

Mechanical Aids for Alignment of Lower-Extremity Prostheses

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IF A prosthetic device is to give optimum service to the amputee, it must always be properly fitted, regardless of its mechanical excellence. This is especially true in the case of the lower extremity, where the prosthesis must function continually and where poor fit or alignment will lead quickly to rejection of the device by the wearer. Among prosthetists there seems to be general agreement that by far the most important factors in the success of any artificial leg relate to fit and alignment on the subject. Fit and alignment are usually considered together, since they are mutually interdependent.

Over the years many different mechanical devices to aid in fitting and alignment of lower-extremity prostheses have been developed to help in the application of one or another particular set of alignment principles in use by individual fitters. Others of these devices are more general in application and are adaptable for use by any prosthetist regardless of the particular alignment principles he advocates. In every case, however, an attempt has been made to improve the fitting and alignment technique by adopting one definite set of principles and using a mechanical device to aid in the application of those principles.

HISTORICAL BACKGROUND

In 1919 Franz Schede (2) wrote *Theoretische Grundlagen für den Bau von Kunstbeinen*, a work generally considered to be one of the first important contributions in the field of prosthetic devices. In this volume Professor Schede established for the alignment of lower-

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extremity prostheses a set of principles based on application of known laws of mechanics. He was particularly concerned with alignment of the joints in a lower-extremity prosthesis so as to provide sufficient stability during the stance phase. As a result of the interest in his work, there was developed the so-called "plumb-line" method of alignment, a method which, essentially, assumes that the prosthesis carries weight along a vertical plumb line, the elements of the prosthesis then being arranged using this line as a reference. Still in general use throughout Europe and the United States, this system involves the problem of determining the location of the plumb line in the socket so that it can be extended down to the foot and used as a reference. For this purpose, many mechanical devices have been used.

THE FITTING STOOL

One of the oldest devices to aid in the fitting of lower-extremity sockets is the common fitting stool (Fig. 1). This device was well known as early as 1915 and is still in general use. When it is used to aid in establishing a "weight line," wedges are employed to tilt the socket block until the desired orientation is achieved. The hydraulic fitting stool of Habermann (Fig. 2)

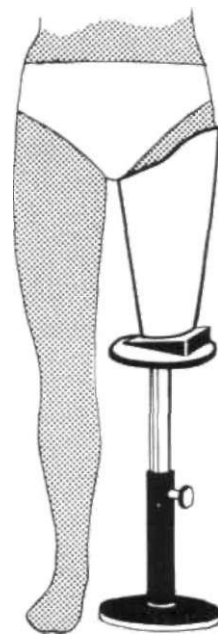


Fig. 1. Common type of fitting stool in use as early as 1915.

is a recent refinement. It requires that the location of one point on the weight line be assumed, usually at the socket brim, and that the plumb line be drawn vertically downward from this point.

Pivot-Point Balancing Devices

In an attempt to eliminate the necessity for the assumption of one point on the weight line of the socket, various modifications of the standard fitting stool have been tried (3,4). Figure 3 is a schematic diagram of a titling stool which uses a fixed ball as the lower contact point. The point of contact of the ball locates one point on the plumb line, which is then extended upward through the socket.

In a further refinement of this technique, introduced into this country in 1947, the plumb line is located at the intersection of two

