ENDOSKELETAL STRUCTURES FOR LOWER-EXTREMITY PROSTHESES

Henry F. Gardner, C.P.O.
Technical Assistant to the Director

Veterans Administration Prosthetics Center
252 Seventh Avenue
New York, New York 10001

Since man first survived the loss of a lower limb, his immediate need was for a prop to support his body weight and enable him to stand up. He fashioned crude devices for himself such as peg legs (pylon) or wooden props or splints which he bound to the stump for support. Records dating from 500 B.C. show these early prosthetic restoration efforts (Fig. 1). Considering the nature of society in those days, we realize that those who withstood the loss of a limb depended upon the restoration of their mobility for survival. No attempts were made to disguise or enhance the appearance of appliances whose function was so essential that the patient tolerated considerable pain and effort to use them. Few, if any, patients survived amputations above the knee and these crude appliances did not generally include adequate knee functions. It was not until later, during the 15th and 16th centuries, that armorers and metal craftsmen, skilled in fashioning body armor, began to use sections of armor modified for weight bearing—leading to some improvement in cosmesis.

Due mainly to medical and surgical progress during the 18th and 19th centuries, patients survived amputations at higher levels, and the simple peg leg without knee function compelled them to ambulate with a grotesque gait leading to attempts to provide active knee motion (Fig. 2). Limited knee function permitted ambulation with a marked reduction in the limp. Efforts were also made to conceal the disability by shaping the appliance and covering it with clothing. Increasing numbers of amputee survivors and changes in social values led skilled craftsmen to devote their efforts to prosthetics and techniques for fitting; thus, more comfortable sockets developed. Control methods improved as did cosmetic shaping and finishing. Because of its physical properties including high directional load capacities and ease of carving, wood crustacean-type limbs became most widely used. Sockets were receptacles hand carved into the externally shaped wood leg.

Today, hand carving is rapidly being replaced by casting methods

FIGURE 1.—Mosaic from the Cathedral of Lescar, France, depicts an amputee supported at the knee by a wooden pylon. Some authorities place this in the Gallo-Roman era. (From Putti, V., Historic Artificial Limbs, Paul Hoeber, Inc., New York, 1930.)

which result in reproducible total-contact sockets of superior fit. The socket portion of the prosthesis, which once was an integral part of the shank or thigh, is no longer dependent upon the crustacean-like shell for support. The cosmetic quality of artificial limbs has also been improved substantially. This was due principally to recognition of the psychological significance of the body image for rehabilitation, and the fact that a limb is more than simply a walking device to its possessor.

In recent years, we have seen the rebirth of pylon-type prostheses, particularly for temporary artificial legs. However, these are not the crude devices of the 15th century. They use biomechanically designed sockets, articulated joints, and controls for alignment and for knee function (Fig. 3 and 4).

