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Case note

Prosthesis with electric elbow and hand for a three-year-old multiply handicapped child

W. F. SAUTER, R. DAKPA, E. HAMILTON, M. MILNER and H. R. GALWAY

Hugh MacMillan Medical Centre, Toronto

Abstract

The usefulness of wisely prescribed powered components in the rehabilitation of upper extremity amputees has long been recognized (Schmidl, 1973). Their value is especially evident in the prosthetic rehabilitation of high level adult and child amputees (Heger et al, 1985). In recent years, manufacturers of prosthetic hardware have provided practitioners with a wide selection of either myo-electrically or switch controlled electromechanical components and systems. As a rule, however, most commercially available components are designed to serve the adult amputee and do not lend themselves for use in the prosthetic rehabilitation of children. One current exception is the availability of child-size electric hands.

The availability of the world's first child-size electric hand in 1970 at the Ontario Crippled Children's Centre later known as the Variety Village 105 hand, gave tremendous impetus to the fitting of younger children with externally powered components and myoelectric control systems. However, this trend served to benefit the young below-elbow patient only (Sorbye et al, 1972).

The successful fitting of higher amputation levels in this age group stopped at the elbow level. Existing artificial elbows such as the Variety Village and Hosmer elbow with their necessary powerpacks are simply too bulky and too heavy for pre-school age children. The need for a lightweight compact electric elbow, suitable for 3-8 year old children, still has not been addressed. This single case report illustrates an innovative and successful conversion of a 6-3/4 Otto Bock hand into a small electric elbow. The idea was first proposed by Schmidl (1973).

The patient

The patient was first seen by the clinic team in July 1981 at the age of 14 months. She was diagnosed as having bilateral upper limb hemimelia to both humeri, and bilateral proximal femoral focal deficiency of her lower extremities of the Aitken type.

When first seen she had already been fitted with conventional prostheses on her upper extremities but had not yet learned to use them. As is typical for patients with bilateral upper extremity deficiencies she had developed good foot skills, and the chances of her becoming a proficient user of an upper extremity prosthesis were thought to be slim if immediate action was not taken. For ambulation, she had been fitted with a swivel-walker but was reluctant to use this. During the next clinic visit, it was decided that the patient should be encouraged to stand and walk on her own feet with the support of a walker. In becoming a more proficient ambulator, her height could then be increased by eventually introducing a pair of "stubbies".

On her next visit, 3 months later, her upper extremity prosthetic function was still totally inadequate. In standing, she used the prostheses to hang on to her walker. Whilst sitting, the control harness of her conventional artificial arms would become slack and useless. In fact, she had started to use her feet more than ever. It became quite evident that this tiny patient lacked the energy and physical strength required to operate conventional upper extremity artificial limbs. The logical alternative therefore was to use electrically powered components for prehension and elbow flexion.

All correspondence to be addressed to Mr. W. F. Sauter, Coordinator, Powered Upper Extremity Prosthetic Program, Hugh MacMillan Medical Centre, 350 Rumsey Road, Toronto, Ontario M4G 1R8, Canada.

Myoelectric possibilities

In March, 1983, the patient was first introduced to a myo-tester by watching a team member from the therapy staff using it. The relationship between muscle actions and meter responses was quickly understood and, with little coaxing, she agreed to try the device herself. The electrodes were placed on the biceps and triceps of her left arm. She had adequate signals from both muscles but was unable to separate the action of the antagonists. It was therefore decided to use a Variety Village 3-state control system.

The 3-state control systems originally introduced by Reiter in 1948 and further developed at the University of New Brunswick (Scott, 1968) are specifically designed to operate one actuator from one muscle. These systems are therefore advantageously employed where there is a scarcity of useable control sites such as in the intra-scapulothoracic amputee, or as in this case, in the congenital amputee who is unable to separate the electrical activities of muscle antagonists. As the name implies, 3-state systems are multi-level systems in which two discrete signal levels other than zero, are used to specify particular prosthetic functions. In practice, if the patient's signal level is lower than the first preset switching level, the actuator (hand) remains still. If however, the signal level rises beyond the first switching level, the hand will close. Only when the signal level rises past the second preset switching level will the hand open. The 3-state system is then calibrated to match the patient's signal output.

