,5,18,19).* In these designs, weight-bearing occurs chiefly about the top posterior portion

of the socket, particularly in the region of the ischial tuberosity, with a lesser amount on the gluteal muscle. The addition of a well-defined ischial seat reduces piston action of the stump in the socket to a minimum and allows for a looser fit at the top of the socket. Incorrect shape, size, or location of the ischial seat leads to definite discomfort and frequent loss of suction, particularly when the wearer is sitting. In some very muscular stumps, the ischial seat may be reduced in size and in some cases removed entirely. Such amputees bear weight on their well-developed muscles, with the load distributed around the top portion of the socket. The socket is shaped the same except for the reduction or removal of the ischial seat.

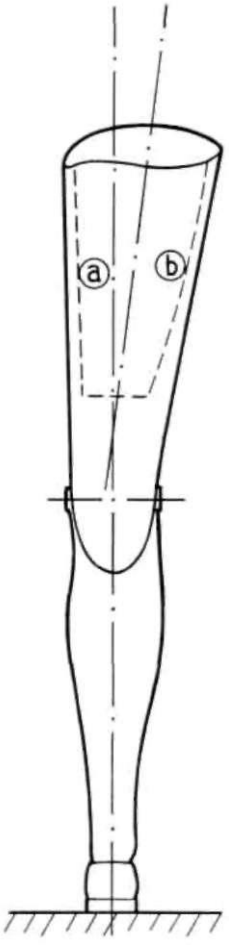


Fig. 5. Posterior view of the above-knee prosthesis showing position of the socket in relation to the rest of the leg. The medial line (a) should be approximately vertical. The lateral line (6) is sloped downward and inward. From Haddan *(8)*.

FACTORS RELATING TO THE AMPUTEE

General Physical and Mental Factors

A complete history and physical examination is the first step in determining the desirability of fitting the suction socket. Age is an important consideration, and as a rule elderly amputees are poor candidates for the suction socket. But old age *per se* is not a contraindication. Amputees over 70 years of age have been fitted successfully. As already noted, the suction-socket prosthesis is activated almost entirely by the muscles of the stump, and for this reason it requires considerably more effort and muscular skill to learn to use it. If, therefore, the elderly amputee is, as is so often the case, debilitated and feeble, with muscles weak and flabby and with poor coordination and balance, he is a poor candidate for the suction socket. On the other hand, if he is strong, alert, and agile (that is, if he "appears younger than he is"), and if the stump is in proper condition and of adequate length, there is no reason why the elderly amputee cannot use a suction socket successfully.

Experience has indicated that children as young as seven years can be fitted successfully *(1)*. The problem of lengthening and replacement as growth proceeds is no different from that with the conventional prosthesis.

Before a suction socket is prescribed, every effort should be made to determine the psychological make-up of the amputee. All reports indicate that most failures have been due to

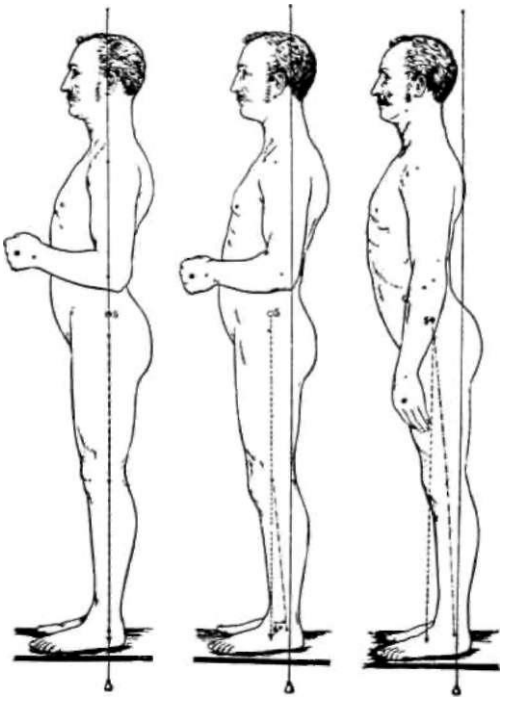


Fig. 6. Normal posture and two postural deviations which must be compensated for in fitting and aligning the prosthesis. Left, normal; center, slight deviation from normal presenting few difficulties in prosthetic fitting; right, extreme postural abnormality which, unless corrected by postural exercises, would present almost insurmountable alignment problems. From Gocht (7).

psychological or emotional difficulties. Learning to wear and use a suction-socket prosthesis requires cooperation, effort, patience, and perseverance. If the amputee is impatient, resentful, undependable, easily discouraged, unreasonable, or otherwise emotionally unstable, he most likely will be uncooperative and is apt to be a poor subject for the suction socket. Many failures can be attributed to the fact that the amputee is either unwilling or unable to devote the necessary time and effort to obtain a satisfactory fitting. As experience has been gained by the prosthetists, and with the additional aid of the recently developed alignment devices (page 23), the time required for construction and fitting has been considerably lessened in recent years. The interesting observation has been made that, when an amputee has to purchase his limb himself, he is likely to be much more cooperative than if he is given one by some agency.

