A POWERED AID FOR ALIGNING THE LOWER-LIMB MODULAR PROSTHESIS[a]

D. A. Hobson, B. Sc., Mech. Eng.
Design Engineer

Manitoba Rehabilitation Hospital
800 Sherbrook Street
Winnipeg 2, Manitoba, Canada

THE PROBLEM

The recent advent of the "modular system" of artificial limbs for lower-limb amputees has opened many new possibilities. The modular system, in contrast to the wooden exoskeletal conventional limb, has a pylon (aluminum tube) as its central structural element, and employs a soft rubber cover to obtain the necessary cosmetic effect. Further, in the system developed locally, the pylon has alignment units located at both ends which permit the position of the limb segments to be altered at any time. This built-in ability to alter the alignment in order to reduce the forces acting on the stump during walking is one of the major advantages of the modular limb system over the conventional type.

Unfortunately, the modular concept itself does not solve all the problems. For instance, the alignment of the limb joints and segments, which is crucial to the maintenance of stump comfort and condition, is presently derived largely by means of a trial-and-error procedure. Visual observation of the joints and segments during walking trials, sometimes further reinforced by amputee reactions, is a time-consuming and often inaccurate process. In addition, present methods of altering alignment require such a large time lapse between successive trial settings of the alignment jig, that memory fading is usually sufficient to obscure the results of the previous trial. This means that the prosthetist and the amputee are constantly working in a state of lost reference.

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[a] This development was carried out at the Manitoba Rehabilitation Hospital under the technical direction of James Foort.

POWERED ALIGNMENT UNIT

A. Purpose:

A powered aid has been developed in an attempt to solve the above-mentioned problems; more specifically (Fig. 1):

1. To minimize the memory-fading problem by permitting alignment changes while the amputee is actually walking on his prosthesis.
2. To improve the accuracy by permitting the amputee to alter his own alignment based on the interpretation of the forces he feels on his stump while walking.

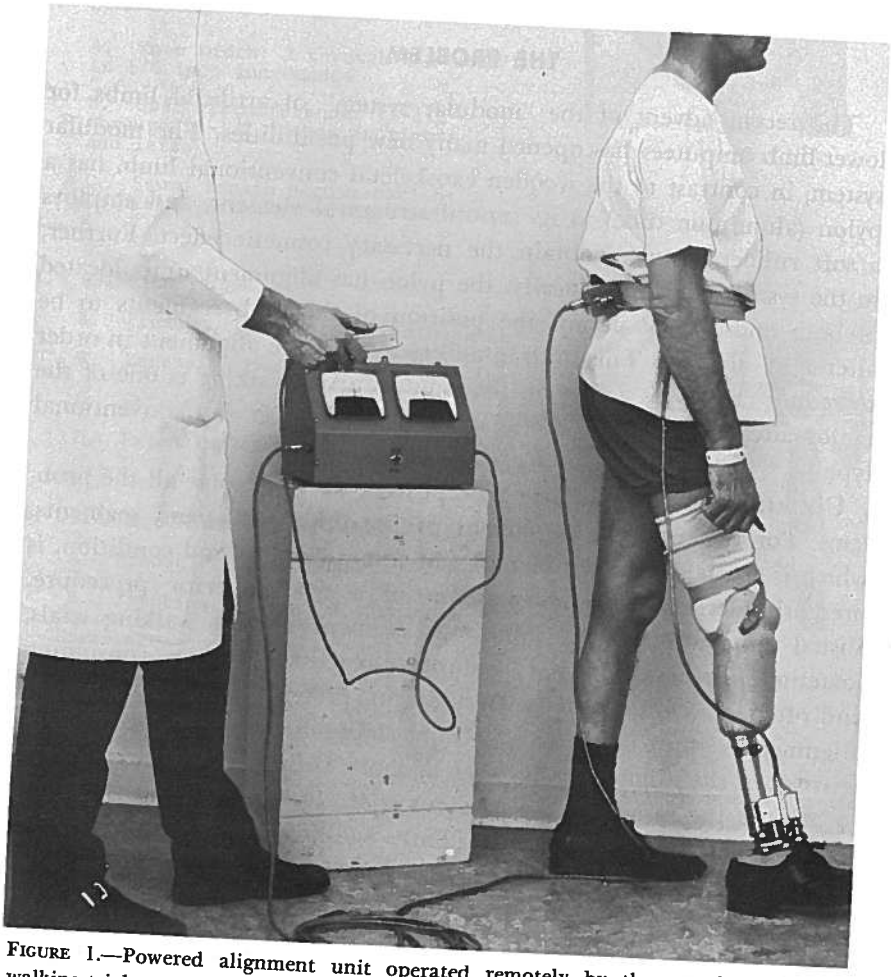

FIGURE 1.—Powered alignment unit operated remotely by the prosthetist during walking trials.