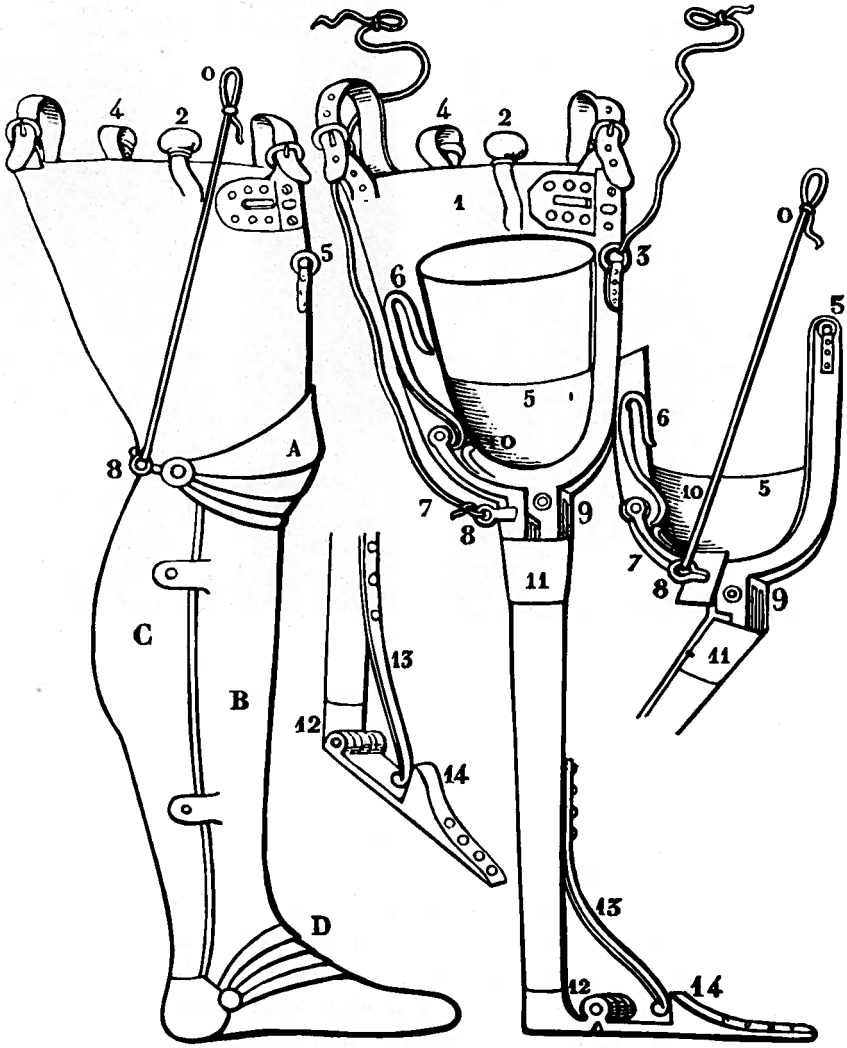

FIGURE 2.—This is the first known jointed leg prosthesis from the 16th century. (From Paré, A., Oeuvres Completes, Edition Malgaigne, Paris, 1840, from the copy in the Armed Forces Medical Library.)

The immediate postsurgical prosthetic fitting technique in particular has reemphasized the need for adjustability in both alignment and knee function. Versatile appliances are needed to provide for the rapidly changing prosthetic needs of new amputees. New devices have been developed to fulfill these requirements. Skeletal prostheses of modular design superior in adaptability, adjustability, and interchangeability to the conventional crustacean-type appliances are now available. The

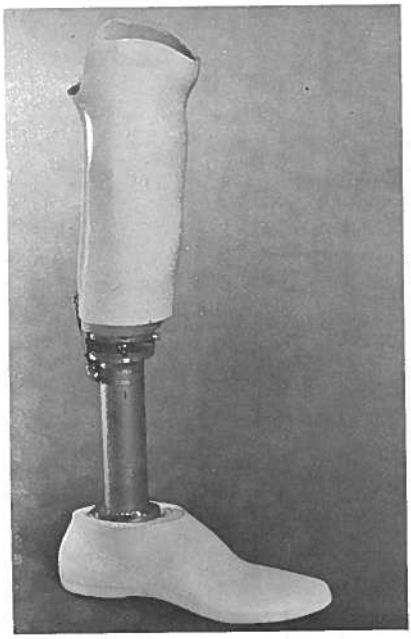

FIGURE 3.—The below-knee skeletal prosthesis (VAPC Standard) retains its alignment adjustability for definition as well as temporary use.

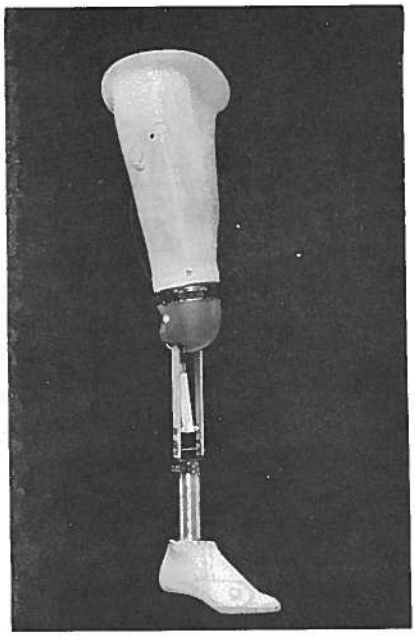

FIGURE 4.—The above-knee skeletal prosthesis (VAPC Standard) accommodates the interchange of six fluid and mechanical knee-control systems. The alignment adjustability is preserved in the definitive prostheses.

VAPC Above-Knee and Below-Knee Standard Prostheses are modern examples (BPR 10–10).

The obvious advantages of skeletal structures are the use of standardized components which are easily interchanged in the prosthesis to provide any desired combination of function. The reduction of assembly time, through the use of mass-produced prefabricated modules, and the economy of standard replaceable components reduce the initial cost of the prosthesis and the subsequent cost of adjustment or replacement of components or modules. Skeletal-type prostheses were designed specifically to facilitate easy and accurate socket changes, alignment adjustments, and knee resistance adjustments. Cosmetic finishing of these appliances was not seriously considered until the desirability of these capabilities was recognized as being equally beneficial for definitive prostheses.

