Modifications of the Switch Control for a Powered Hand on an Elbow Disarticulation Prosthesis

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CASE PRESENTATION

We were presented with a twelve year old girl who was a congenital amputee. The patient, although functionally an elbow disarticulation, had three digit remnants present on the distal residual limb. These digits were not mobile and essentially not functional.

The patient had been attempting to wear a conventional prosthesis from approximately age eight. She could generate enough cable excursion to operate the elbow (i.e. full flexion and extension), however, she could not operate the conventional terminal device. The patient's parents found themselves forcing the child to wear the prosthesis against her will. Of course, the parents could not enforce the wearing time while the child was away from home with, for instance, school, play. The patient's parents found themselves having to deal with a common problem in upper extremity prosthetics—prosthesis rejection.

The physician, when faced with providing the patient with her third prosthesis, wanted to forego the prescription in hopes of circumventing another rejection. In interviewing the child, he found that she had two reasons for rejecting her prosthesis. First, she could not operate the terminal device, so that the prosthesis became to her a non-functional burden, and, second, the appearance of the terminal device was not cosmetic.

Subsequent to the patient interview, the physician requested that the child be provided an elbow disarticulation prosthesis which utilized a myo-electrically controlled hand.

THE PROSTHETIC PRESCRIPTION

The prosthetic evaluation concluded that the patient had no usable myo-electric potential at the level of either her biceps or triceps. The deltoid muscle exhibited a usable potential at the level of both the medial and anterior fibers. It was decided that the placement of electrodes over the deltoid muscle was undesirable because of the high proximal socket trimline required to mount the electrodes.

It is conceivable that with proper preprosthetic training the patient could have developed some myo-electric potential in either the biceps or triceps muscle.

The patient lived approximately 100 miles from the nearest therapeutic training facility and transportation was a problem, making training impractical.

Potential volume changes of the residual limb were also considered. A myo-electrically controlled prosthesis could not be worn with a prosthetic sock. In addition, use of surface electrodes necessitates an intimate socket fit. With these factors in mind, the prescription was changed from a myo-electric control system to a switch control system.[1]

The definitive prescription called for a hybrid system, utilizing a conventional elbow disarticulation socket, Dorrance E-2500 child size outside locking hinge, Variety Village 127-00 pull switch, Variety Village 6V dc-220 ma power supply, Otto Bock 6¾ externally powered hand, with Otto Bock quick disconnect wrist.

BIOMECHANICAL CONSIDERATIONS

Body powered control of an elbow disarticulation prosthesis is typically achieved from shoulder girdle movement harnessed so that gleno-humeral flexion and scapular abduction creates enough excursion of the control cable to flex the forearm. Shoulder depression with gleno-humeral extension and abduction then controls elbow joint lock. When the elbow is locked, additional pulling of the control cable will operate the terminal device.

Because of the nature of these control factors, operation of a pull switch to control the powered hand was a problem. All of the "normal" harnessing to allow for operation of the forearm and elbow joint had to be retained, and an additional movement for control of the pull switch to operate the hand had to be located and harnessed. The only other control movements considered to be functional were shoulder elevation or chest expansion. Even though the excursion needed to operate the pull switch was small (approximately 12mm), it was determined that these two control movements were too inaccurate for the fine cable control needed to operate the hand with precision. In addition, shoulder elevation and chest expansion are cumbersome movements, and conspicuous, and should be avoided if possible.

The solution seemed to be a connection from the terminus of the control cable directly to the pull switch, instead of the terminal device (Fig. 1). This allowed for full elbow flexion, however, the force on the cable terminus required to flex the forearm caused the switch to be activated before the forearm was locked into its desired flexed position.

DESIGN AND PULL SWITCH MODIFICATIONS

The pull switch had to be modified so that it would provide enough opposition to the control cable force to allow for forearm flexion and yet, once the elbow was locked, the opposition had to be small enough to allow activation of the switch.

The Variety Village 127-00 pull switch seemed most suitable for the needed modifications (Fig. 2a).

