

## **Functional benefit of an adaptive myoelectric prosthetic hand compared to a conventional myoelectric hand**

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### **Abstract**

Eight patients with a traumatic unilateral upper limb amputation, who used conventional myoelectric prostheses, were also fitted with a commercially available myoelectric prosthetic hand with an adaptive grip, in order to compare the functional benefit of the two types of prostheses.

Comparisons were made regarding width of grip, force of grip, scores in a standardised grip function test and prosthesis preference. The conventional prosthesis showed significantly better results regarding these parameters. The adaptive hand does not appear to be fully developed for practical use in prosthetic rehabilitation.

### **Introduction**

Myoelectric prostheses were developed about 1960 and have become useful in prosthetic rehabilitation (Schmidl, 1973). At the authors' centre, the conventional type of myoelectric prosthetic hand is used in below-elbow amputation. It is also used in above-elbow amputation if the length of the stump is sufficient for the use of a body-powered elbow. In these patients the functional results are often good enough to provide a reason for regular use of the prosthesis. In a few patients with a high above-elbow amputation some functional improvement has also been observed from a conventional myoelectric hand, in systems in which the more proximal functions of the prostheses seemed to be the limiting factors (Thyberg and Johansen, 1985; Johansen *et al.*, 1986).

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Until now the prosthetic hand has a non-adaptive grip and one trend in prosthetic research has been to construct a prosthetic hand with a grip more like the human hand (Kato, 1978). Different prototypes have been developed and for some years the adaptive myoelectric ES hand has been commercially available (Boenick and Becker, 1980; Roesler, 1982). The authors' aim was to study the usefulness of this prosthesis, compared to a conventional non-adaptive myoelectric prosthesis, in rehabilitation of patients with a traumatic unilateral upper limb amputation.

### **Material**

#### *Patients*

Eight consecutive patients attending the prosthetic clinic, who reported regular use of their conventional myoelectric prostheses, were offered a trial of the new prosthesis with an adaptive grip. All patients accepted. Patient data are given in Table 1. All were men with a unilateral traumatic upper limb amputation and no additional impairment.

Six patients were fully employed, 3 in practical work, 3 in mainly desk work, and 2 were studying.

All patients were trained to use myoelectric prostheses during their initial rehabilitation programmes, and they all reported a daily use which tallied with the observed need of frequent technical service.

#### *Prostheses*

Each patient was fitted with one myoelectric adaptive hand (ES Hand, Protesindustri AB) and one myoelectric prosthetic hand of conventional type (Otto Bock 8E38=7 3/4) at the same time and with identical sockets (Fig. 1). The prostheses were adjusted at delivery

Table 1. Patient Data

Patient No	1	2	3	4	5	6	7	8	Median
Age	41	38	27	63	58	27	31	58	39.5
Time since amputation (years)	4	2	3	46	39	2	29	20	12
Time since 1st myoelectric prosthesis (years)	2	2	2	5	17	2	9	20	3.5
Amputation level	AE	BE	BE	BE	BE	BE	BE	BE	
Amputation side	R	L	L	R	R	R	L	L	
Dominance before amputation	R	R	R	R	R	R	?	R	

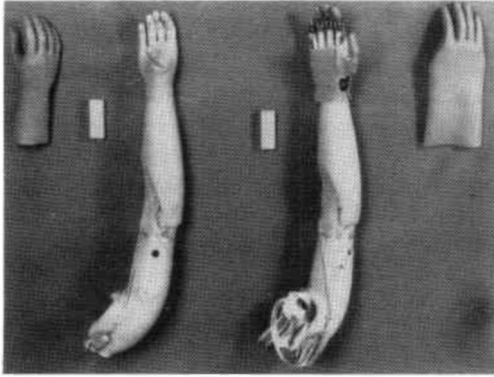


Fig. 1. Adaptive hand (left). Non-adaptive hand (right).

and the patients' ability to control the prostheses was checked.

The adaptive hand (Fig. 2) is produced in one size for adults. It has a motorised adaptive grip (Boenick and Becker, 1980) in which flexion in the second and third digit respectively is continued until further flexion in each finger is stopped by the object. This is achieved by wires arranged like tendons. The fourth and fifth digits are flexed by the same type of mechanism

but flexion is stopped automatically when flexion in the second and third digit is stopped. Thus, the grip is not adaptive with regard to all fingers independently. Flexion of the thumb is also motorised and is activated simultaneously with flexion of the fingers. In addition to the usual prosthetic tip pinch or power grip the position of the thumb can be altered to get a pinch grip against the lateral aspect of the second digit. The hand was delivered with a short technical instruction, cables, glove and batteries (Otto Bock type 757B8). Since no wrist unit was available from the manufacturer, an Otto Bock (10SI=50, 10S4, 10S7) wrist unit was added to the system.