The VA Prosthetics Center has experimented with several materials and techniques in an attempt to provide an acceptable cosmetic treatment. An ideal cosmetic cover should permit customized shape and color and still permit access to the internal adjustment devices. Our

early efforts in this connection employed Koroseal foam blocks. They fulfilled the requirements of low cost, low weight, easy shaping, and soft feel. But two blocks were needed for each prosthesis leaving a discernible seam between them. The use of prebored, polyethylene foam blocks fitted over the skeletal leg prosthesis seems to satisfy all the requirements. The internal bore in the foam block is designed to fit over the VAPC Standard Above-Knee (Multiplex) Prosthesis (Fig. 5). Because of the variations in below-knee socket size and shape, some additional internal sanding is required to fit the foam block over the shank and socket of the VAPC Standard Below-Knee Prosthesis.

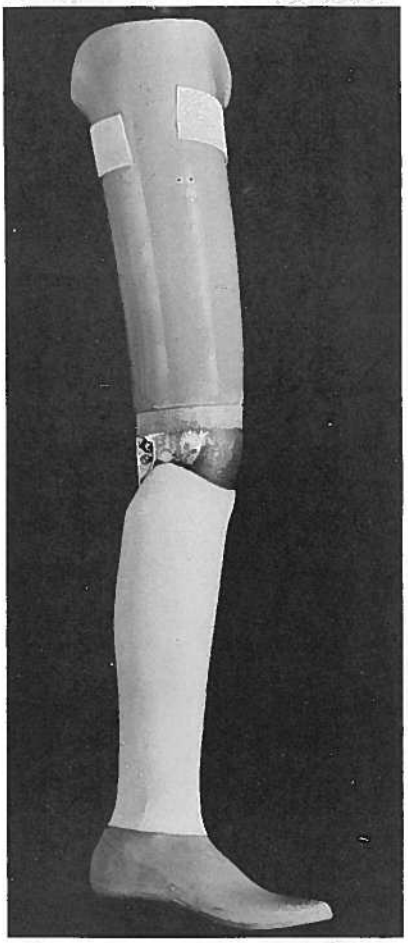

FIGURE 5.—A prebored block of polyethylene foam fitted over the pylon forms a soft leg shape when externally sanded.

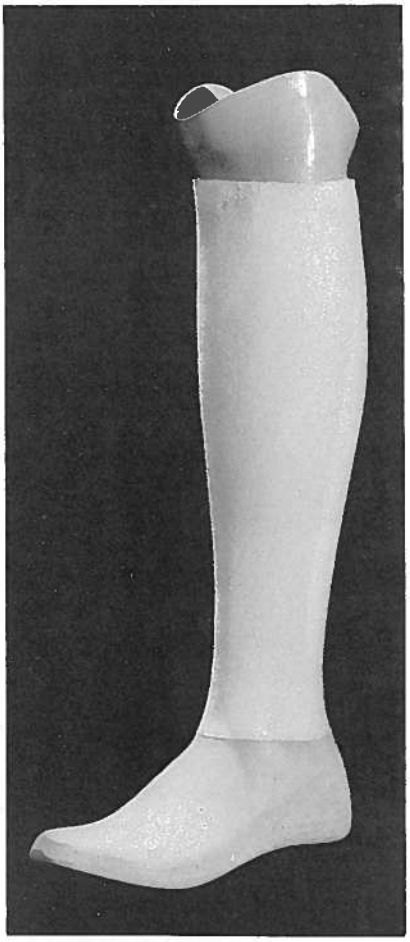

FIGURE 6.—Polyethylene foam block, fitted over skeletal below-knee prosthesis and externally shaped, has soft feel.