Because the patient needed extensive training, the parents were instructed to teach these procedures to their child with the understanding that the training sessions were to be continued at home until the patient reached a satisfactory level of control performance.

The above-elbow socket

From a plaster impression taken the same day, a 'half and half' above-elbow socket was made (O.C.C.C., 1980). This type of socket differed considerably from the conventional above-elbow prosthetic socket in design as well as in choice of materials. The socket incorporated the shoulder as well as the above-elbow stump. The shoulder portion of the socket was made from silicone rubber and was therefore flexible and very comfortable. This portion of the socket replaced the sometimes excessive amount of webbing needed to achieve effective suspension. At the same time the flexible shoulder part helped to eliminate the rotational problems encountered with conventional designs. Below the axilla level, the layers of reinforced stockinette used in the making of the socket were impregnated with acrylic resin. The resulting socket was therefore self-suspending. A single transverse chest strap was used to hold it on to the patient. The patient accepted the socket and after the electrodes were installed and temporary wiring was connected, the socket became part of the training equipment.

The powered elbow mechanism

Since it had already been decided to combine the myoelectrically controlled hand with an electrically powered elbow, the use of existing components such as the Variety Village and the Hosmer elbows was considered and subsequently discarded because of their weight and size. Attempts to use an Otto Bock wrist rotator were aborted for the same reasons.

The possibility of using a modified Otto Bock 6-3/4 hand was then pursued. First, a 6/32 screw was installed to hold the two chassis plates together in alignment. Then the hand was modified by cutting off the chassis as close to the

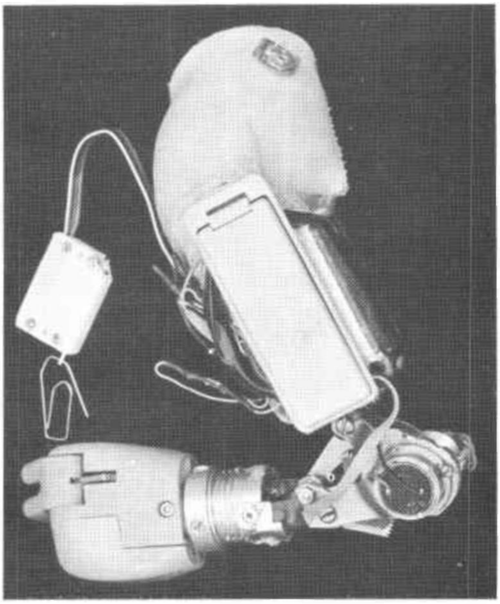

Fig. 1. Attachment of the modified hand as an elbow to a child-size prosthesis.

