THE BELOW-ELBOW MYO-ELECTRIC PROSTHESIS

A COMPARISON OF THE OTTO BOCK MYO-ELECTRIC PROSTHESIS WITH THE HOOK AND FUNCTIONAL HAND

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The place of the myo-electric prosthesis in below-elbow amputees has been reviewed. Forty-three patients were seen and all possessed both a myo-electric prosthesis and a standard artificial limb. Nearly half the patients used the newer device almost all the time at work and many of these wore it for the majority of their waking hours. Its use at work was mainly related to the patient's type of job and here in turn there was concern about damaging the device. It is suggested that acceptance would be further increased if greater attention were paid to the durability of the arm and its glove. Criteria for prescription and future developments are discussed.

The myo-electrically controlled prosthesis for below-elbow amputees, first used on a significant scale by Kobrinski and co-workers in 1960, is now used internationally at a number of different centres. The myo-electric programme at the Workmen's Compensation Board of Ontario started in January 1974 (Table I), at first using the Russian arm (Rehabilitation Institute of Montreal, or RIM arm) and now predominantly using the German Otto Bock six-volt system, an example of which is shown in Figure 1. There are currently about 25 to 30 new fittings a year. These patients had all been

Fig. 1

The six-volt Otto Bock myo-electric prosthesis.

Table I. Numbers of the different types of myo-electric prostheses fitted per year by the Workmen's Compensation Board Hospital and Rehabilitation Centre, Toronto

Year	RIM	Otto Bock 12-volt	VANU	UNB	Otto Bock six-volt	Total
1974	1	1				2
1975	2		1			3
1976	1	3			1	5
1977				1	28	29
1978				1	22	23
Total	4	4	1	2	51	62

previously fitted with a hook and with a cable-operated hand, and they had kept these earlier prostheses after being fitted with the myo-electric device.

In view of the greater expense, both in actual equipment and in specially skilled personnel, it was wondered if the programme was indeed justified or

whether the myo-electric limbs were too complicated, too delicate or too unreliable to be used in a widely scattered population of injured work-people. The purpose of the present review was to assess the value of the below-elbow myo-electric prosthesis in injured workmen. The assessment was to include the amount of time these limbs were actually worn and used, and to make a comparison between them and the standard prostheses.

MATERIALS AND METHODS

Up to the end of 1978 59 patients with below-elbow amputations had been fitted with myo-electric hands. None of the prostheses had a powered unit for rotating the wrist. Three patients required bilateral prostheses. Forty-three patients were reviewed, and the time between fitting and follow-up averaged 16 months. Of the remaining 16, two patients had left Ontario, one had definitely rejected his prosthesis and returned it, and one bilateral amputee was a probable non-user; one patient whose prosthesis had a three-state control was having such difficulties over repair that he was not included; the remaining 11

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patients did not wish to come in because of work or for personal reasons, but they were thought to be in no way different from the 43 patients reviewed. Using a standardised questionnaire, one of us (MDN-B) had a personal interview, lasting approximately one and a half hours, with each patient. The physical characteristics of every stump were noted. The patients were then put through a series of tests with both the myo-electric arm and the standard limbs. An occupational therapist (HH), with a special interest in the upper-limb amputee, did the actual testing.

Because the standard artificial limb in most common use was the hook, the comparison between it and the myo-electric arm was not straightforward. Both had a positive mechanism for opening the grip, but in the one arm it was electrically triggered and powered while in the other it was directly powered by body movement. The electric arm had a type of positive closing mechanism similar to its opening mechanism while the standard prosthesis closed by itself using elastic bands, on release of the opening pressure. The device at the end of each of the artificial limbs was also of course completely different, being in the one case a hook and in the other a component more reminiscent, at least externally, of a human hand. The methods of assessment took account as far as possible of all these differences.

RESULTS

The average age of the patients at the time of review was 36 years, the oldest patient being 57 and the youngest 20 years. Only one was a bilateral amputee. The unilateral amputations were on the right side in 22 patients, and on the left side in 20. The dominant side had been injured in 63 per cent. There were 39 men and four women.

The first part of the questionnaire was aimed at getting reliable information about the actual use of the various prostheses with which the patients had been supplied. In almost all cases there were four possible modes: use of the electric hand, use of the hook, use of the cable-operated or functional hand, and no prosthesis. The patients were asked to divide their waking hours into three parts: time at work, time in their own home, and time out socially. The distribution of their time between each of the four modes within each division was learned in conversation, and the results are shown in Figures 2, 3, 5 and 7. The patients were also asked to answer from memory the same questions for the period before they had the electric hand, and were thus used as their own controls; the results are given in Figures 4, 6 and 8.