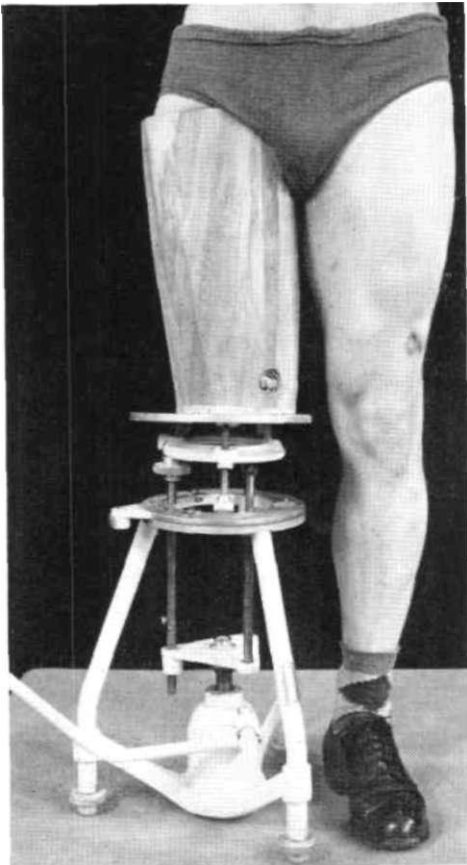


Fig. 2. Modern titling stool with hydraulic height adjustment. Manufactured in Germany by Habermann.

vertical planes (Fig. 4). The lower edge of each plane is determined by use of a triangular block giving a line contact along the bottom of the socket. 4

Another pivot-point balancing device (Fig. 5) locates a similar point near the top of the socket block by supporting the socket in a clamp which pivots about a fore-and-aft axis and allows the pivot point to be moved medially or laterally as desired. Weight is transmitted to the floor through a connecting pylon.

Vise-Type Fitting Stand

Another school of thought in the alignment of the above-knee socket believes that establishment of a plumb line is not as important as is establishment of the proper inclination of the socket in space. In the vise-type fitting stand (Fig. 6) of Habermann (/), the socket can be adjusted in inclination to any position desired. Once the proper inclination and height have been established, the socket is clamped rigidly in space, and the amputee "marks time" in the socket. If necessary, changes are made until the amputee is able to bear weight

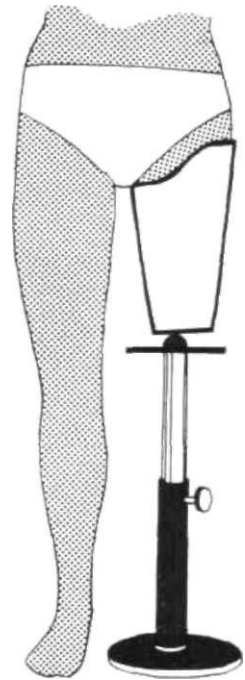


Fig. 3 Point-balance fitting stool with a fixed ball as the supporting point

comfortably and to use his stump efficiently in the control of body movements. After an arbitrary plumb line has been assumed, the optimum socket orientation is incorporated into the final prosthesis.

All of these mechanical aids have helped in the so-called "static alignment" of the prosthesis, a condition which determines the stability of the artificial limb in the stance phase. The "dynamic" factors, which affect the swing phase of the prosthesis, and which account for the differences between the static

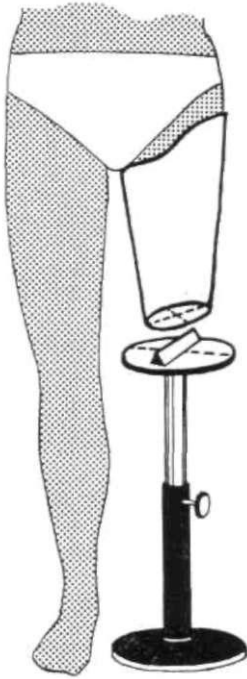


Fig. 4



Fig. 5

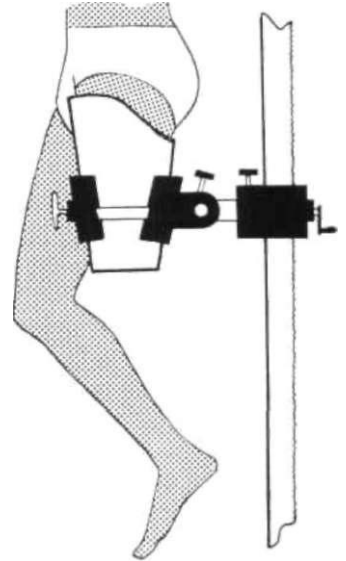


Fig. 6

Fig. 4. Line-balance fitting stool with triangular block as a support.

Fig. 5. Pylon-type fitting stand with support at a point near the top brim of the socket.

