

Recent Advances in Above-Knee Prosthetics

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During the past few years, many innovations have been introduced into the practice of above-knee prosthetics. Most of the literature on the new practices has been provided by the innovators, and therefore the reports and articles on the subject generally are limited to a single approach. It is the purpose of this article to survey past and present practices and to set forth, as accurately as possible, a perspective of procedures and devices available today for the management of the above-knee amputee.

Amputation through the thigh results in distinct functional losses. The obvious ones are loss of support by the long bones and loss of joints, resulting in inability to stand and move extensively from place to place. In addition, the appearance of the patient becomes altered from the "normal" in both static and dynamic conditions.

Lost support and mobility can be replaced to some extent by the use of a wheelchair or crutches or both, but it has been shown that use of an articulated prosthesis is the most effective means of compensating for these losses. An amputee with a functional prosthesis can negotiate stairs, ramps, and other obstacles and, therefore, can move through areas that would be impracticable if not impossible for a wheelchair. Crutches, properly used, offer a great deal of facility of movement but require the use of considerably more energy than a well-fitted and -aligned above-knee prosthesis, or even a peg leg (2,19). Also, when crutches are used the hands are not free during ambulation.

Another argument for the use of a functional prosthesis is that a fairly normal appearance can be achieved.

The basic functional prosthesis for the above-knee amputee consists of a socket, a knee unit, a shank, and a foot-ankle unit. In cases where it is not deemed advisable to keep the socket in place by air pressure (suction socket), suspension must be provided by a belt about the pelvic area or by a shoulder harness.

Not so many years ago it was common practice for the prosthetist to make in his shop nearly every part for a prosthesis from basic materials such as wood, steel, and leather. This practice was time-consuming and wasteful. To eliminate as much manual work as possible, the prosthetist today designs and fabricates the socket from basic materials to fit each patient individually, but uses prefabricated components, which he purchases from manufacturers, for the rest of the prosthesis (2, 16).

SOCKETS

Until the introduction of the suction socket in the late 1940's (9), it was common practice to provide the above-knee amputee with a so-called plug-fit socket suspended by a pelvic band connected to the socket by a metal "hip" joint (Fig. 1) (23). The plug fit did not provide for a very adequate distribution of forces between stump and socket. There was a tendency for the formation of an adductor roll, and the stability provided between stump and socket left much to be desired. The pelvic belt was heavy. The "hip" joint restricted motion essentially to flexion and extension, and was subject to frequent breakage. Most of the sockets were

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Fig. 1. Typical prosthesis for above-knee amputees during the 1940's. Note pelvic band, mechanical "hip joint," carved wooden socket with a "plug fit," and pelvic-control knee joint.

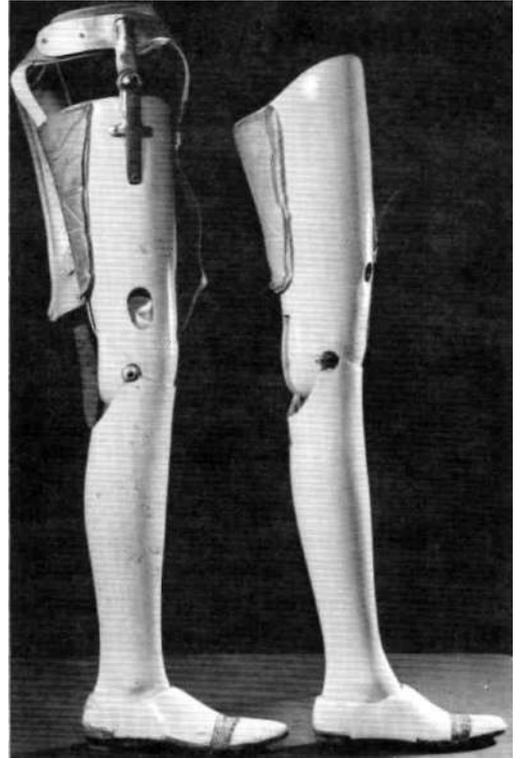


Fig. 2. An early version of the suction-socket prosthesis (*right*), shown in comparison to the so-called conventional above-knee prosthesis.

carved from willow wood and reinforced with rawhide, although sockets formed from aluminum sheet were not uncommon.

The primary purpose of the suction socket (Fig. 2) was to provide increased function and comfort by eliminating the mechanical hip joint and pelvic belt. Pressures between the stump and socket were distributed over wider areas; stability and, therefore, control were improved materially. A socket of the quadrilateral shape (11,17) became standard whether or not suction was used for suspension. The waist belt and Silesian bandage were introduced as more comfortable suspension methods to supplant the pelvic belt and hip joint in some cases. Willow wood remained the material of choice, but plastic laminate

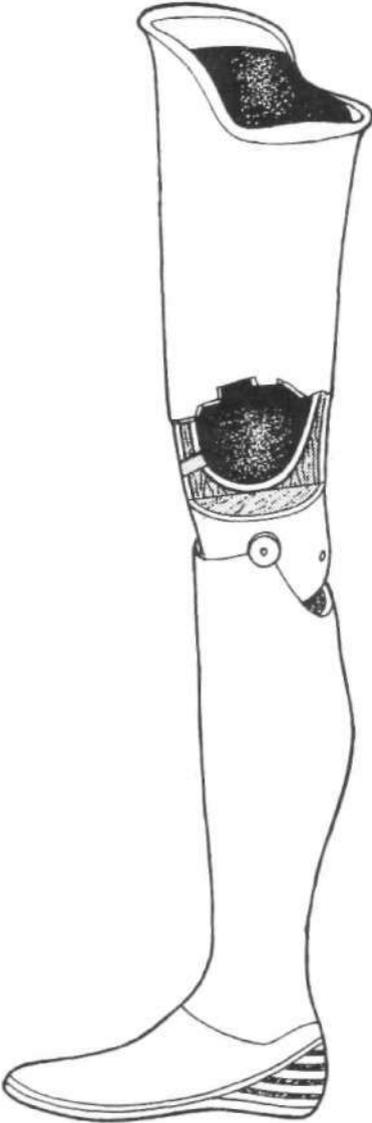


Fig. 3. An above-knee prosthesis with a quadrilateral, total-contact socket.

(usually nylon stockinet impregnated with a polyester resin) replaced rawhide as a reinforcement material.

Experience with problem cases, with the early versions of the suction socket in which a certain amount of air space is left below the distal end of the stump, led the University of California, Berkeley, to

develop the modification now known as the total-contact above-knee socket (Fig. 3)(5,6). In a certain number of cases, edema developed in spite of most careful fitting with the "open-end" socket. It was found that the edema could be eliminated by providing a small amount of counter-pressure over the distal end. It was also found that the entire stump must be in contact with the socket in order to keep the circulatory system in balance. The introduction of counterpressure also reduced the unit pressures at the proximal region of the stump, and the contact over the end of the stump seemed to enhance proprioception.

To provide a well-fitting total-contact socket of wood requires a great deal of skill and is quite time-consuming compared with the use of plastic laminates. Plastic laminates, which had proven so useful in the fabrication and fitting of upper-extremity and below-knee prostheses, had not been used for above-knee sockets because of the difficulty encountered in obtaining an adequate cast for preparation of the positive model needed for molding the laminate. A few highly skilled prosthetists had been known to produce adequately formed casts using only their hands, but this achievement was exceptional. To solve this problem, several devices were developed so that casts of above-knee stumps that required a minimum amount of modification could be achieved.

The UC-Berkeley device (Fig. 4)(5,12) uses a series of adjustable brims with which the cast is taken under weight-bearing conditions; the Veterans Administration Prosthetics Center device uses a three-part universal jig for holding the stump in position, also under weight-bearing conditions (Fig. 5)(12); the New York University casting fixture is a portable device that holds the cast in position but does not require the patient to be in a weight-bearing position (Fig. 6)(12); and Northwestern University has developed

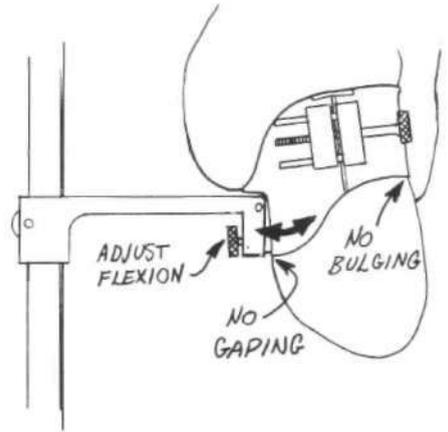
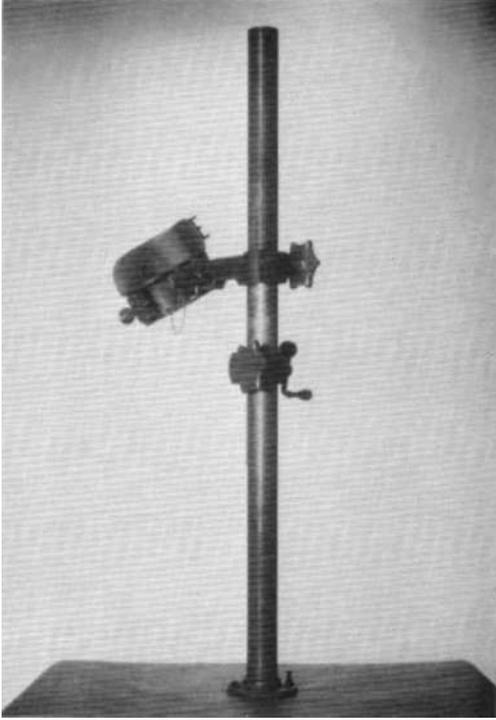


Fig. 4. The fixture for the "brim-fitting" technique developed at the University of California Biomechanics Laboratory (San Francisco and Berkeley). Adjustable, easily interchangeable brims are available in a complete range of sizes. The view on the right shows attitude of patient in fixture; right leg is not shown for clarity. See Figure 7 for still another view.

a modification of the UC-Berkeley technique in which a cast sock is used to suspend the stump and thus assist in forming the desired contours (Fig. 1)(10).

The object of each of these tools is exactly the same: to provide a cast of the above-knee stump that requires the least modification for the fabrication of a well-fitting, quadrilateral, total-contact socket. Each has its advantages and disadvantages. None is superior to the others in all aspects, and selection is based on the personal preferences of the prosthetist. Many facilities have two or even all three devices available for use as circumstances dictate.

FITTING AND ALIGNMENT

The basic rationale of alignment as set forth by Radcliffe (17) in the early 1950's is essentially unchanged, although proper

use of some of the hydraulic knee units demands some variations.