Slump Considerations

Length. Stump length is not so important a consideration as might be thought. Contour, muscle tone, and mobility are important determining factors in deciding whether or not a short stump can be fitted. Naturally, the longer the stump the better is the muscular control and the easier is the fitting and training problem. But stumps as short as 3 in. (measured from the crotch) have been fitted successfully. Usually the shorter stumps require the addition of an auxiliary suspension belt (such as the Silesian belts shown in Figure 2) in order to stabilize the socket on the stump.

End-bearing supracondylar and Gritti-Stokes amputation stumps can be fitted successfully with the suction socket, although in such cases the mechanical knee joint usually has to be placed at a level slightly below that of the opposite knee.

Stump Contour. With the conventional socket, a conical-shaped stump has always been considered desirable. Such is not the case with the suction socket. A stump'of more cylindrical shape, with only slightly tapering sides and a fairly broad end, seems to maintain better suction and friction than does the conical or pointed stump. Most undesirable is a long, redundant, flabby mass of skin and fat extending beyond the bone end. Such a mass of tissue not only offers fitting problems but is prone to become edematous and swollen, thus making it difficult to don the leg or to remove the stump from the socket. In such cases, surgical revision is advisable before a suction socket is prescribed.

Excessive subcutaneous fat or extreme flabbiness of stump muscles frequently results in marked changes in the contour of the stump after the suction socket has been worn for a while. Repeated modification of the socket thus becomes necessary. With excessive subcutaneous fat, the stump may shrink considerably after wearing the socket, necessitating the insertion of leather liners or even the making of a new socket. Muscles that are atrophied and flabby and of poor tone will develop and increase in size with the use of the suction socket, necessitating enlargement of the socket.

Muscle Control and Strength. Good muscular control and mobility of the stump are essential for successful use of the suction socket. Fixed deformities due to muscle contracture are very common in amputations above the knee, particularly in the older age group, and they not only present very serious fitting and alignment problems but also handicap the amputee in walking. Flexion and abduction deformities are the usual ones, and the shorter the stump, with resulting greater muscle imbalance, the more likely are they to occur. Once they do occur they are very difficult to correct. It is imperative, therefore, that every effort be made postoperatively to prevent such deformities. Studies in alignment conducted at the University of California *(20)* indicate that the most efficient gait with the suction-socket prosthesis is obtained by fitting the socket with the stump in adduction and slight flexion (Fig. 7). Severe flexion-abduction deformity of the stump makes such alignment very difficult, if not impossible, without producing marked tilting of the pelvis and excessive pressure on the stump.

The adductor and hamstring muscles are important not only in controlling the limb but also in preventing flexion-abduction deformity by overcoming muscle imbalance. The shorter the stump, the less power remains in these muscles and the greater the tendency to

deformity. It is well known that, in order for muscles to function at maximum efficiency, they must have a fixed insertion. In amputations through the thigh, the major muscles are sectioned well above their insertions, and all too often these muscles are allowed to retract upward, no attempt being made to fix their cut ends to fascia or over the end of the bone. Failure thus to fix the free ends seriously impairs muscle function in controlling the stump. In considering an amputee for a suction socket, the stump should be carefully examined to determine how well the thigh muscles are functioning and whether there are any fixed deformities. If any are present, active and passive exercises should be carried out to correct them as much as possible before the socket is fitted.

Scars. Deep linear scars near the socket brim may interfere with maintenance of suction. Tender, adherent scars in the weight-bearing area beneath the ischial tuberosity and over the buttocks may cause pain sufficient to prevent the wearing of a suction socket. Deep, folded, adherent, or puckered scars over the end of the stump, which so often cause difficulty with the conventional socket, rarely offer any problem with the suction socket. In fact, it has been observed repeatedly how often these scars smooth out and become more pliable after a suction socket has been worn for some time.

Ulceration and Infection. Open ulcers, draining sinuses, and active deep infection of the soft tissues of the stump, as well as active osteomyelitis, are definite contraindications to the use of the suction socket. With adequate surgery and use of antimicrobial drugs, these conditions can usually be eradicated readily.

Bony Spurs. Although in many thigh stumps bony spurs develop at the end of the femur, they rarely offer any difficulty in the fitting or wearing of a suction-socket prosthesis. Occasionally, however, a large spur will develop on the lateral side of the bone in a stump with a fixed abduction, thus producing painful pressure against the side of the socket. Relieving the socket at point of pressure, realigning the socket, or surgical removal of the spur usually solves such a problem.