From Figure 2 it can be seen that 18 patients used their electric hand almost all the time at work, and these patients also wore it, on average, for 59 per cent of the time at home and 91 per cent of the time when out socially, and thus used it for a very large proportion of their waking time. A similar number of patients used the electric hand almost all the time at home, and almost everyone used it predominantly when they were in contact with the public, proving immediately, if nothing else, its considerable cosmetic value. No patient had completely rejected the myo-electric prosthesis, though three of the 43 wore it very little. Thus the rejection rate in the 59 patients fitted was three to eight per cent. Even though this was a partly self-selected group, this figure

should be compared with the reported rejection rate of 67 per cent for standard prostheses below the elbow (Vitali *et al.* 1978).

Figures 3 and 4 show the use of the hook before and after the patient was given the electric hand. There is a general shift to the left-hand columns: the number of non-users at work has increased, and the number of those using the prosthesis at work has decreased; a marked fall-off in use at home can also be seen. Figures 5 and 6 show a similar picture for the functional hand. It appeared that this device was seldom used with any regularity except on social occasions, and with the advent of the electric hand it became virtually obsolete.

Fig. 2

Histogram showing the use of the myo-electric prosthesis (see Figs 3 to 8).

Figures 7 and 8 show that the total time for which patients used a prosthesis increased.

Several factors possibly influencing the patients in their use of the electric hand were next investigated. These included the age of the patients at the time of the accident, the period of time for which they had used the standard artificial limb, the age they were when they received the electric hand, their relative use of the

Table II. Use of the myo-electric limb related to patient's type of work. Analysis of first 19 patients, omitting three who were in the range between 25 and 75 per cent of time

Worn less than 25 per cent of time at work	Worn more than 75 per cent of time at work
Machine operator	Solicitor's clerk
Sheet-metal worker	Claims adjudicator
Punch-press operator	Student accountant
Club custodian	Construction electrician
Fork-lift driver	Electroplating chemist
Factory worker	Quality control inspector
Factory timekeeper	University student
Superintendent at apartment block	Computer programmer

different types of standard prostheses, the degree of their dislike of harness, and the incidence of neuromata, skin grafts and other problems in the stump. While some of these factors did have significance, the overwhelming influence proved to be the patient's type of work. The findings given in Table II for the first 19 patients seen were repeated throughout the series. It is clear that, with

one or two important exceptions, those patients who used the electric hand predominantly at work tended to have office-type jobs.

Reasons for use and non-use. The reasons patients gave for using their myo-electric prosthesis rather than one of the other arms included cosmesis and lack of a harness, and were not particularly helpful. However, the reasons

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7

Fig. 8

Figures 3 to 8—Histograms illustrating prosthetic use. Each histogram shows the number of patients using that particular prosthesis (or no prosthesis) and for what percentage of their time at work, at home or when out socially.

they gave for not using the electric arm were more informative, and these answers are in Table III. Much the commonest reason for non-use at work was fear of damaging either the prosthesis itself or its investing glove. Half the patients found that the glove was much too easily torn or cut, while almost all of them found that it could be irreparably ruined by grease or such a common thing as newsprint.

Table III. Frequency of a given reply in answer to the question, "What tends to stop you from using the myo-electric hand?"

	<i>Per cent</i>
Fear of damage	65
Spontaneous movement	11
Instability of socket under load	11
Pain	5
Less functional than hook	5
Repair difficulties	2

Table IV. Showing how much the myo-electric prosthesis was used functionally

	Work	Home	Out
Number of active hand movements per hour	29	12	9
Percentage of time worn but switched off	26%	35%	45%

Functional value. It is sometimes suggested that the electric hand is not truly functional, but rather a cosmetic device to help hide a grossly disfiguring deformity. An attempt was therefore made to estimate the number of grasping movements made with the hand per hour, and also the amount of time for which the hand was worn but switched off. These figures (Table IV) were derived simply from protracted conversations with the patients, and are therefore at best only approximations. A monitoring microcounter was not available at the start of this study; however, patterns gradually emerged as the review progressed, and it is thought that the quoted figures do have some significance. There was a clear gradient between the use of the electric hand at work and its use on social occasions: when used at work, the mean number of grasping movements was much greater and the time for which it was worn but switched off was less. It seemed clear, therefore, that the electric hand was put to a considerable degree of functional use when the patient was at work, but when he was in contact with the public the value of the arm tended to be more cosmetic and passive.