In order to make it easier for the prosthetist to achieve optimum alignment, the University of California, Berkeley, developed the adjustable leg (Fig. 8) and alignment duplication jig (Fig. 9)(20). Dynamic alignment is obtained during amputee ambulation with the adjustable pylon, and the alignment obtained is transferred to the finished prosthesis during fabrication by use of the alignment duplication jig. This procedure proved to be highly satisfactory for use with single-axis, constant-mechanical-friction knee joints, since the adjustable leg also contained this type of joint. Because the functions of the Hydra-Cadence leg demanded that it be aligned somewhat differently, the STAROS-GARDNER coupling (Fig. 10) was designed (20). When

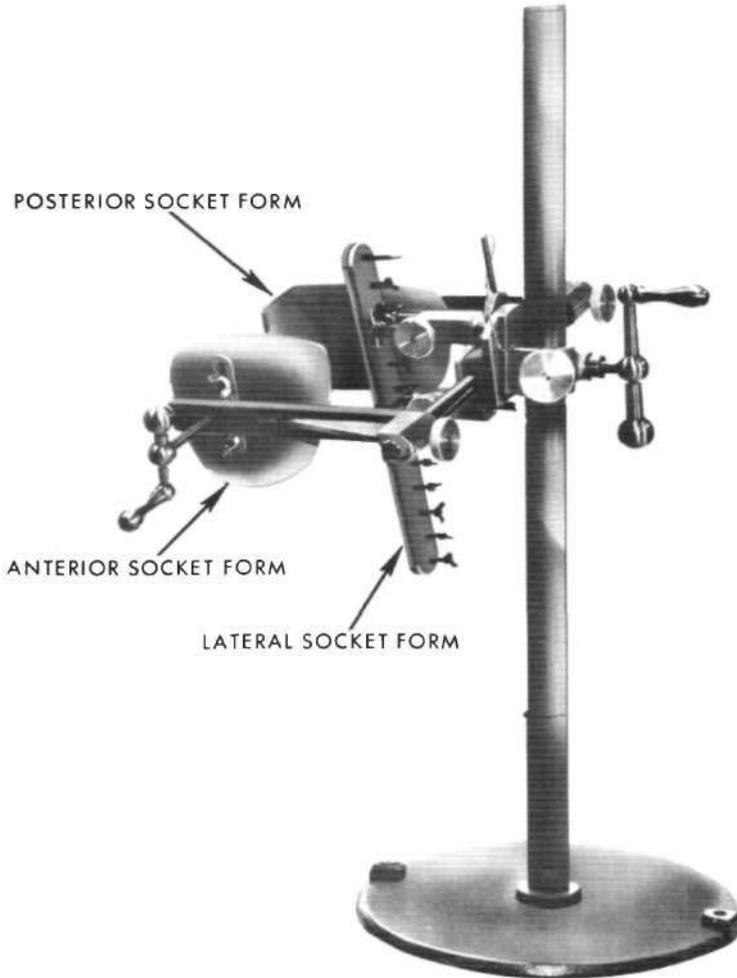


Fig. 5. The fixture for casting the impression of an above-knee stump developed at the Veterans Administration Prosthetics Center.

placed between the top of the knee block and the thigh piece or socket, the Staros-Gardner coupling provides all the adjustments permitted by the adjustable leg except mediolateral placement of the foot with respect to the knee axis, an adjustment not often used and, then, only to provide better cosmetic appearance. A technique was developed so that when final alignment was achieved a wooden block could be substituted for the coupling, thereby eliminating the need for the alignment duplication jig.

COMPONENTS

Components for above-knee prostheses can be obtained from central manufacturers in a number of ways. The most common approach is to purchase "knee-shin set-ups" and foot-ankle units, and to connect these to each other and to the socket in the alignment best suited for the individual patient. The knee-shin set-up usually consists of a wooden knee block, the proximal portion of a hollow wooden shank, and a knee control mechanism (Fig. 11). Excess wood is provided so that the

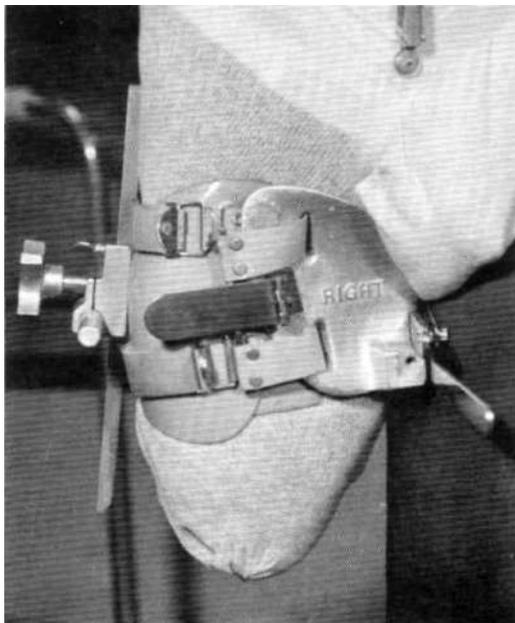


Fig. 6. Anterior view of the New York University casting brim in use.

knee and shin can be individually contoured, and in the finished prosthesis the entire unit is reinforced structurally by the application of a plastic laminate over the exterior. Complete wooden set-ups are available, but are seldom used. However, when coordinated motion between knee and ankle is incorporated in the prosthesis, as in the Hydra-Cadence unit, a complete set-up is used.

A number of temporary, or preparatory (see *inset* on p. 18) prostheses, popularly known as "pylons," are available (Fig. 12). Usually these devices are used with an ordinary foot-ankle unit which can be incorporated into the final or definitive prosthesis.

KNEE UNITS

Probably no other component of artificial limbs has received as much attention from designers and "gadgeteers" as the knee joint. Several hundred patents have been issued for knee designs, and many types have been produced and offered to the public, but relatively few designs have been used widely.

The primary functions of a knee unit for above-knee prostheses are control of the leg during standing and the stance phase of walking, and control of the shank during the swing phase of walking.

Swing-Phase Control

The articulated above-knee prosthesis functions as a compound pendulum. As the thigh stump is brought forward during the latter stages of stance phase, the knee begins to flex and the foot is lifted from the ground because of the effects of inertia. The force propelling the shank acts more or less horizontally through the knee joint, while the center of gravity of the



Fig. 7. A method, developed at Northwestern University, which uses the University of California casting fixture.

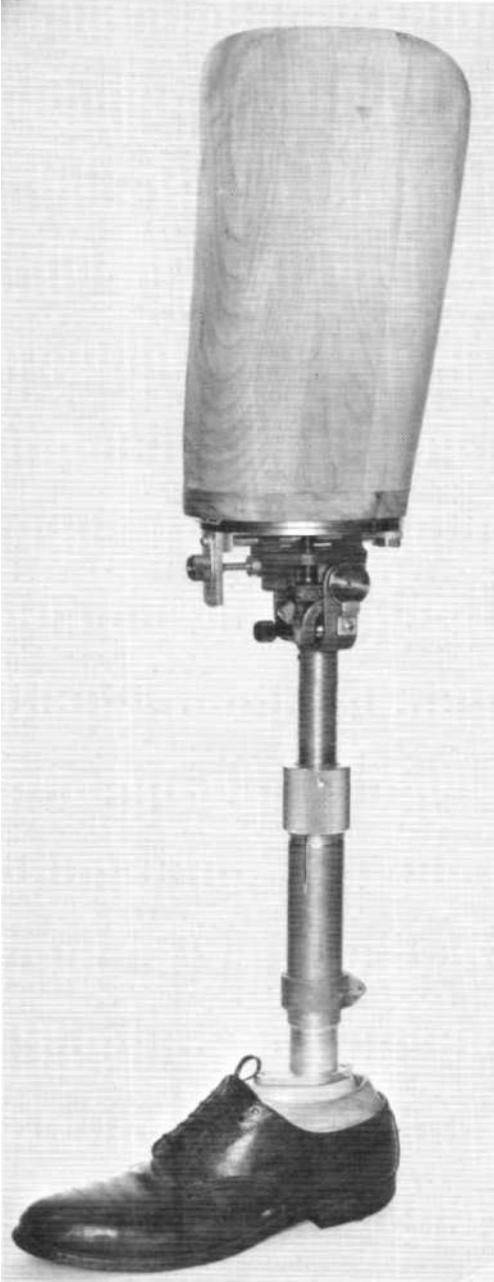


Fig. 8. The adjustable above-knee leg developed by the University of California Biomechanics Laboratory (San Francisco and Berkeley).

shank is well below this level; thus a moment is created, resulting in rotation of the shank about the knee joint in a backward direction (Fig. 13)(15,16).

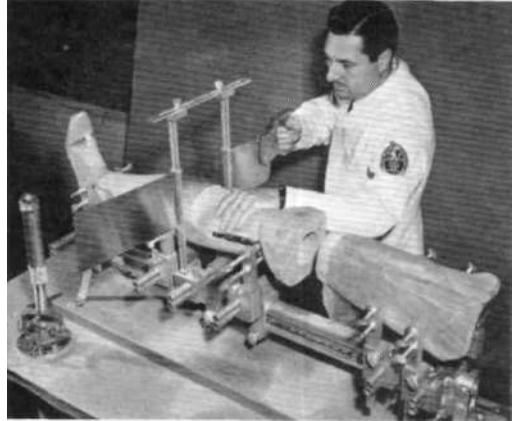


Fig. 9. The alignment duplication jig developed by the University of California Biomechanics Laboratory (San Francisco and Berkeley) to be used in conjunction with the adjustable leg shown in Figure 8.

The less friction there is in the joint, the higher will be the rise of the heel for any given acceleration. Therefore, when a nearly frictionless joint is used, the amputee must use very short steps at a low cadence, so that the shank and foot will return to the proper fully extended position to support him as stance phase is begun. If friction, or some other form of resistance, is introduced, rise of the heel is restrained and shank motion toward full extension is retarded, so that longer steps at higher cadences are possible. When the amount of friction is constant, only one best speed is available to the patient. To overcome this limitation, designers have turned to hydraulic and pneumatic devices to obtain desirable resistance.

To guide the design of swing-phase control units, the University of California has plotted knee moments against time for the ideal prosthesis during swing phase (Fig. 14)(28). This diagram is based on data accumulated from four normal young males, allowances being made for weight and weight distribution between normal and artificial limbs. The values, of course, will change as cadence is varied and as the height and weight distribution are changed. However, the general pattern should not change.



Fig. 10. Staros-Gardner coupling being used to achieve alignment in an above-knee prosthesis. When the desired alignment has been achieved the coupling is replaced with a section of wood. A technique has been developed so that alignment can be maintained without need for the alignment duplication jig.

Constant Friction (Mechanical)

Constant friction in a way is a misnomer, because the amount of friction or restraint can be controlled or set, but does not vary in accordance with the needs of the amputee during a given cycle. The amount of

friction can be controlled in a number of ways, the most common being the application of a braking surface to the peripheral area of the knee bolt (Fig. 15). The typical knee-moment diagram for a constant-friction knee unit is shown in Figure 16.