Fig. 6. Vise-type fitting stand.

and dynamic conditions in the stance phase, are adjusted as necessary after the amputee is walking on the rough leg.

SCHNEIDER'S "GEHMASCHINE"

Hans Schneider (6) of Nuremberg, Germany, has long advocated the use of an adjustable leg or "walking machine." Essentially, his method is to allow the amputee to walk on a trial prosthesis (Fig. 7), changes being made empirically until the alignment is considered satisfactory. Then, as the optimum alignment is being duplicated in the final prosthesis, various measurements are read from the adjustable leg and a measuring stand (Fig. 8). It is claimed that from these measurements the fit and alignment can be duplicated in additional prostheses ordered later.

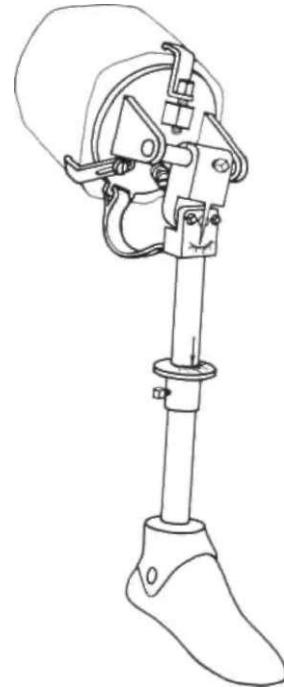


Fig. 7. Schneider's "Gehmaschine."

THE UNIVERSITY OF CALIFORNIA ABOVE-KNEE
ADJUSTABLE LEG

A study of methods for alignment of the above-knee suction-socket prosthesis was started at the University of California, Prosthetic Devices Research Project, in the autumn of 1946. As one of the first phases of investigation, two adjustable prostheses were designed and constructed. These experimental devices (Figs. 9 and 10) allowed adjustment of a large number of variables, and data were collected having to do with the effect of a change in one of the many alignment variables upon the behavior of the prosthesis (5). It soon became apparent that devices of this nature were not

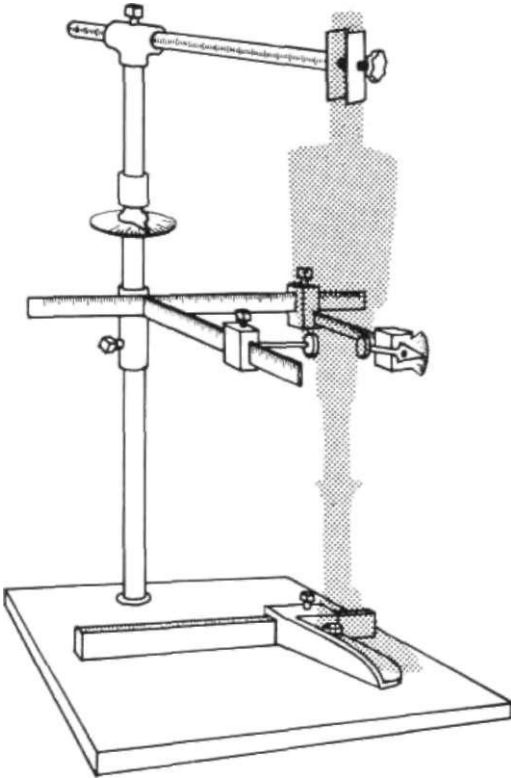


Fig. 8. Schneider's alignment stand.

only useful as research instruments but that they might also have some practical use as limbshop tools. Accordingly, there was designed and constructed for limbshop purposes a series of models of a simplified device in-