Skin Disturbances. Skin sensitivity, irritation, and infections are not uncommon in amputation stumps, and there appears to be considerable variation in the skin's resistance to pressure, friction, and irritation among individual amputees. Some are constantly troubled, while others have no difficulty. Dermatological complications are cited as a fairly common cause of failure in the use of the suction socket. Usually they can be prevented by proper hygienic care of the stump and good fitting, or else they can be relieved by dermatologic treatment. Skin allergy and contact dermatitis, of rare occurrence with the suction socket, usually can be controlled readily. The troublesome adductor roll, with recurring "pressure boils" (suppurative hydroadenitis and folliculitis), so commonly encountered with the use of the conventional socket, rarely if ever occurs with the well-fitted suction socket. In fact, when such a condition exists with a conventional socket, and the socket is converted to a suction one, usually the roll and

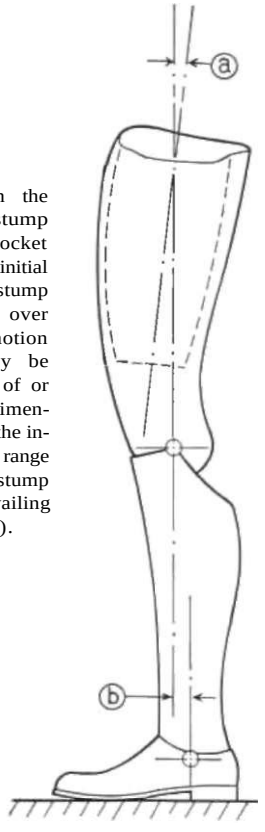


Fig. 7. Alignment in the sagittal plane. The stump should be oriented in the socket with several degrees of initial flexion *(a)* to allow the stump to control knee stability over the widest range of hip motion possible. The ankle may be positioned either in front of or behind the knee. The dimension (i) will depend upon the individual amputee, his age, range of motion in the stump, stump musculature, and prevailing terrain. From Haddan(#).

cysts rapidly disappear. This is one of the great advantages of the suction socket.

Perspiration. One troublesome problem occurs in individuals who perspire excessively and who also have a high bacterial count in their perspiration. Irritation or skin friction in such a situation leads to suppurative hydroadenitis and furunculosis. Excessive perspiration is not uncommon when the suction socket is first worn, but it usually subsides after varying lengths of time. In alleviating these superficial skin infections, x-ray treatment is often of value. Autogenous vaccines have also been used with some success. Before any suction socket is discarded as a failure, every possible effort should be exerted to treat and eradicate such troublesome skin conditions. Some of them can be anticipated from previous history and careful examination and can be eliminated by proper treatment before the socket is fitted.

Condition of Ike Opposite Extremity

During the experimental program, and in the early suction-socket schools, abnormalities and disabilities in the opposite extremity were considered as constituting an important factor—and even as a probable contraindication—in determining the suitability of the amputee for a suction socket. Subsequent experience has shown that abnormalities in the opposite extremity, while still to be considered, are not necessarily contraindicative. Amputees with disabilities so great as to require permanent bracing of the opposite limb have been fitted successfully with suction sockets; many persons with below-knee amputations on one side are wearing above-knee suction-socket prostheses with ease and comfort on the other. In fact, in such cases the suction-socket leg appears to have several advantages over the conventional above-knee leg. Survey studies also reveal that some bilateral above-knee amputees have been successfully fitted with suction-socket prostheses. But of course it is apparent that all such cases must be selected only after a very thorough analysis of individual problems.

Peripheral vascular disease which has necessitated amputation is in itself no contraindication to use of a suction socket, provided the opposite limb is not too seriously affected by the disease.

CONCLUSIONS

On the basis of the surveys reported upon, it appears quite definite that the suction-socket prosthesis has many advantages over the conventional belt- or shoulder-suspended leg. Approximately 75 percent of all above-knee amputees can be fitted successfully with the suction socket. Chief causes of failure, listed in decreasing order of importance, are psychological difficulties, general physical factors, stump abnormalities, and social and economic factors. Teamwork between physician, prosthetist, therapist, and amputee is an essential requirement in the successful fitting and wearing of the suction-socket prosthesis. Meticulous attention to fitting and alignment techniques is important, as is also adequate training.

Research studies in gait and principles of alignment, and the development of new alignment devices and duplicating jigs, have been of great value in reducing the time involved in construction and fitting by eliminating, to a great extent, trial-and-error methods. Although many limb manufacturers in this country still do not appreciate the advantages of the suction-socket above-knee limb and make no attempt to fit it, the wide acceptance of the above-knee suction-socket prosthesis in the United States today indicates that it can no longer be considered an experimental device, its use limited to a few selected amputees. Use of the above-knee suction socket is now so prevalent that it can be safely stated—and fairly stated—that the majority of above-knee amputees can successfully be fitted with the suction-socket prosthesis.

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