Once a desired alignment has been achieved, the powered unit would be removed, and the alignment derived from it transferred to the permanent prosthesis.

B. Description:

The object of the initial design was to realize a powered unit to be placed at the ankle level (Fig. 1), permitting change in the alignment of the foot under dynamic conditions. An identical or similar unit could be used to obtain the alignment changes at higher levels.

At its center the powered unit incorporates a standard spherical bearing, about which two powered jack screws drive the foot to a desired inclination from a zero reference. The driven motions can occur either simultaneously or sequentially about two axes at right angles to each other located at the level of the ankle. The maximum range is 9 deg. in either of the four directions from the neutral position. Two Globe motors (12 volts) with attached gear reductions are used to drive the custom-designed jack screws. The screws themselves are mounted in spherical bearings to permit the required motions about the two axes without binding. The precise indication as to the number of degrees of rotation obtained in the two reference planes is indicated on the display meters. The feedback signal to the meters comes from two standard multiple-turn trimmers which are mounted on the end of the jack screws.

The unit itself is attached between the foot and the tubing of the pylon. The controls and position feedback are connected to the unit by a cable running from a junction box on the patient's belt down to the unit itself. The unit is operated with a hand control optionally manipulated by either the amputee or the prosthetist. With the amputee operating, the trailing cable from the patient to the meter can be disconnected, as the hand control has its own power source (Fig. 2). However, when operated in this fashion, the meter cord must be plugged back into the belt box after the alignment change has been made, so that an indication of the angle change will be transferred back to the meters for recording purposes. When operated in the latter fashion, the hand control is disconnected from the above box and plugged into the meter panel. Of course, the training cord is now required for purposes of control and foot angle feedback.

C. Results:

The results to date include trials on 12 subjects. The following comments are based on this limited evaluation and should not be considered as conclusive:

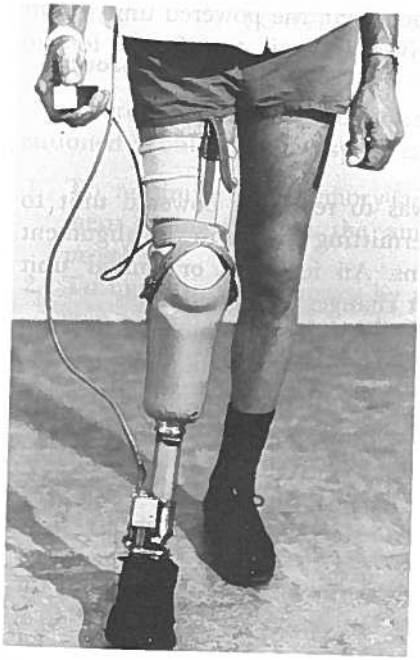

FIGURE 2.—Powered alignment unit operated by the amputee while walking.

1. All amputee subjects on their own appeared capable of arriving at a foot alignment which felt most comfortable to them.
2. A comparison of the final alignment derived independently by the prosthetist and the amputee showed considerable disagreement, with the amputee appearing to be more consistent.
3. The accuracy and snugness of the socket fit affect the amputee's sensitivity with regard to interpreting the force pattern acting on his stump for purposes of a meaningful self-alignment change.
4. The consensus of the participating prosthetists was that by using the powered unit, foot alignment could be achieved more rapidly with an improved final result, when compared to conventional methods.
5. The weight of the unit located at the ankle does not appear to be a restricting factor, except in one case in which the amputee commented to the contrary.
6. The amputee is capable of detecting foot malalignment and of effecting the appropriate change in only a few steps and within a limited space.
7. The subjects tested have not demonstrated a consistent ability to repeat their foot alignment with ± 1 deg. in a number of successive trials.
8. A combination of prosthetist doing the gross adjustment followed

by the amputee doing the fine tuning seems to yield the best results.

D. Future Plans:

The results so far are encouraging to the point that further tests and prototype powered units are planned. Some of the future steps will be:

1. Fabrication of a second unit to be located immediately below the below-knee socket.
2. Extension of the system to deal with the above-knee alignment problem.
3. Streamlining of the process so that prosthetists will be encouraged to use the unit routinely.
4. Encourage reproduction of the system as indicated by the clinical demand.