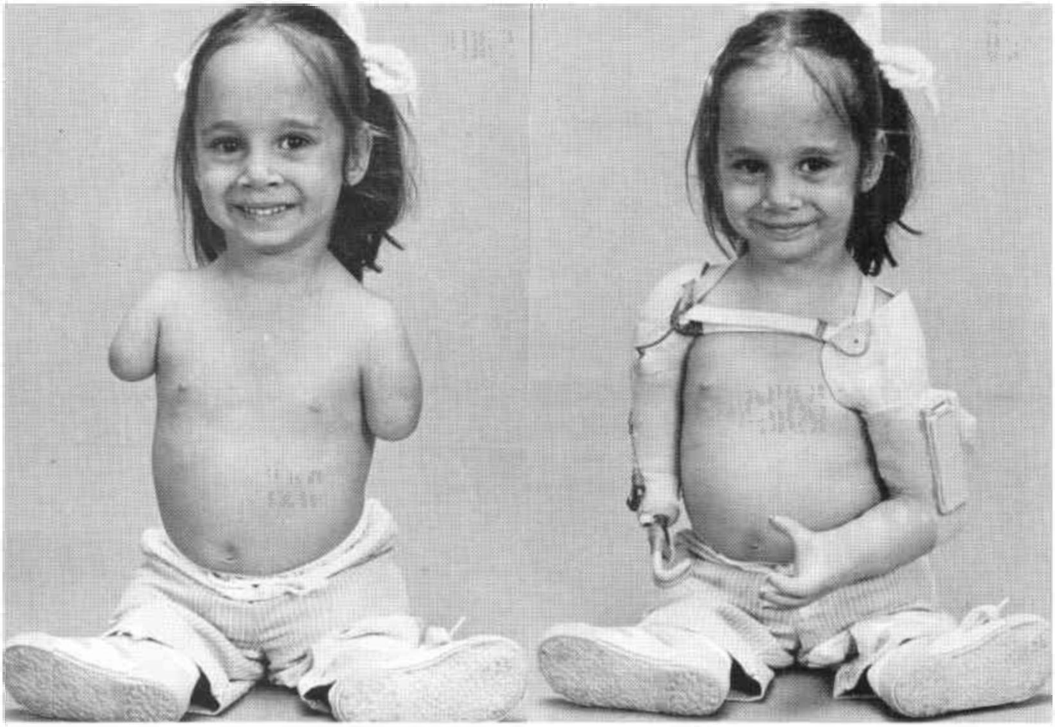

Fig. 2. Patient with completed prosthesis.

motor as possible. This shortened the hand body by one inch. Next, the thumb was cut off just below the tip. An 'L' shaped piece of 1/8" aluminium was riveted on to the thumb stump. This 'L' bracket was then shaped to fit on to the above-elbow socket and fastened to it with epoxy. Then the two fingers of the 6-3/4 hand were cut just at the base of the first IP joint and spread apart enough to accommodate the wrist unit of the electric hand (Fig. 1).

The elbow joint thus constructed is attached to the humeral socket by its thumb. Because the thumb and fingers are coupled, the elbow-cum-hand-body pivots at the thumb joint and moves downward while the forearm-cum-finger assembly moves into flexion. This 'ersatz' elbow is quiet, weighs only 155 g, moves from 90° to 135° in under one second and costs about one third of the price of other elbows. Because the patient uses this device mostly in sitting this range of motion was sufficient. By doubling the size of the gear segment attached to the finger assembly, the range of motion was later extended from full extension to 130° flexion.

Control of elbow flexion and extension was achieved with the use of a VV pull-switch (catalogue #127-00*). This switch is attached to the posterior proximal aspect of the humeral socket. The fishline activating the switch is anchored on the transverse dorsal part of the patient's harness. Thus abduction and/or humeral flexion of the prosthesis at the shoulder causes the fishline to tighten and trigger the switch. Variations in the amount of excursion of the fishline will either result in flexion or extension of the elbow. An Otto Bock 6V-225mAh-757B8 battery installed on the lateral aspect of the humeral socket is the power source. This battery serves both the hand and the elbow.

The patient accepted the prosthesis readily and with several hours of training by the therapist satisfactorily managed to control both prehensile and elbow movements (Fig. 2). Unfortunately, in using the device at home, the patient pinched herself with the electric hand and for two weeks refused to make use of it.

As she had always been a good foot user, she temporarily resumed using her feet but after two weeks, she reverted to using the prosthesis.

*Variety Village Electrolimb Production Centre, 3701 Danforth Ave., Scarborough, Ontario. Tel 698-1415.

Conclusion

Now 18 months after the prosthesis was supplied, the patient continues to wear it daily, she has achieved good control and uses the device effectively. She still continues to use her feet for many activities when seated.

The elbow itself has proven to be a useful device for this patient and it is planned to use the same design on other patients.

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