#### Method

All patients were instructed to use the adaptive hand as much as possible, without regard to preference during the first two months after delivery. During the following ten months both types of prostheses could be used and the patients were tested concerning grip function and technical parameters. At follow-up after one year the patients were asked which type of prosthesis they preferred for further

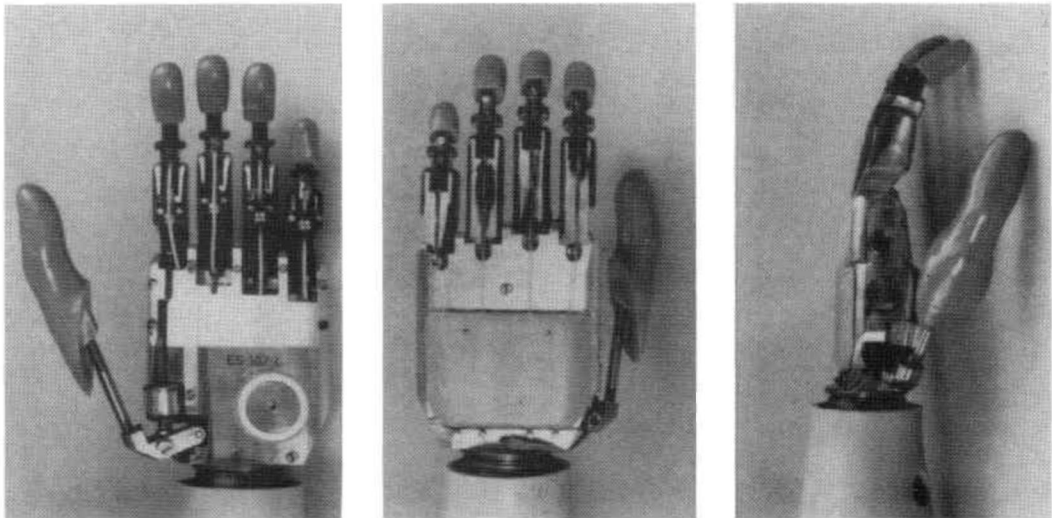


Fig. 2. Adaptive hand.

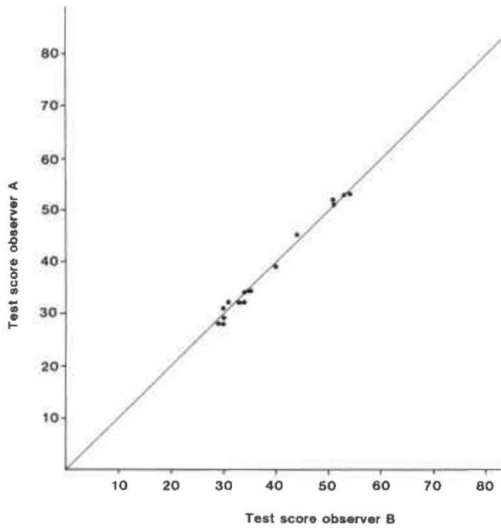


Fig. 3. Interobserver correlation in grip function test ( $r_s=0.97$ ,  $p<0.001$ )

use. In addition their opinion was sought regarding the cosmetic appearance of the prostheses.

The patients were tested with a standardised grip function test (Sollerman, 1980; Wilton, 1990). The test is based on previous studies by Sollerman and Sperling, where the grip pattern of the healthy hand is divided into seven main hand grips related to normal function of the human hand. The test consists of 20 different ADL tasks scoring from 0 to 4 points.

Each patient was assessed at three sessions with each type of prosthesis in an alternating order. The highest score obtained with the adaptive hand was compared to the highest score obtained with the non-adaptive conventional hand.

To assess the reliability of the test, 7 out of 8 patients participating in the main study and 9 additional patients, with unilateral upper limb amputations and fitted with myoelectric non-adaptive prostheses, were tested and scored by two independent observers.

Width of grip, force of grip, weight of hand and maximum circumference of the hand were tested according to previously published test instructions (Ingvarsson *et al.*, 1982).