Externally, the block is shaped by band saw and sander to the patient's requirements. The product is a cover of white material with a fine soft texture (Fig. 6). A mid-calf stretch hose is used as the external cover for the below-knee prosthesis (Fig. 7). A full length lightweight two-way stretch nylon hose is used to cover the above-knee prosthesis (Fig. 8). A Velcro band applied around the top of the socket anchors

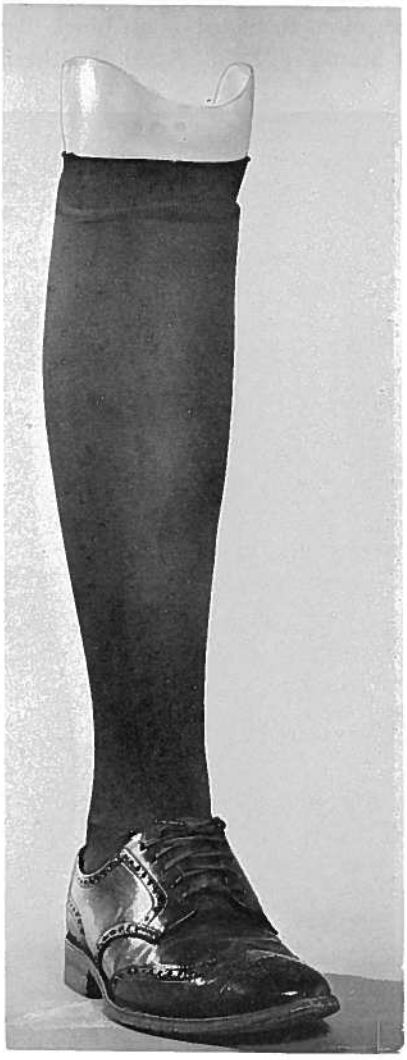

FIGURE 7.—Polyethylene leg shape covered by knee-length stretch hose.

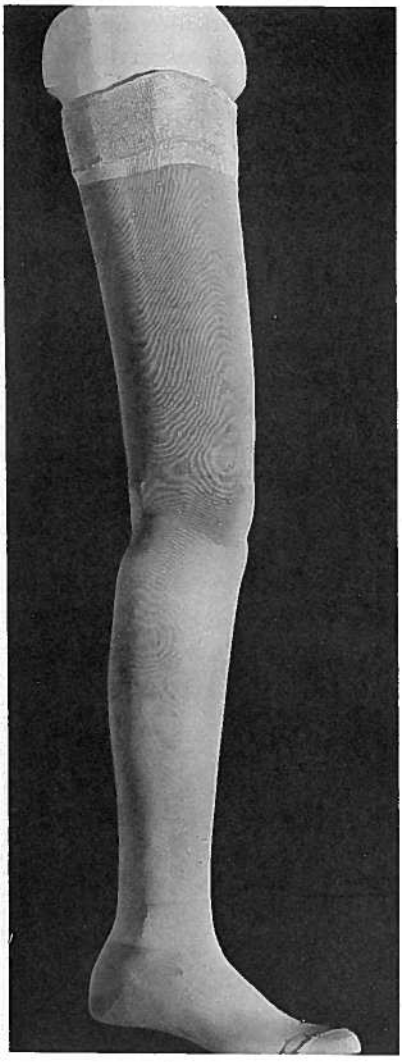

FIGURE 8.—A lightweight nylon stretch hose covers the polyethylene shank and plastic laminated socket.

the sock. The hose is easily removed and changed by the patient.

Using the concept of cosmesis, definitive prostheses can be made with a customized "flesh-like" finish and still provide access to the internal adjustment devices.

The advantages of the polyethylene leg cover are the ease of fabrication, easy customization, low material cost, and the "flesh-like" feel of the soft material. The removable cover also permits ready access to the structure for easy interchange or adjustment of components at any time during use.

The results of a comparative analysis of the fabrication time between the conventional PTB with wood shank and plastic laminate finish and the PTB skeletal prosthesis with the foam shank cover are given in Table 1.

TABLE 1.—*Fabrication Time Analysis between Conventional PTB Wood Shank and Plastic Laminate Finish and PTB Skeletal Prosthesis with Foam Shank Cover*

	VAPC Skeletal Prosthesis with foam hr.	Conventional prosthesis laminated over wood hr.
Socket layup and lamination	1-½	1-½
Setup and static alignment	¼	2
Transfer of alignment or secure[a]	¼	1
Shape	1-½	2
Lamination	None	1-½
Total	4	8

[a] For the skeletal design, the alignment obtained on the standard metal shank is "secured." No alignment transfer is needed.

The comparative weights of the two prostheses made over the same cast for the same patient show a 24 percent difference in overall weight, the skeletal prosthesis weighing 3.24 lb. and the conventional weighing 4.03 lb. The calculated moment of inertia is essentially the same for both prostheses with minor variations noted in the radius of gyration, the percentage of difference being small.

Manuals describing the foam finishing in detail are currently available for both the above-knee and below-knee VAPC skeletal prostheses. Reprints are available from the United States Manufacturing Co., P.O. Box 110, Glendale, California 91209.