The forearm flexion attachment was moved distally to lessen the force needed to flex the forearm. Flexion of the 11 inch forearm with the Otto Bock 6¾" hand attached, requires 4.7 pounds of pull. Because more force would be required to flex the forearm while lifting objects, the spring tension of the pull switch was increased to 10.5 pounds.

The Variety Village switch 127-00 has a single cam type shaft which moves laterally in the switch housing. This shaft protrudes on one end of the housing for attachment to the control cable. The cam shaft is spring loaded internally so that the shaft retracts to the "off" position when not in use. The internal spring was removed and an external spring of greater tension was added. To aid the external spring, an opening was made in the switch housing for the cam shaft opposite the end which already protrudes (Fig. 2b). A 4mm length of 2mm bar stock was brazed to the end of the cam shaft as an extension. A spring generating 10 pounds of tension was attached to the cam shaft extension and the entire assembly was mounted in the forearm cavity. The switch was mounted with two machine screws, which threaded into the body of the switch. The spring was

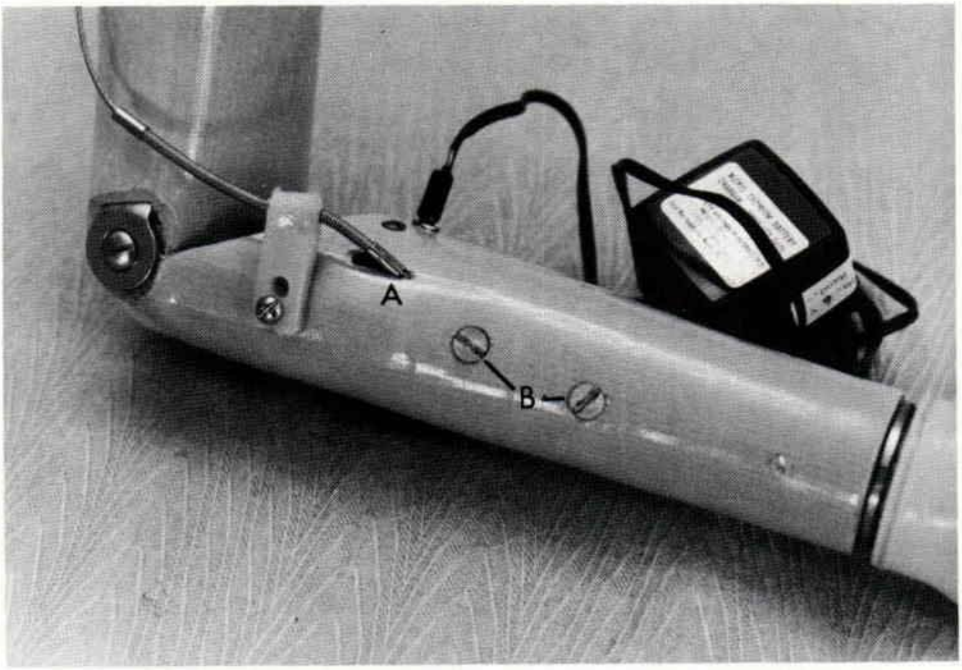

Fig. 1 — A) Control cable terminus; B) Pull switch mounted inside forearm cavity.