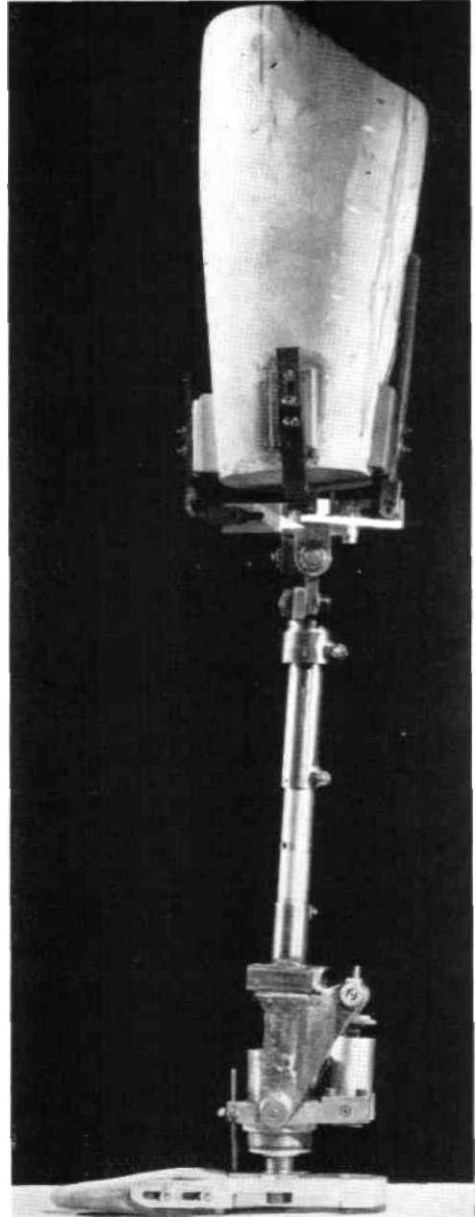


Fig. 9. Experimental adjustable above-knee leg used for research at the University of California.

corporating only those adjustments found most important, as determined using the research devices.

The initial effort was to develop a device for alignment of the above-knee suction-socket

prosthesis. Out of (his work came the above-knee adjustable leg shown in Figure 11. Several units of this design were used in the experimental program at the University of California and were given shop trials in the San Francisco Bay Area. They were found very useful in the alignment of above-knee prostheses in the shops and, in addition, were

widely used for demonstration of alignment principles. But use of the above-knee adjustable leg was then limited because of the difficulty in transferring the optimum relationships from the adjustable trial prosthesis to the final setup.

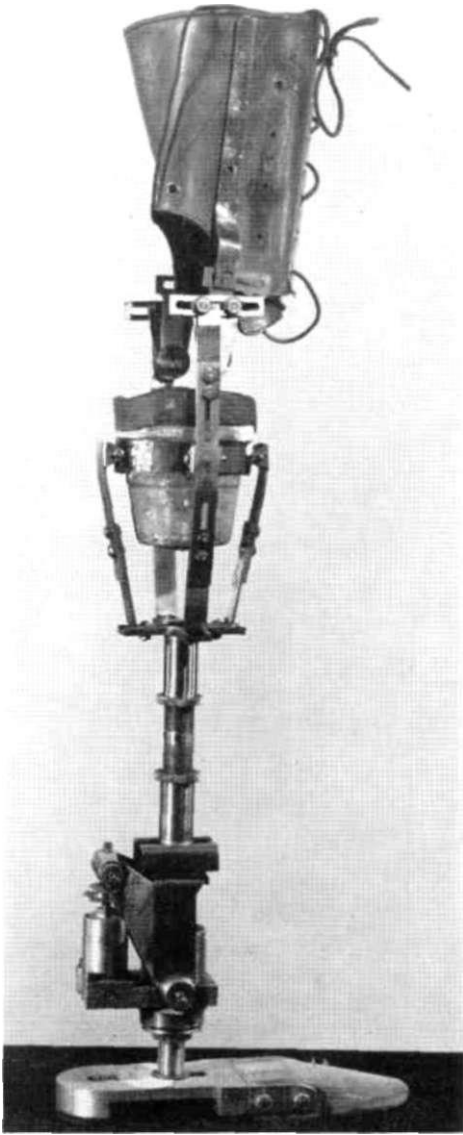


Fig. 10. Experimental adjustable below-knee leg (University of California).