Intermittent Friction

To more closely approximate the ideal knee-moment diagram, several designs have been made to vary the amount of

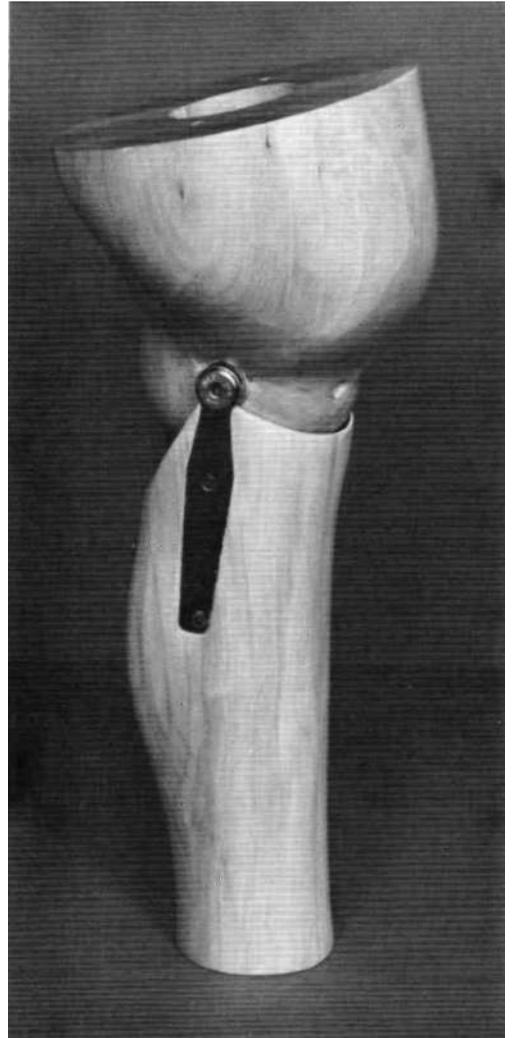


Fig. 11. Typical knee-shin wood set-up. Courtesy U.S. Manufacturing Co.

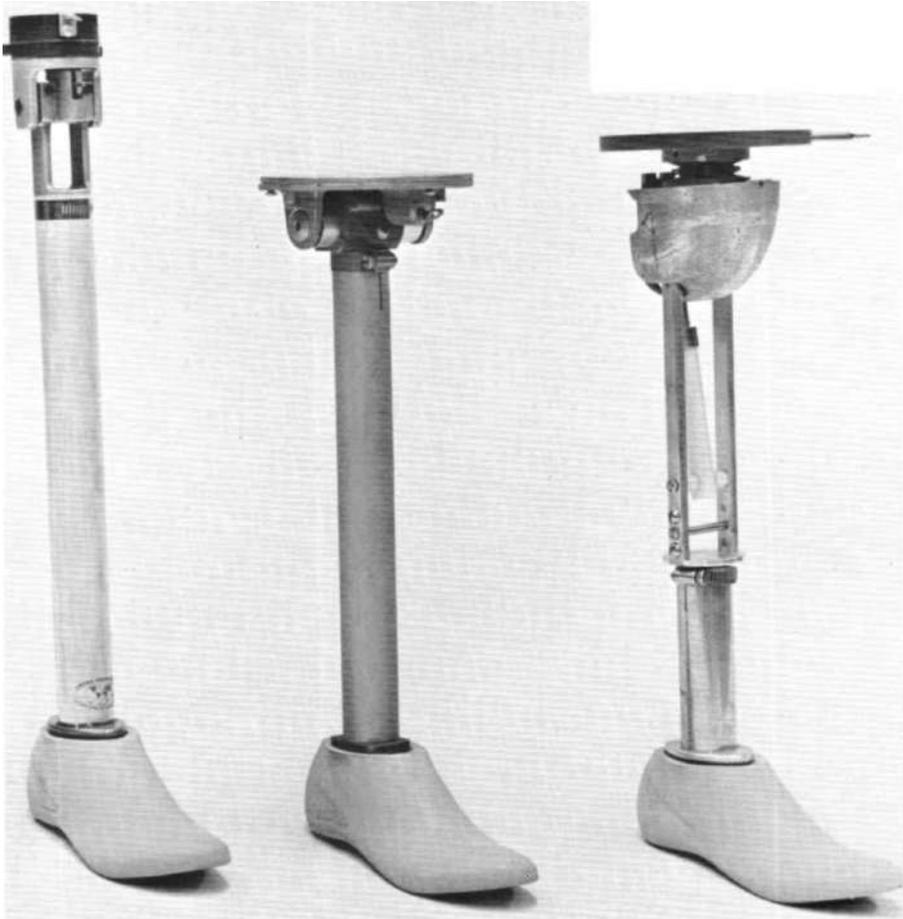


Fig. 12. "Pylons" for above-knee amputations. *Left*, U.S. Manufacturing Co.; *Center*, A. J. Hosmer Corp. unit based on the UCB adjustable leg; *Right*, VAPC unit designed to accommodate a variety of knee-control devices.

mechanical friction applied at predetermined points during the swing phase. The Northwestern University Intermittent-Friction Knee Unit (Fig. 17) is one such device that is available commercially. Mechanical friction is provided by pressure between three disks mounted concentrically with the long axis of the knee bolt. The resistance offered by each individual disk is brought into play at varying intervals during the swing phase. The knee-moment diagram of the Northwestern University unit is shown in Figure 16. The unit is available in a wood set-up, and is

delivered with three disks installed. Two additional disks of different configurations are provided for interchange with the regular disks, so that the pattern of resistance about the knee can be changed to suit the amputee on an individualized basis (22).

Hydraulic Swing-Phase Control Units

Because the resistance offered by an orifice to the flow of a fluid increases at a greater rate than the increase in velocity of the fluid, hydraulic systems are ideally suited for control of the shank during

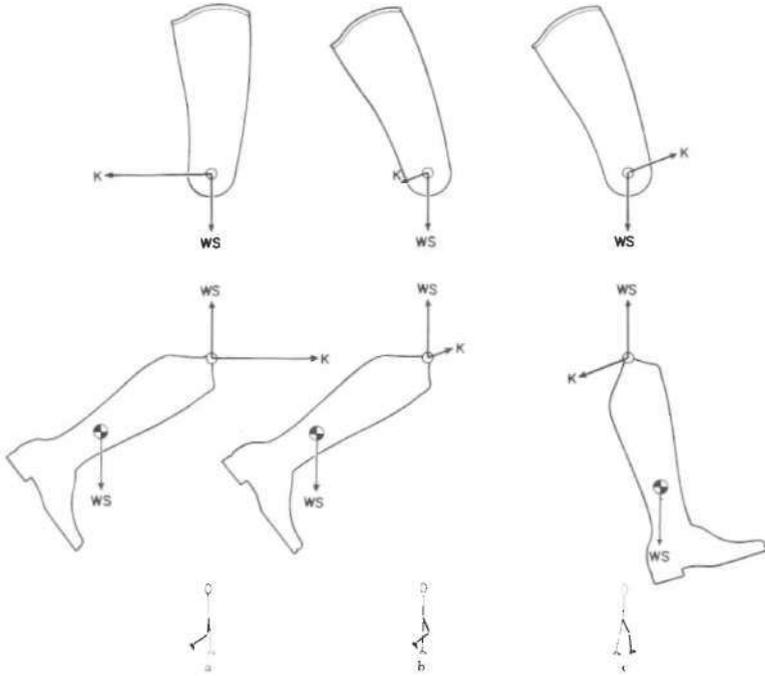


Fig. 13. Forces developed during rotation of the shank about the knee joint during forward swing of the thigh.

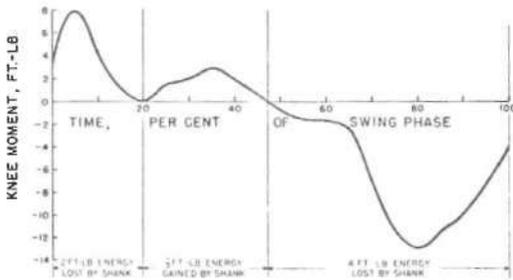


Fig. 14. Knee-moment pattern required for natural swing of an artificial leg. This curve was developed by the University of California Biomechanics Laboratory based on data collected during the study of human locomotion (18).

swing phase. Thus, heel rise and terminal deceleration can be controlled automatically over a wide range of cadences, giving the amputee much more flexibility in speed of ambulation (19). The value to be obtained by applying these principles has been recognized for many years, but a

good deal of engineering was required to develop units that met the exacting demands of limb prosthetics (13,21).

The Henschke-Mauch Model "B" unit (Fig. 18) is a very sophisticated device available in a wood set-up to make its use compatible with standard components and practices. A number of orifices are so incorporated into the cylinder wall that the moving piston successively blocks off escape of the fluid and thus varies the resistance throughout the swing phase in order to approximate the ideal moment curve (Fig. 16). Resistance to flexion and to extension may be adjusted independently of each other by the wearer.

In a clinical evaluation program conducted by the Veterans Administration, involving more than 30 test subjects, the results were overwhelmingly in favor of the Henschke-Mauch unit in comparison with mechanical friction devices previously worn by the amputees in the study (25).

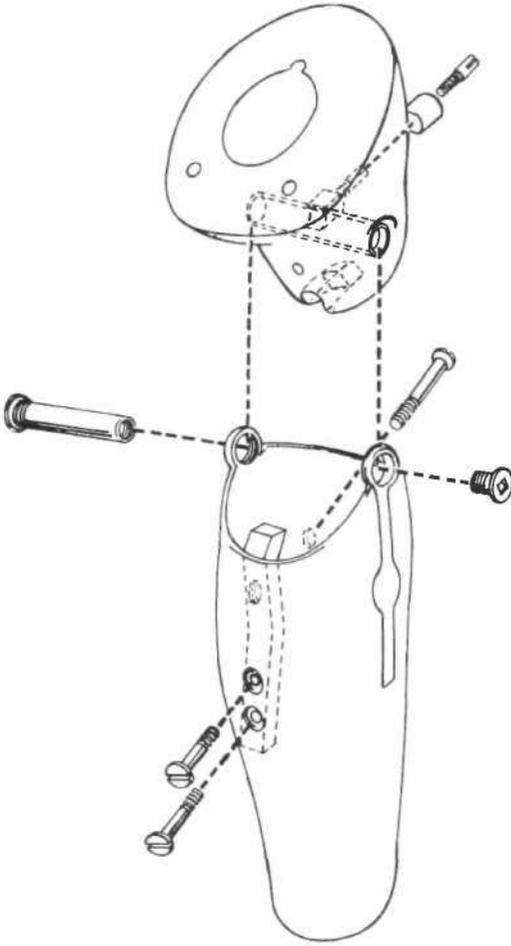


Fig. 15. One type of constant-friction single-axis knee joint.