Sensory feedback. It is generally considered that the myo-electric prosthesis has a complete absence of

feedback, and that the patient relies entirely on vision (Herberts, Almström and Caine 1978). It is usually stated that the patient is worse off in this respect than with the standard artificial limb, where some measure of feedback is achieved by the tension and position of the harness (Hirsch and Klasson 1974). The patients were therefore questioned closely about this aspect, making sure that they understood clearly the nature of the question. Only 23 per cent agreed with the traditional concept, and 33 per cent were quite certain, indeed often emphatic, that the electric hand gave more feedback. This effect appeared usually to come from the closer fit of the socket, and the more natural controlling

Fig. 9

Histogram of lengths of stumps.

mechanism with the use of muscles in the stump itself. Vibration was sometimes mentioned. A surprising number of patients stated spontaneously that the electric hand felt more like a part of them than did a standard artificial limb.

Length of stump. These measurements are shown in Figure 9. Too long a stump seemed to be more of a problem than a very short one. One patient with some of the carpal bones remaining had to be fitted with such an

Fig. 10

Showing how short a stump could still be successfully fitted.

unsightly prosthesis, in order to allow room for the prosthetic components, that it became virtually rejected; when she was viewed from the front the artificial hand was much lower than her normal hand, and this difference was very noticeable. Even the shortest stumps, however, were compatible with good function, although in these cases the Münster socket required particularly skilful fitting. An example of a short but satisfactory stump is shown in Figure 10. By detailed measurements we found that the lack of a suspensory harness produced less difference than one might expect in terms of stability to applied load: for example, the ability to hold a weight when the elbow was at a right angle was the same. Similarly the loss of movement in the elbow was not significantly greater than that with the standard artificial limb.

Acceptability. There appears to be an innate drive to use the myo-electric prosthesis, with its combination of good appearance and function, together with the lack of a harness. This innate drive, however, is modified by various factors, some of which will tend to increase use and some to decrease it. If, therefore, we are to try to predict the use of the myo-electric prosthesis by a given patient, and prescribe accordingly, we must give these factors their due weight.

The most important factor is certainly that the patient has a suitable job, bearing in mind the limitations of the present device.

All patients with a standard artificial limb disliked the harness, and the greater the degree of their dislike the greater their drive to use the myo-electric prosthesis. By wearing such a prosthesis, the patient loses the discomfort of the harness, but sometimes this advantage is outweighed by problems with the stump, due to the necessarily closer fit of the myo-electric arm. This trouble, however, is unusual and it is surprising what apparently unsatisfactory stumps can in fact be successfully fitted. (See for example Figure 10.)

The cosmetic drive will be less if the patient has been a previous good user of a cable-operated hand, although such patients are rare.

The younger the patient at the time of the original

accident, the more he tended to use the myo-electric prosthesis, although this correlation was rather weak; however, there was no correlation with the interval between a patient's accident and his being given a myo-electric hand. Some patients adapted themselves very well to the latter after many years of using a standard artificial limb or even if they had not used any prosthesis at all for several years.

DISCUSSION

Many disciplines govern the relationship of this type of patient with his environment. It is suggested that electrical engineering has recently tended to outpace the other disciplines. There would be, for example, a great advantage in having a mechanically better type of hand capable of finer control of the fingers and with a much more durable covering, akin to normal skin. This would enable many more people to use their hands at work. Similarly, we should realise that this type of hand is neurophysiologically very primitive, and there would be a further great gain in terms of a more naturally functioning and life-like arm if more of the electromyographic information in the residual limb, at present wasted, could be used—as exemplified by some of the present work in Sweden on pattern recognition (Herberts *et al.* 1978). We feel that motor function rather than sensory feedback is the more fruitful line of research to take at present.

Philosophers may argue that we should train the patient to perform most tasks single handed and not fit unilateral amputees with an artificial limb at all. On the basis of this review, however, this negative view appears unjustified, and it is suggested furthermore that we should try to develop an all-purpose electric hand enabling this to be the patient's only artificial limb, dispensing finally with the standard limb. Such a programme would also be of especial benefit to those very handicapped people who have lost both their arms, and to children with congenital limb deficiencies who may otherwise form groups too small to gain all the attention and funding that they require.

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