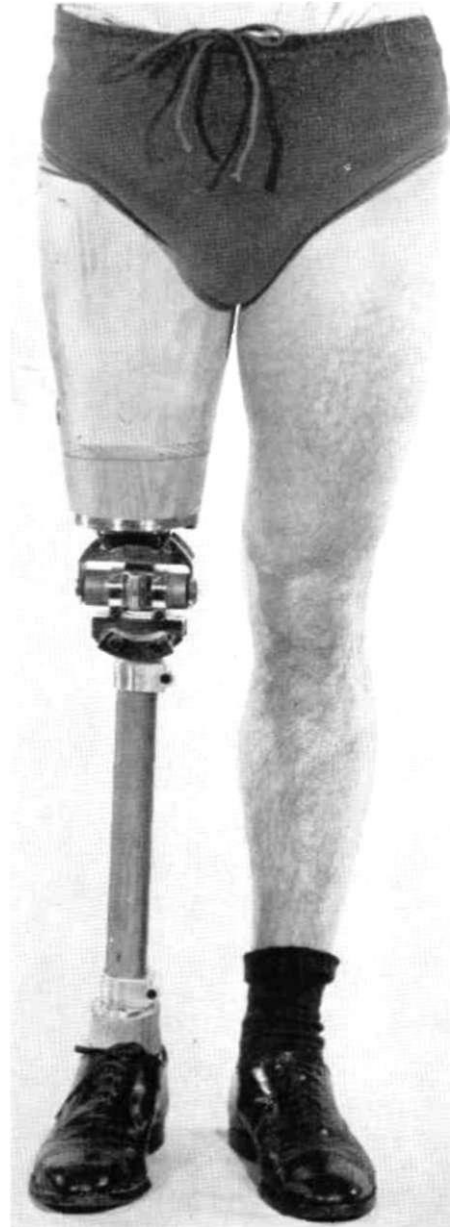


Fig. 11. The UC adjustable leg.

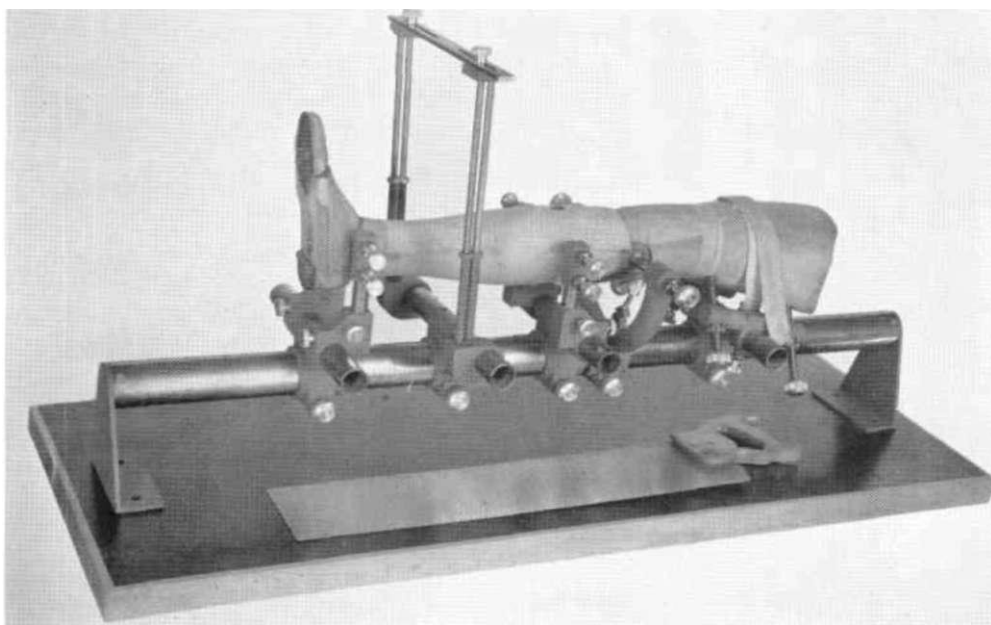


Fig. 12. The alignment duplication jig.