The ability to vary gait easily and a reduction in effort required and fatigue produced were the advantages most frequently cited. The last two advantages are particularly noteworthy, since the experimental prostheses were heavier than the prostheses worn previously.

The DuPaCo "Hermes" Knee (Fig. 19) is quite similar in design and function to the Henschke-Mauch Model "B" unit and is also available in a wood set-up. Resistance to flexion and to extension may be adjusted independently of each other by the amputee. A clinical study of the

DuPaCo knee by the Veterans Administration resulted in very positive reactions, strikingly similar to those obtained in the study with the Henschke-Mauch Model "B" unit (26).

Unlike the Henschke-Mauch and DuPaCo units, the "Hydra-Cadence" hydraulic leg (Fig. 20) is an integrated system incorporating some ankle control as well as swing-phase control. This system is available only in a metal frame, with a specially designed foot-ankle assembly. For appearance, the metal frame that constitutes the shank is covered with a cosmetic cover of a relatively thin, semirigid plastic cast to resemble an average normal shank. The swing-phase unit is a relatively simple piston type and does not offer quite as precise control of function as the more sophisticated units. In addition to control of the shank during swing phase, resistance to plantar flexion is controlled hydraulically, and motion between the ankle and knee are coordinated so that dorsiflexion of the ankle takes place after the knee has been flexed 20 deg. The object of the coordinated motion feature was to provide additional toe clearance during the swing phase, but unfortunately the motion does not take place at the time when it is needed most. Nevertheless, as in many other instances, the side effects are highly useful. One advantage of coordinated motion appreciated by amputees is that during sitting dorsiflexion of the foot allows the wearer to draw his artificial foot comfortably under his knee, thus keeping it out of the way when he is seated in a theater or bus. In clinical tests conducted by the Veterans Administration, the overwhelming majority of test subjects preferred the "Hydra-Cadence" unit to their conventional limbs (24).

The swing-phase control system of the "Hydra-Cadence" unit is offered in a wood set-up or separately for use in a pylon as the "Hydra-Knee" (Fig. 21).

Although the problems of leakage and high maintenance costs have been overcome to a point where hydraulic devices

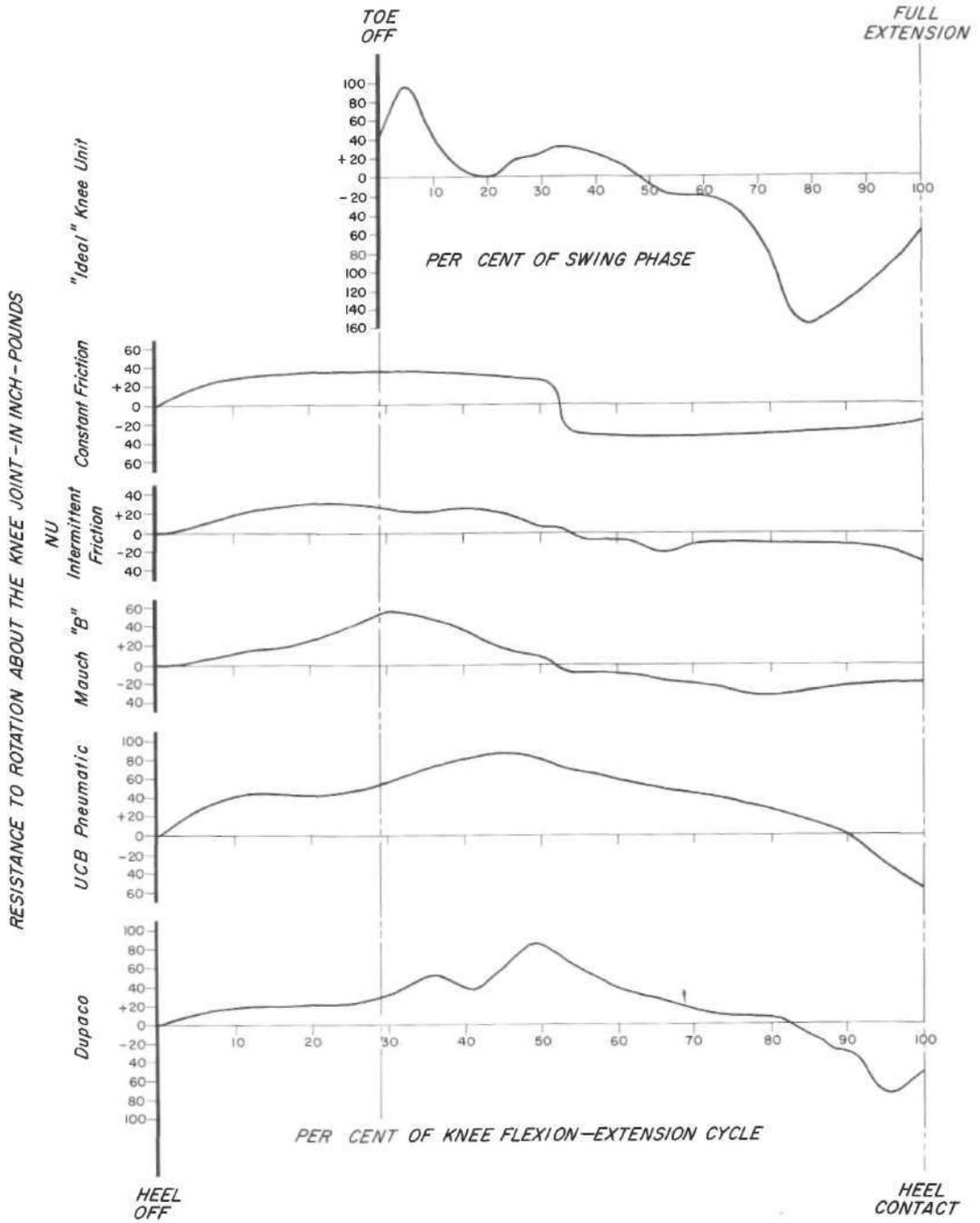


Fig. 16. Knee-moment patterns of various swing-phase units in comparison with the ideal curve of Figure 14. Data were taken at the Veterans Administration Prosthetics Center. The knee units were adjusted for intermediate resistance, and were subjected to 43 cycles per min.

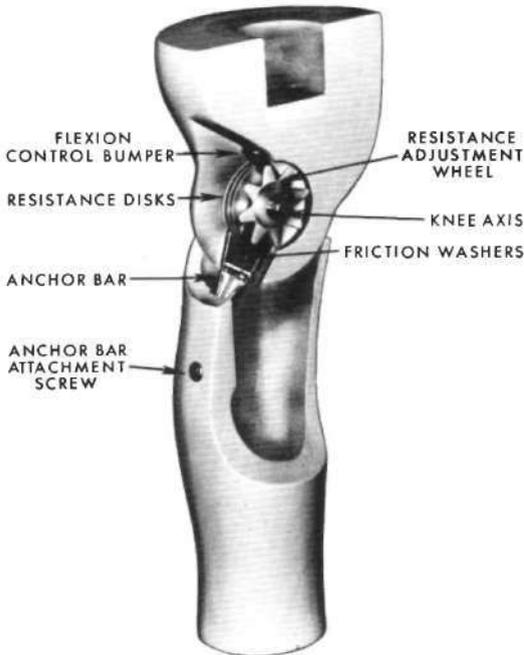


Fig. 17. Intermittent-Friction Knee Unit developed at Northwestern University, installed in a wood set-up.

are practical, pneumatic systems also have appeal since manufacturing costs should be materially lower. Pneumatic systems are not apt to produce a knee-moment curve as smooth as those obtained with hydraulic units, but many feel that they offer an excellent compromise suitable for many amputees.

One such device nearly ready for commercial distribution is the University of California Pneumatic Swing-Phase Unit (15,21). Like the Henschke-Mauch and DuPaCo units, the UCB device consists essentially of a moving piston in a cylinder (Fig. 22). It will be available initially in a pylon-type shank and wooden knee block.

STANCE-PHASE UNITS

Increased understanding of fitting and alignment has alleviated many of the former problems of stability control of the leg during stance phase, especially for those patients with relatively strong stumps. Nevertheless, there appears to

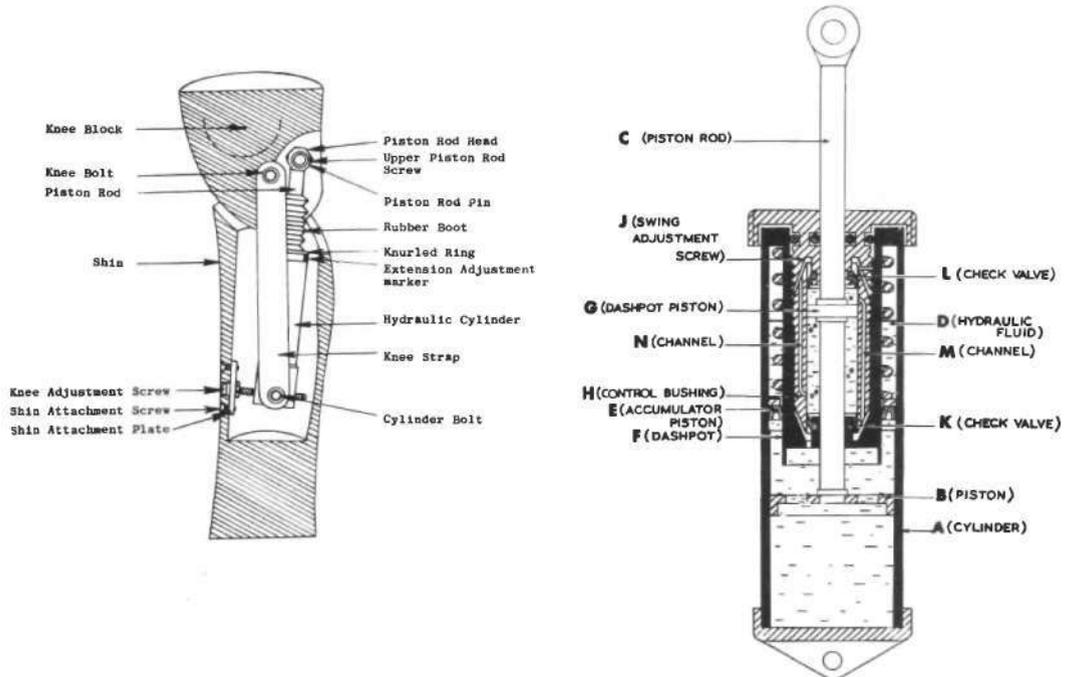


Fig. 18. The Henschke-Mauch "Hydraulik" Knee Unit. Left, Unit installed in a wood set-up; Right, cross-section of the Model "B" (Swing-Phase) Unit.