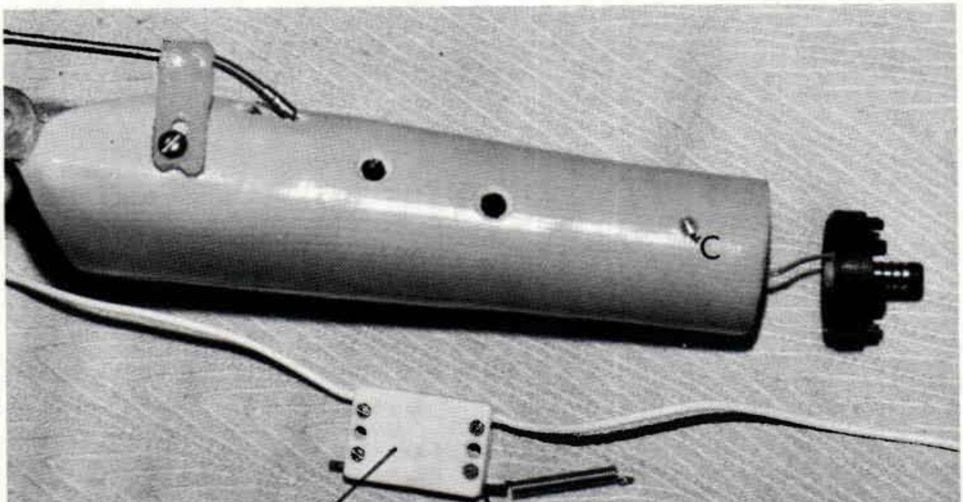

Fig. 2 — Disassembled forearm A) Variety Village 12700 pull switch; B) New opening and cam shaft extension with spring attached.

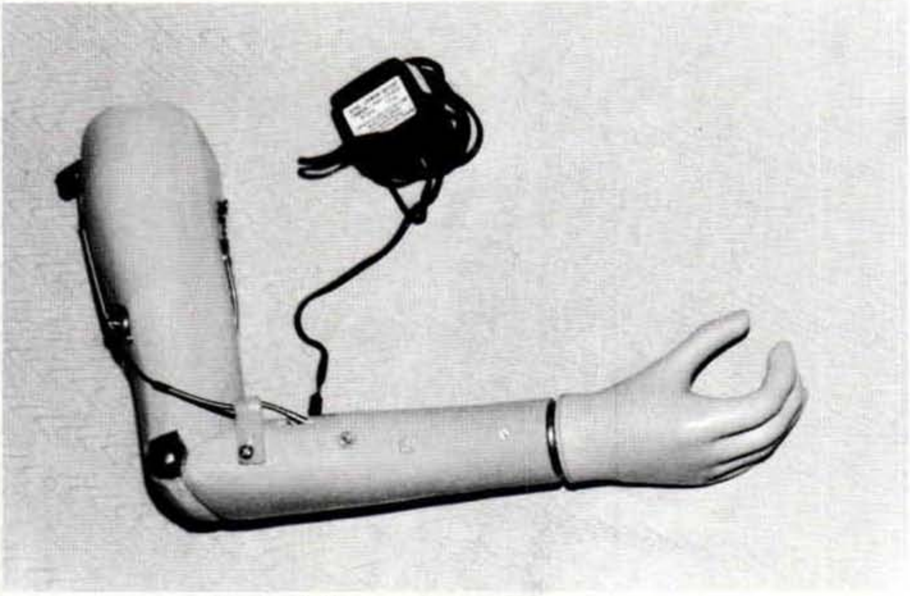

Fig. 3—Finished prosthesis with battery charger.

attached distally by means of a nut and bolt (Fig. 2c).

Once assembled, the entire switch assembly and power supply fit into the arm cavity. The batteries were mounted permanently so a jack was provided proximally for the battery charger. The proximal location is used so the cosmetic glove does not have to be rolled down for charging.

The finished prosthesis does not require any cables distal to the switch control on the forearm. (Fig. 3).

TRAINING AND FOLLOW-UP

The patient had been seen by an occupational therapist one time for therapy. The movements for control were essentially the same as for her conventional prosthesis. It took approximately 40 minutes for the patient to learn the fine control movement needed to find the different positions of the pull switch. At the close of the therapy session, the patient could open and close the hand with 100% accuracy. We anticipate that the speed with which she operates the prosthesis will improve with practice.

Approximately 12 months have passed since the delivery of this prosthesis. The patient's earlier signs of prosthetic rejection have been remediated. Thus far the initial reaction has been a positive one on both the part of the patient and the parents. To date we have not had any mechanical failure on the hand or modified switch.

REFERENCE

1. Spaeth, John P., Klotz, John, Handbook of Externally Powered Prostheses for the Upper Extremity Amputee. C. Thomas, Springfield, Illinois, 1981. (Springfield: C. Thomas, Publisher 1981)