THE UC ALIGNMENT DUPLICATION JIG

To fill this need, the designers produced the Alignment Duplication Jig (Fig. 12), which is essentially a rather specialized set of clamps and an associated saw guide to maintain the socket, knee axis, ankle axis, and foot in a fixed position, thus permitting the temporary adjustable knee to be removed and replaced with wood, plastic, or metal structural members and joints. Three models of the alignment duplication jig were constructed and loaned, along with models of the above-knee adjustable leg, to the representatives of the Orthopedic Appliance and Limb Manufacturers Association who were then serving as the Technical Advisory Committee to the Lower-Extremity Technical Committee of ACAL. The representatives of the limb industry were unanimous in their conclusion that use of these devices offered considerable advantage to the prosthetist for alignment of all above-knee suction-socket prostheses.

On the basis of the experience gained, the above-knee adjustable leg was redesigned, as shown in Figure 13, and drawings for both the adjustable leg and the duplication jig were made available to the artificial-limb industry.

Devices similar to those shown in Figures 12 and 13 are now being manufactured² and can be purchased by limbshops.

THE UC COMBINATION ADJUSTABLE LEG

Because of the acceptance of the above-knee adjustable leg during its trial period of limbshop use, the Technical Advisory Committee of OALMA recommended that a similar unit be developed for alignment of below-knee prostheses. As a result, the combination above-knee/below-knee adjustable leg (Fig. 14) was designed and constructed at the University of California. Its use as a below-knee alignment device is indicated in Figure 15. The principal advantage of this unit over previous designs is that no tools are required in making adjustments.

USE OF THE ADJUSTABLE LEG AND ALIGNMENT DUPLICATION JIG

The basic difference in the use of the University of California alignment devices, as compared with Schneider's apparatus, lies in the manner of duplication of the optimum

² By the Plastic Fibre Limb Company, Minneapolis, Minnesota.

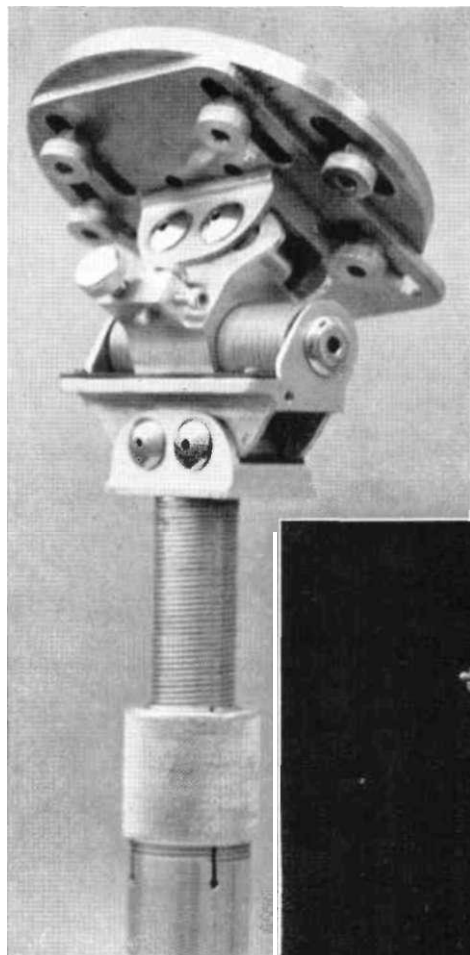
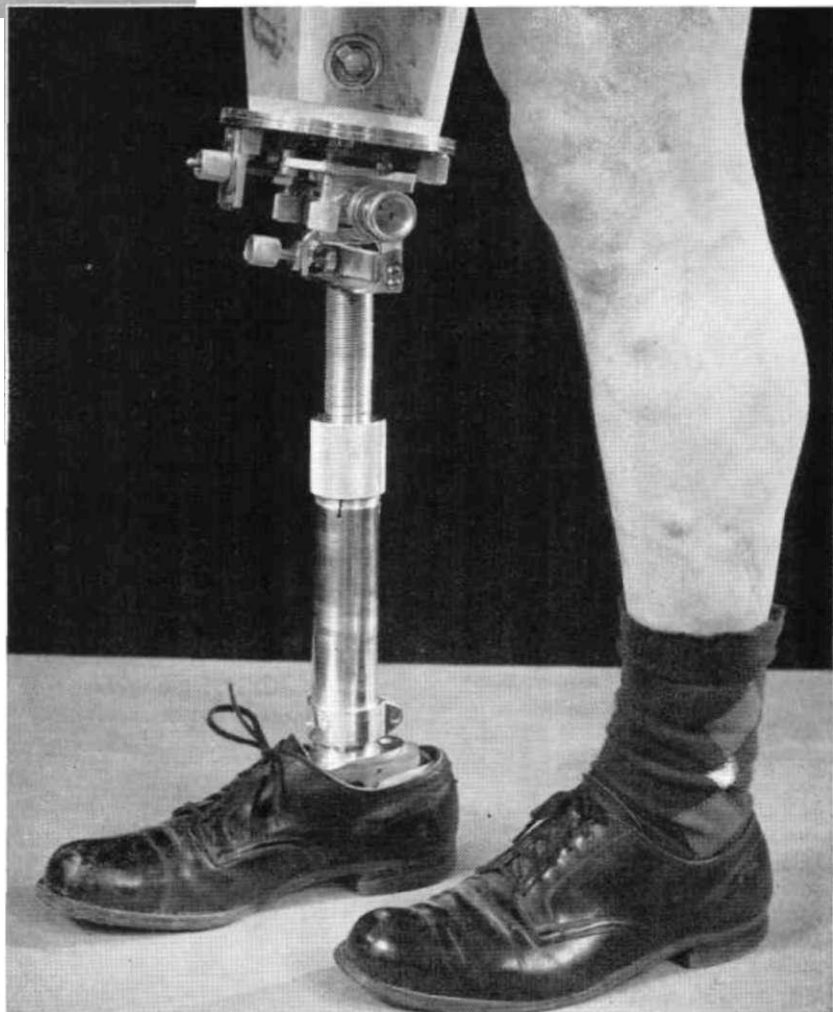