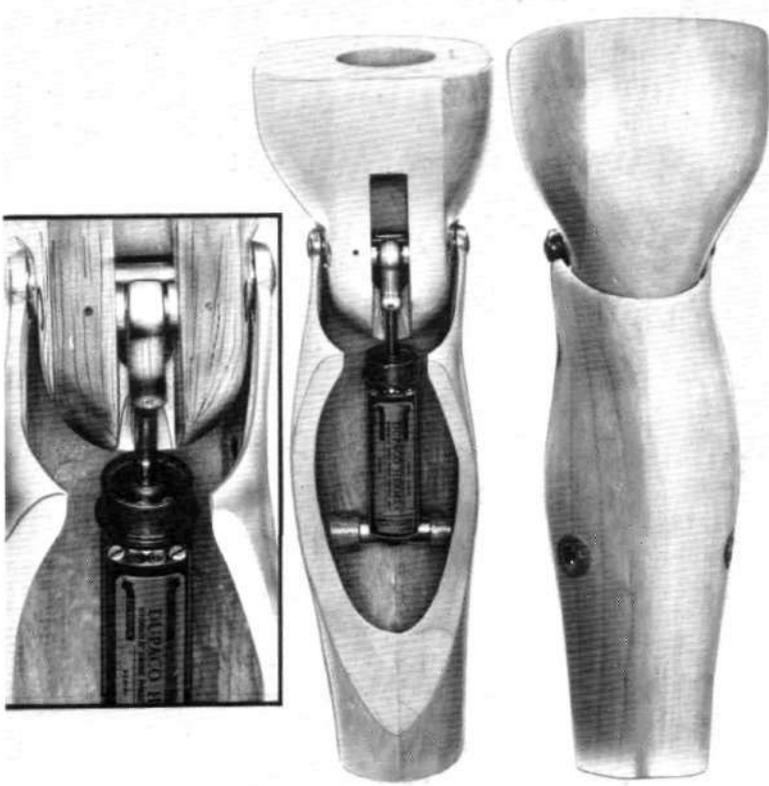


Fig. 19. DuPaCo "Hermes" Hydraulic Swing-Phase Control Unit mounted in a wood set-up.

be a real need for knee units that provide assurance against buckling yet do not interfere with other functions of the leg. The increase in the number of "geriatric" patients in recent years has tended to highlight this need. Patents have been granted for many ways of stabilizing the knee, but few have been found practical.

Doubtless the most widespread stance-phase control device in use today is the Otto Bock knee (Fig. 23). Purely mechanical in action, the Bock knee provides resistance to flexion by a friction braking action effected by weight-bearing. When weight is placed on the prosthesis, the knee block moves slightly toward the shank to engage a "V"-type brake. Swing-phase control consists of constant friction and a spring-biased extensor mechanism.

The Henschke-Mauch Model "A" unit (Fig. 24), currently in an advanced experimental stage, consists essentially of the Model "B" unit (Fig. 18) with provisions for stance-phase control added. Braking of the knee joint is controlled by the complex interaction of a pendulum and a counterweight suspended in hydraulic fluid (16). The braking action is brought into play whenever required to arrest buckling action, and is removed only by the prolonged hyperextension moment typical of late stance phase, so theoretically there should be a smoother transition between stance phase and swing phase than that provided by other units. Moreover, for special tasks, the amputee can set the knee either in "freewheeling" or almost fully locked position.



Fig. 20. "Hydra-Cadence" Artificial Leg with cosmetic cover removed.

A clinical evaluation by the Veterans Administration involving 50 units has nearly been completed. It is expected that the Henschke-Mauch Model "A" unit will be available for general use in the near future.

FOOT-ANKLE UNITS

Many attempts have been made to develop foot-ankle units that offer more than the minimum function required, which is controlled plantar flexion. Through the years several designs have been manufactured and made available, but none has found widespread use, usually because

the maintenance requirements of the units have outweighed any functional gain they offered. Thus, today, nearly every artificial leg (except the "Hydra-Cadence") incorporates either a SACH (solid-ankle cushion-heel) foot (Fig. 25) or a so-called conventional foot (Fig. 26). Both designs provide controlled resistance to plantar flexion, firm resistance to dorsiflexion, and limited toe motion, but little else. Resistance to plantar flexion can be adjusted more easily in the conventional foot by introducing rubber bumpers of different densities. The absence of parts in the SACH foot which rotate or rub and its resistance to moisture make its use attractive. Since its introduction in 1958, the design of the SACH foot has been refined

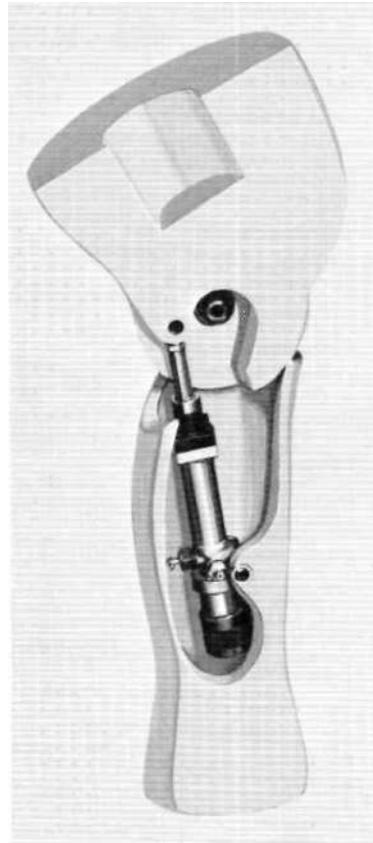


Fig. 21. "Hydra-Knee" installed in a wood set-up.

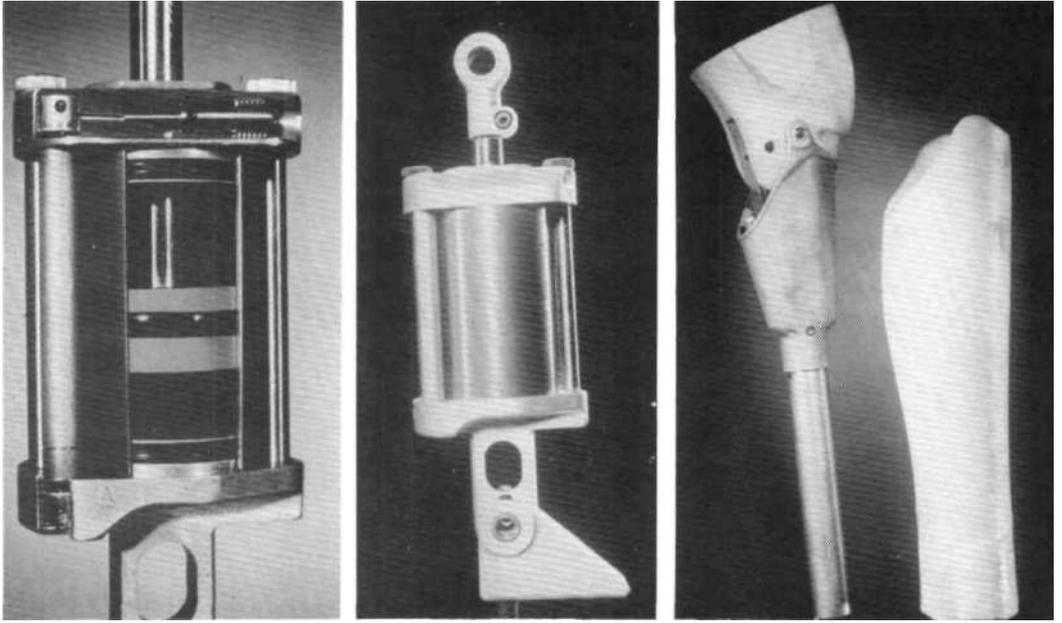


Fig. 22. Pneumatic Swing-Control Unit developed at the Biomechanics Laboratory, University of California (San Francisco and Berkeley). *Left*, Cutaway view; *Center*, complete unit; *Right*, pylon and cosmetic cover designed especially for the pneumatic unit.

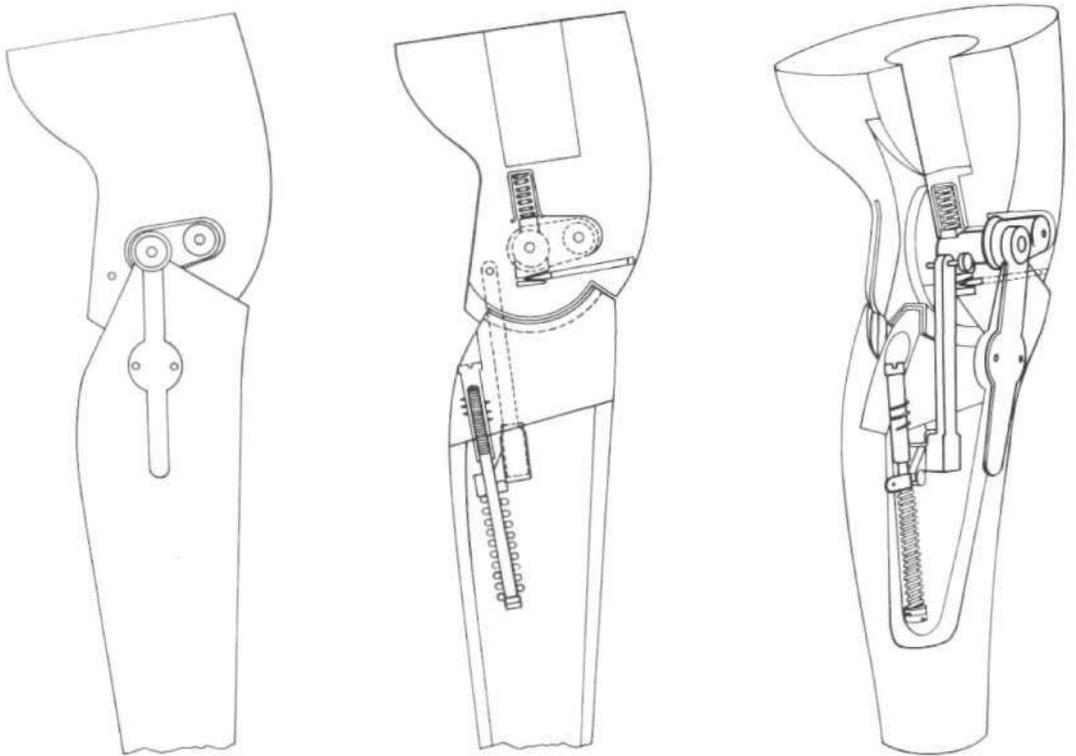


Fig. 23. The Otto Bock Safety Knee Unit.

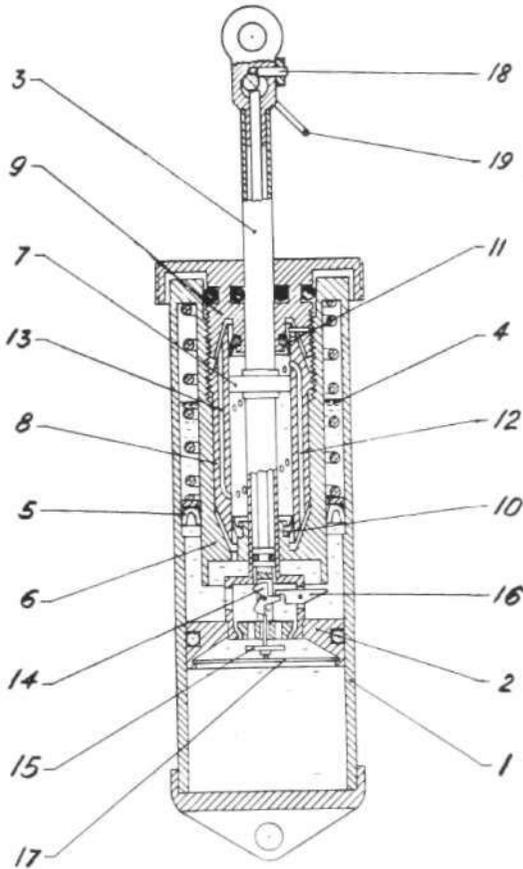


Fig. 24. Henschke-Mauch "Hydraulik" Model "A" (Swing and Stance Control) Unit. 1, Cylinder; 2, piston; 3, piston rod; 4, hydraulic fluid; 5, accumulator piston; 6, dashpot; 7, dashpot piston; 8, control bushing; 9, swing adjustment screw; 10 and 11, check valves; 12 and 13, channels; 14, pendulum; 15, valve; 16, counterweight; 17, spring; 18, stance adjustment screw; 19, selector switch.

in a number of ways. Initially the SACH foot was made by laminating layers of foam rubber around a wooden keel. Later, techniques for molding the rubber were developed and most units are manufactured in this manner. However, the laminated type is available for special applications where shaping to unusual sizes and configurations is required.

Very recently, a special SACH foot has been made available by Kingsley Manufacturing Co. for use in immediate post-surgical fitting procedures (Fig. 27). This version has a flat, wide sole designed for

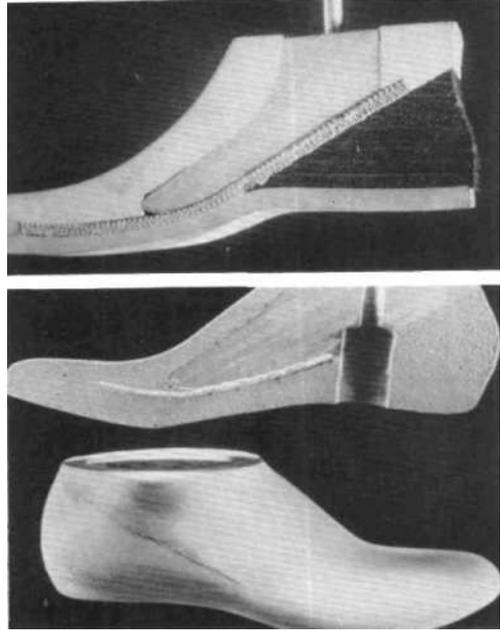


FIG. 25. The SACH (solid-ankle, cushion-heel) Foot. *Upper*, Laminated type; *Lower*, molded type.

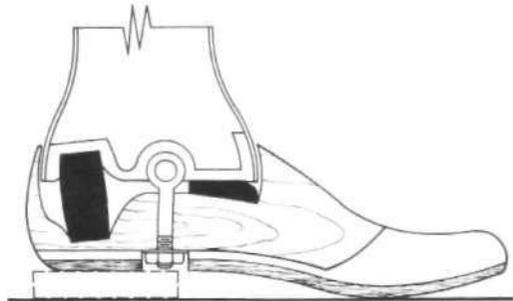


Fig. 26. Cross-section of a typical "conventional" foot-ankle unit.

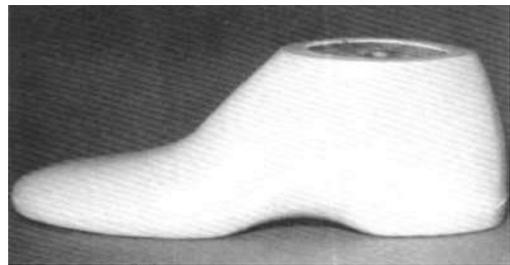


Fig. 27. Special SACH foot for use in immediate post-surgical fitting procedures. *Courtesy Kingsley Manufacturing Co.*

DEFINITIONS

Preparatory Prosthesis

A cosmetically unfinished functional replacement for an amputated extremity, fitted and aligned in accordance with sound biomechanical principles, which is worn for a limited period of time to expedite prosthetic wear and use and to aid in the evaluation of amputee adjustment.

Pylon

A rigid supporting member, usually tubular, that is attached to the socket or knee unit of a prosthesis. The lower end of the pylon should be connected to a foot-ankle assembly.

Rigid Dressing

A plaster stump wrap, usually applied in the operating or recovery room immediately following operation, for the purpose of controlling edema and pain. It is preferably shaped in accordance with the basic patellar-tendon-bearing (PTB) or quadrilateral designs, but is not necessarily so.

Immediate Postsurgical Prosthetic Fitting

A procedure wherein a functional socket, designed for weight bearing and walking, is fitted to the patient immediately after operation in the operating or recovery room, or at some time prior to removal of sutures. As distinct from the rigid dressing, referred to above, this socket should be shaped in accordance with the basic PTB or quadrilateral design; it incorporates provision for easy attachment and detachment of a pylon and foot-ankle assembly.

Early Prosthetic Fitting

A procedure wherein a preparatory prosthesis, as defined above, is provided for the amputee immediately following removal of sutures.

Permanent Prosthesis

A replacement for a missing limb, which meets accepted checkout standards for comfort, fit, alignment, function, appearance, and durability.

use without a shoe while the patient is in the hospital. This permits equal leg length when the natural foot of the patient is bare or is covered simply with a sock or slipper. It is also about 20 per cent lighter than the conventional SACH foot, and resistance to toe break is less.

The Veterans Administration Prosthetics Center is responsible for updating the specifications for the SACH foot, and makes periodic checks of mass-produced units on a random basis.

At the present time, development of a more functional foot-ankle unit using hydraulic principles is under way.

PYLONS

Recently a number of devices known as pylons (see "Definitions") have been developed to meet the requirements imposed by immediate and early postsurgical fitting, namely, functional devices that contain built-in alignment features but are

light enough for use throughout the day. Also, devices used in fitting immediately postoperatively should be easily removable from the socket so that the device may be disconnected when the patient is sleeping. Provision for locking the knee joint manually is desirable for use with infirm patients.

The Hosmer Above-Knee Temporary Leg (Fig. 28) is a modification of the adjustable leg originally designed by the University of California Biomechanics Laboratory for alignment adjustment during walking trials.

The U.S. Manufacturing Co. above-knee constant-friction pylon (Fig. 29) is simple, is light in weight, and provides all adjustments necessary in aligning a leg. However, the wedge disks used to change the adduction-abduction and flexion-extension attitudes of the socket require compensatory adjustments to maintain position in one while the other is

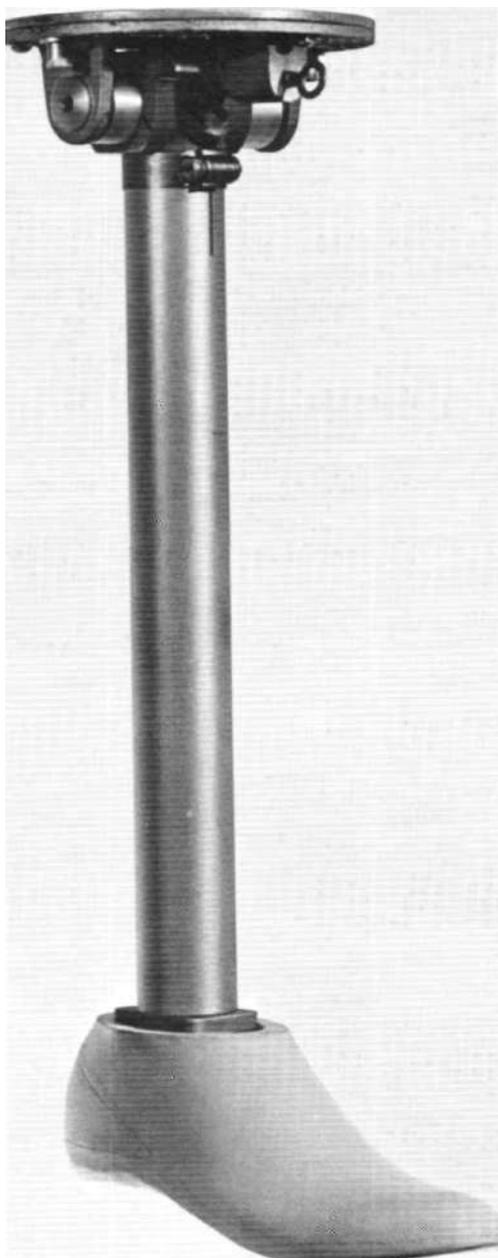


Fig. 28. The Hosmer Above-Knee Temporary Leg.

changed. Hence some degree of skill in using this unit is required.

The U.S. Manufacturing Co. also provides an above-knee temporary prosthesis with the "Hydra-Knee" unit installed



Fig. 29. The U.S. Manufacturing Co. Above-Knee Constant-Friction Pylon. The expanded metal straps at the top are provided for use with plaster-of-Paris sockets. *Courtesy U.S. Manufacturing Co.*

(Fig. 30). Alignment adjustment is provided in the same manner as in the above-knee unit shown in Figure 29. Cosmetic covers similar to those used with "Hydra-Cadence" units are available.