Fig. 13. Revised design of the adjustable leg as released to the artificial-limb industry.

Fig. 14. Combination above-knee/below-knee adjustable leg in use as a trial above-knee prosthesis.



alignment. The adjustable leg is used in much the same manner as is Schneider's device. A set of guiding principles for fitting and alignment has been established, and the adjustable leg is used as a means of applying these principles to the conditions existing with a particular amputee. But the devices serve as shop tools only, and any set of principles can be applied by the prosthetist.

In the use of the alignment duplication jig, the assumption is made that the optimum alignment will be influenced considerably by the fit of the socket. Since subsequent sockets for a particular amputee are not apt to be exactly alike, it is considered unnecessary to try to duplicate in all later prostheses the alignment of the first. Each socket is considered as a separate alignment prob-

lem, and the alignment duplication jig helps in the construction of the final prosthesis rather than as a measuring instrument.

In the prior art of lower-extremity limb-fitting, there has naturally been the tendency to stop making adjustments as soon as the prosthesis is just "good enough," especially so when a further change would mean breaking a glued connection or resetting a joint. The principal advantage of the UC alignment equipment is that, since all adjustments in the trial prosthesis are easily and quickly made, the prosthetist can make very small changes until both he and the amputee are satisfied

that the best job has been done. The alignment of a leg prosthesis is especially critical in the swing phase and during the periods of transition from stance to swing. Very small changes in alignment can have very noticeable effects upon the performance of the prosthesis at these times. Since small adjustments can be made accurately using the adjustable leg, the prosthetist is able to obtain optimum performance where that is difficult, if not impossible, to achieve by trial-and-error methods. Besides this, the adjustable leg has found considerable use as an educational aid in teaching prosthetists the fundamentals of



Fig. 15. Combination above-knee/below-knee adjustable leg in use as a trial below-knee prosthesis.

limb alignment in suction-socket schools and in demonstration of alignment principles before groups of orthopedic surgeons, physical therapists, and others.

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