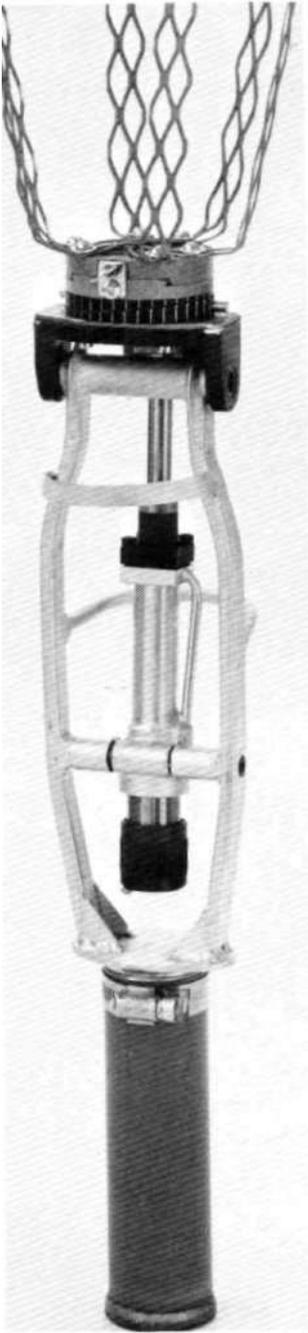


Fig. 30. The Hydra-Knee Pylon. *Courtesy U.S. Manufacturing Co.*

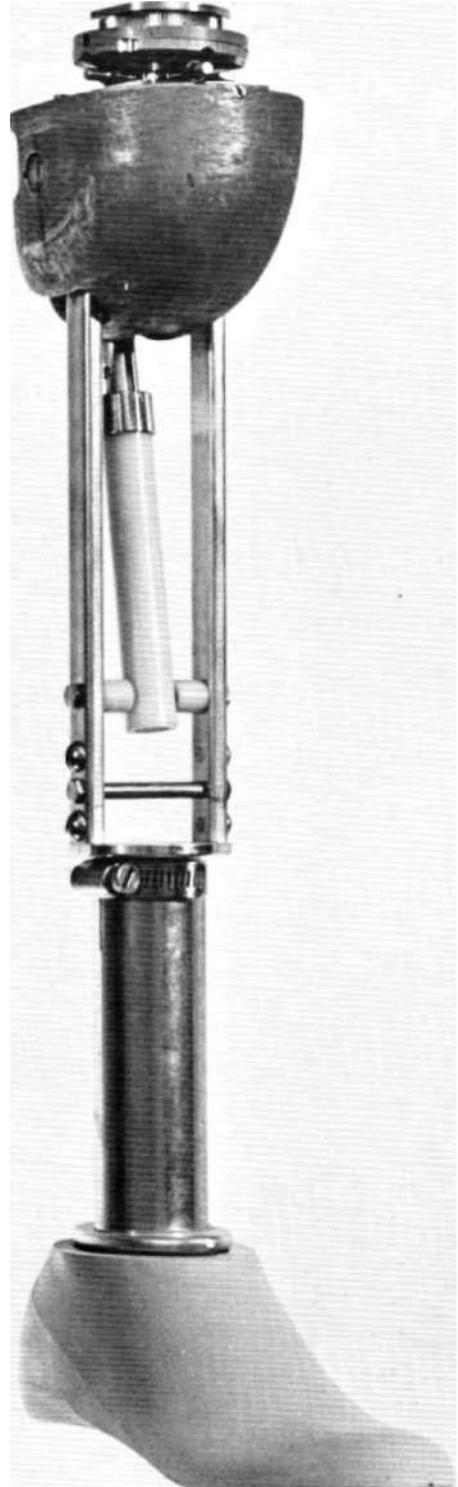


Fig. 31. Pylon developed at the Veterans Administration Prosthetics Center. This unit will accommodate a number of different standard mechanisms for control of the knee.

To provide for independent adjustment in the adduction-abduction and flexion-extension planes, the Veterans Administration Prosthetics Center designed a unit (Fig. 31) in which threaded "disks" are used to provide a wedging action between two conical surfaces placed apex to apex. This device is incorporated in the VAPC "Standard" above-knee pylon which permits the interchange of several knee mechanisms including various constant friction knees, the DuPaCo swing-control unit, both of the Henschke-Mauch knee units, and the UCB pneumatic device. This very desirable interchangeability feature permits the patient to try out a number of swing-control devices at a minimum cost.

It is feasible and practical to use any of these prostheses for indefinite periods. Thus, changes in alignment can be made if they are needed. A comparison of the major features and characteristics of the various pylons is given in Table 1.

TIME OF FITTING

From time to time through the years, a few clinicians have argued for fitting new amputees with temporary or "training" limbs, either for acceleration of the rehabilitation process or to evaluate the patient's potential for use of a prosthesis if there is doubt about his ability to use one. No one argued against this approach provided the temporary limb was properly fitted and aligned. However, when fitting was done before the stump had stabilized the frequent socket changes that were necessary resulted in high costs. If poorly fitted and aligned prostheses were used, more harm than good could result.

The introduction of improved casting methods, improved fabrication techniques, and adjustable pylons led the Orthopaedic Department at Duke University to conduct a series of experiments, beginning about 1960, in which it was demonstrated that it is feasible and, indeed, desirable to

TABLE 1. CHARACTERISTICS OF ADJUSTABLE ABOVE-KNEE PROSTHETIC UNITS

	U.S. Mfg. Co. Standard Adjustable AK Prosthetic Unit	U.S. Mfg. Co. Adjustable Hydraulic Prosthetic Unit	Hosmer Tem- porary Walking Leg	VAPC Standard AK Prosthetic Unit
Weight with straps and 12-in.- long tube	2.5 lb.	3.9 lb.	3.5 lb.	3.75 lb. ^a
Outside diameter of tube	1.625 in.	1.625 in.	1.625 in.	1.625 in.
Wall thickness of tube	.0625 in.	.0625 in.	.0625 in.	.0625 in.
M-L adjustment range	.875 in.	.875 in.	1.75 in.	.75 in.
A-P adjustment range	.875 in.	.875 in.	.5 in.	.75 in.
Socket flexion-extension adjust- ment range	10 deg.	10 deg.	None	8 deg.
Socket adduction-abduction ad- justment range	10 deg.	10 deg.	None	8 deg.
Quick disconnect for socket re- moval?	Yes	Yes	No	Yes
Length of assembly above axis of knee	2.75 in.	2.75 in.	1.4 in.	2.4 in.
Independent adjustability?	No	No	Yes	Yes
Manual knee lock?	Yes	Yes	Yes	Yes
Type of swing-phase control	Constant friction	Hydraulic	Constant friction	Variable friction ^a

^a Will also accept Henschke-Mauch, DuPaCo, and UCB pneumatic knee-control units. Weight is increased accordingly.

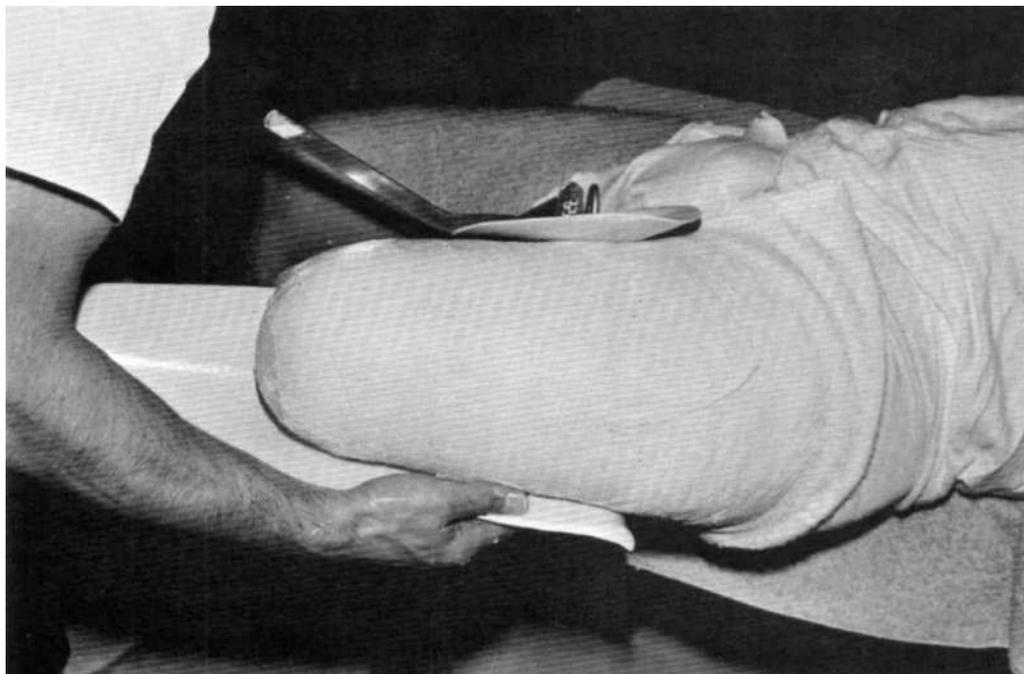


Fig. 32. Use of the Prosthetics Research Study (Seattle) casting fixture to form socket in fitting above-knee case with prosthesis immediately after operation. *Courtesy Prosthetics Research Study, Seattle, Wash.*

fit amputees as soon as the wound has healed (8). In 1963, several groups in the United States began experimenting with the concept of fitting the patient immediately after operation and allowing some degree of ambulation very soon thereafter, a technique that had achieved some success in a rather crude way in France and Poland (4,7,27).

By 1967 the technique had been developed in sufficient detail at the Prosthetics Research Study, Seattle, Washington, and experience with experimental cases was such that it seemed warranted to offer special courses in the Prosthetics Education Program in immediate post-surgical fitting of prostheses. The technique applies to all levels of lower-extremity amputation. Experience has shown that the formation of edema is materially reduced, postoperative pain is reduced, development of contractures is avoided, stump bandaging is unnecessary, and the general well-being of the patient is better than when he is treated in the conventional manner. The procedure obviously reduces both time of hospitalization and

time required for rehabilitation, and it is appropriate for use in virtually all types of cases except where an open amputation is indicated. More time is required by the surgeon and prosthetist in the management of the patient during the first two weeks, but substantial savings are effected in the over-all treatment program.

For the above-knee case, immediate postsurgical fitting consists essentially of providing the patient with a quadrilateral total-contact socket of plaster-of-Paris bandage (Fig. 32) and an easily detachable functional pylon, allowing him to begin weight-bearing about 24 hours after amputation (Fig. 33). No special surgical techniques are needed. Myoplasty, consisting of some method to ensure reattachment of the cut muscles about the thigh, is recommended in any case (4). The cast-socket is left in place for 8 to 12 days, at which time the sutures can usually be removed. A new cast socket is applied immediately and is kept in place until measurements and a cast can be made for the definitive prosthesis, usually 10 to 12 days later. If some other condition precludes

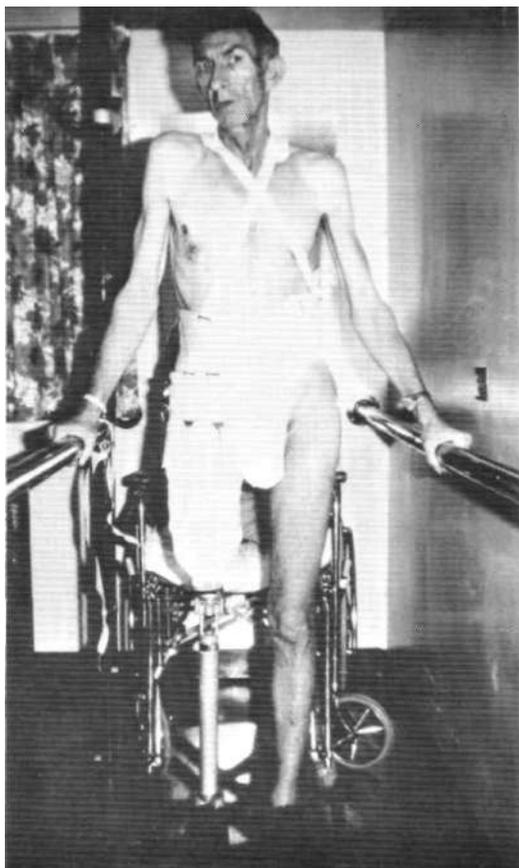


Fig. 33. Above-knee amputation patient fitted with a prosthesis immediately after amputation. Courtesy Prosthetics Research Study, Seattle, Wash.

the patient from walking, a rigid dressing of plaster of Paris should be used, rather than conventional dressings, to keep formation of edema to a minimum and thus provide a stump that will cause the prosthetist less trouble.

Immediate postsurgical fitting and early fitting have been very successful in the hands of competent surgeon-prosthetist teams, and are routine procedures in many centers today. Research in this area is continuing in order to refine the methods still further.

ABOVE-KNEE PROSTHETICS FOR CHILDREN

Amputation in children can be classified as either acquired or congenital. The acquired amputation is the result of

trauma or of disease, usually a malignant tumor. The congenital type is the result of a malformation occurring during embryonic development.

Management of the acquired amputation in children is essentially the same as that for the adult. Because wounds in children tend to heal faster than they do in adults, immediate postsurgical fitting and early fitting techniques are most appropriate. Usually care must be taken to keep the child patient from being too active. The quadrilateral, total-contact, plastic, suction socket is nearly always indicated. A Silesian bandage may be used, but is usually not needed. For patients below the age of puberty, the only knee unit available is the constant-friction type. SACH and conventional feet are available in sizes suitable for children of all ages.

Children with congenital malformations of the lower extremities usually offer a greater challenge. Many times the stump and proximal anatomy are abnormal in structure, and these features must be taken into account in design of the socket and suspension. For guidelines and suggestions for treatment of unusual and bizarre cases, the reader is referred to *The Limb-Deficient Child* (3).

For the high, bilateral above-knee case where conventional above-knee or knee-disarticulation prostheses are not suitable, *i.e.*, the patient is unable to use crutches, the use of the swivel walker is recommended (Figs. 34 and 35)(14). Designed at the Ontario Crippled Children's Centre for use by patients with severe involvement of all four limbs, the swivel walker has met with success wherever it has been used. Motion is effected by displacement of the center of gravity of the body. Although movement is restricted to smooth, level surfaces, the swivel walker offers an effective means of mobility, and the psychological benefits to be gained from it are quite rewarding.

ABOVE-KNEE PROSTHETICS FOR GERIATRIC CASES

At one time it was an almost universal rule to amputate through the thigh in

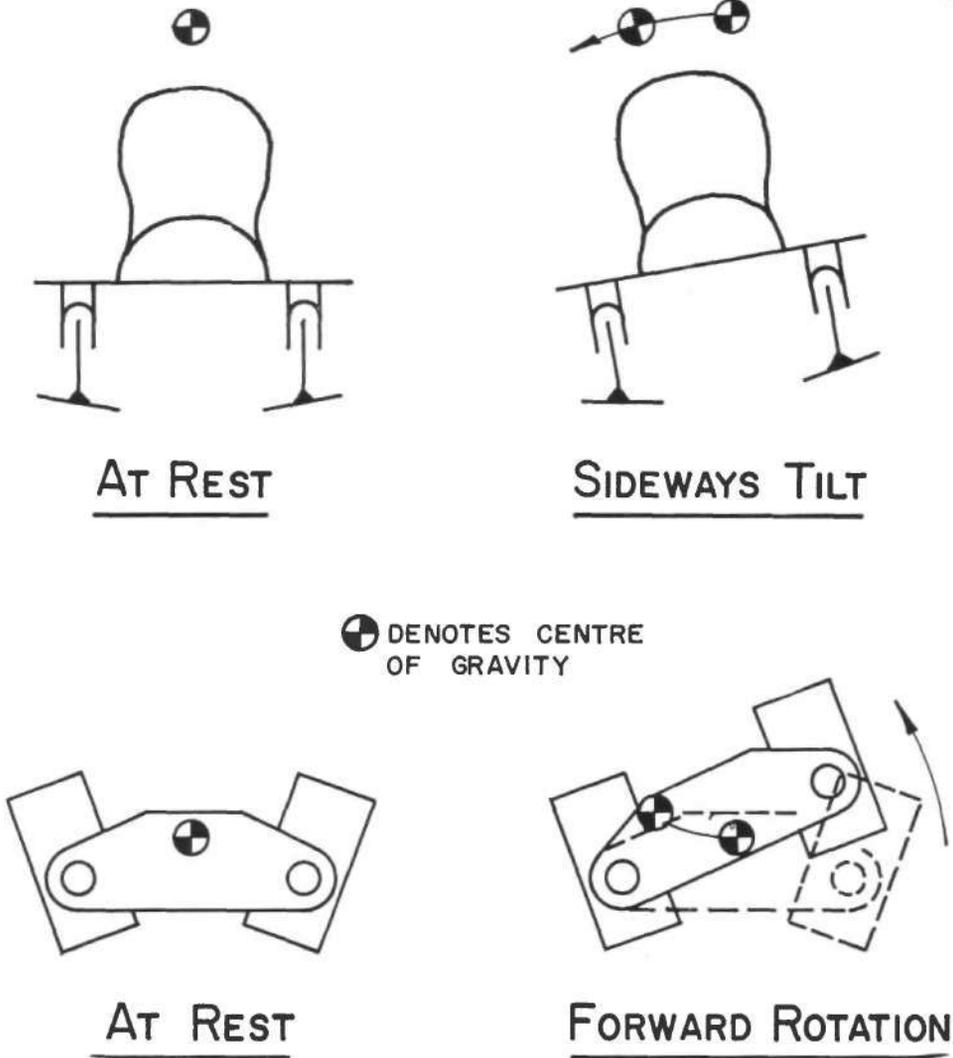


Fig. 34. Principle of the "Swivel Walker" developed at the Ontario Crippled Children's Centre, Toronto, Canada, for very high, bilateral, lower-extremity cases.

cases of peripheral vascular disease when limb ablation was indicated. However, since it has been shown that many knee joints can be saved in spite of what appear to be overwhelming odds, the ratio of above-knee to below-knee amputations is decreasing. Unfortunately, however, there will always be a certain number of above-knee cases.

Immediate postsurgical and early fitting practices should be used whenever possible. Proper use of these procedures reduces the mortality rate drastically and permits the fitting of definitive prostheses considered impossible, or at least impractical, only a few years ago. The use of provisional prostheses permits the clinic team to determine, without question, whether

or not a definitive prosthesis is indicated. The VAPC "Standard" AK Pylon permits experimentation with several hydraulic units as well as with mechanical friction knee control.

In spite of the many useful innovations that have been introduced into the practice of above-knee prosthetics through the years, there is still room for further improvement. Among the developments needed are more foolproof methods of obtaining optimum fit and alignment. Sockets that can be adjusted to meet the constantly changing cyclical demands of the amputee are certainly desirable and possible. Indeed, it might be feasible to provide a socket that is adjusted automatically

to meet the needs of the patient constantly throughout the day. In any event, studies of the effect of pressure on human tissues must lead eventually to a better application of limb prostheses.

Needed also are methods for fitting and fabrication of limbs in even less time than is presently required. Materials that can be formed at temperatures safe to human tissues are now becoming available, and it is hoped that a useful socket can be molded over the stump, eliminating the need for plaster of Paris in taking impressions and making models of the stump. Such a technique, when used with adjustable pylons that are cheap enough and light enough to leave as the "permanent" prosthesis, should permit fast, economical service.

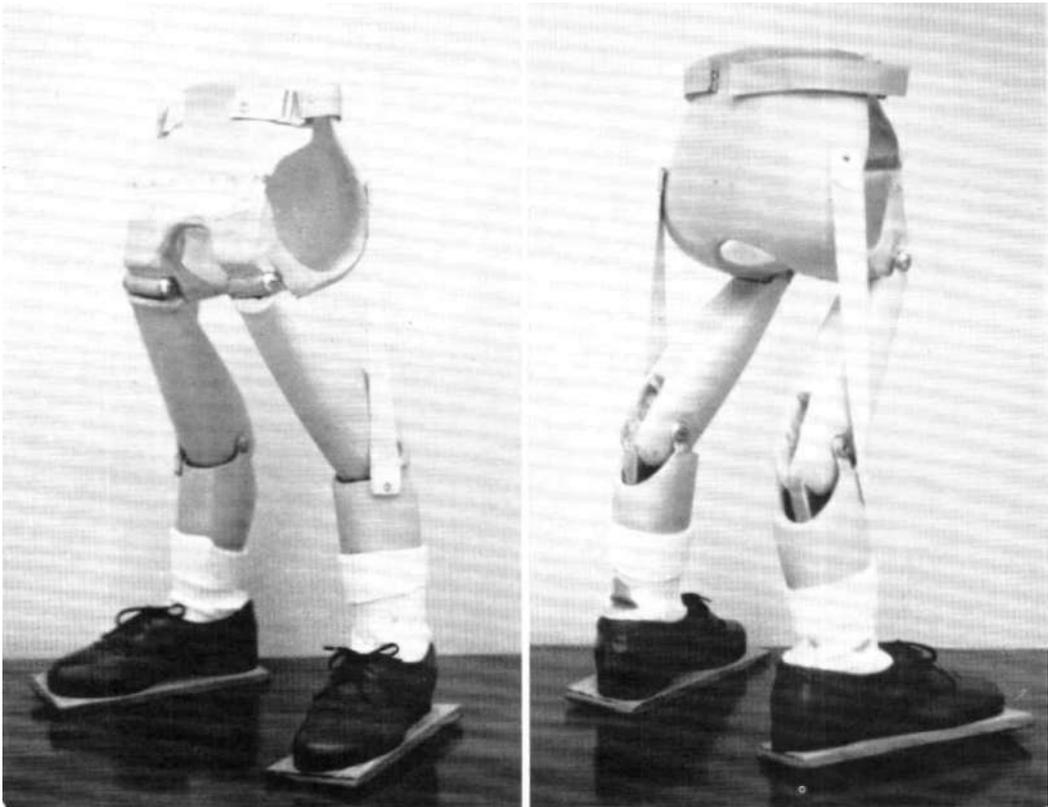


Fig. 35. The OCCC swivel walker with articulated joints that permit a sitting position.

Concurrently with studies designed to point the way to more functional prostheses and more efficient service, a number of surgeons are studying and trying to devise methods for providing more functional stumps. In recent years the techniques of amputation have taken on more significance in the minds of surgeons and, consequently, prosthetists have been seeing stumps that are more functional than has been the case in the past. Further research and a continuation of educational programs should result in even more improvement.

ACKNOWLEDGMENT

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