Width of grip was measured by grasping prisms and cylinders with size intervals of 5 mm and with the hand placed horizontally. Maximum force of grip at 20%, 50% and 80% of maximum gripping width was measured by means of a strain gauged device (AB Detektor, Gothenburg). The mean values of five consecutive tests were compared.

Correlations were described by Spearman's rank correlation coefficient ( $r_s$ ) and differences were tested with Wilcoxon's signed rank test.

## Results

### The grip function test

When scores by two independent observers

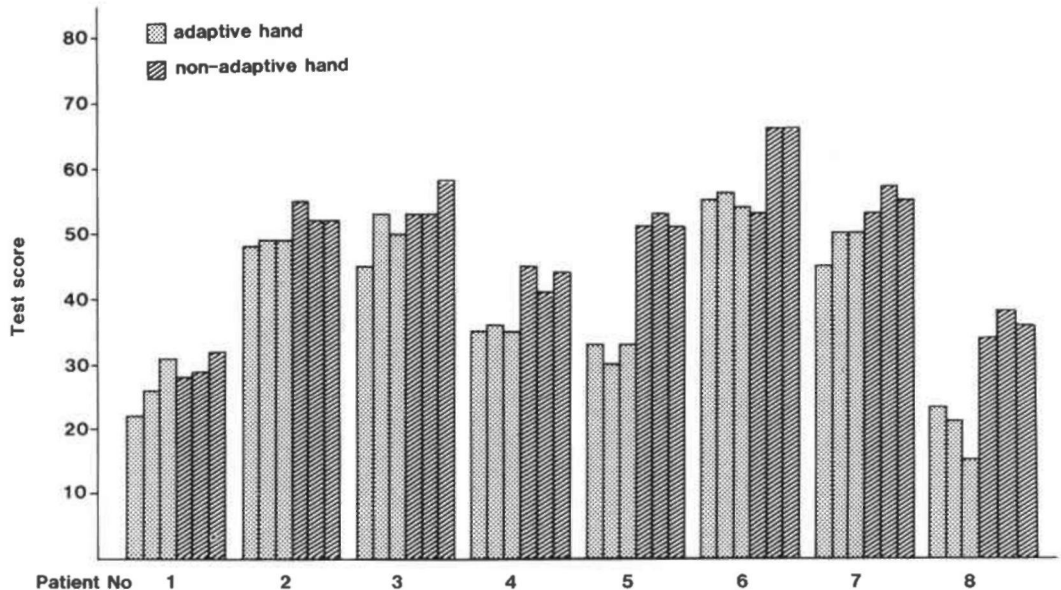


Fig. 4. Comparison of scores of grip function obtained at three test sessions with each type of prosthesis.

Table 2. Mean and range of maximum force of grip at 20%, 50% and 80% of maximum width of grip.

	Width of grip (% of max)	20	50	80
	Adaptive hand Non-adaptive hand	24 (15-43) 105 (90-138)	28 (17-44) 116 (97-151)	30 (17-45) 129 (102-176)

of the grip function test were compared a good correlation was found ( $r_s=0.97$  and  $p<0.001$ ) (Fig. 3).

#### *Adaptive versus non-adaptive hand*

The scores for each type of prosthesis in the grip function test are presented in Figure 4.

In each type of prosthesis the lowest score was usually gained at the first test. The second test tended to give a higher score and the third test tended to give the same score as the second or lower.

The best scores of the non-adaptive conventional hand were significantly better than the best scores of the adaptive hand, ( $p<0.01$ ).

#### *Technical test*

Width of grip and force of grip were significantly greater for the non-adaptive conventional hand (Tables 2 and 3).

The maximum circumference (closed hand) was 270 mm for the adaptive hand and 260 mm for the non-adaptive conventional hand.

The adaptive hand weighed 595g and the non-adaptive conventional hand weighed 505g.

#### *Prosthetic preference*

Both types of prosthesis were available for practical use and after one year the patients were asked which hand they preferred for further use. All patients preferred the non-adaptive conventional hand. The cosmetic appearance of the adaptive hand was considered not to be satisfactory by seven patients. One patient thought the cosmetic appearance of the adaptive hand was good.

#### **Discussion**

The consequences of upper limb amputation may be described in terms of impairment, i.e. level of amputation or loss of hand function. It

may also be described in terms of disability, i.e. loss of ability to perform certain activities. A third alternative is to describe the consequences in terms of handicap, i.e. the disadvantage in relation to a specific environment or social role of a patient (WHO, 1980).

The aim of rehabilitation is to reduce the consequences of amputation and the effect of rehabilitation may be evaluated in relation to the above-mentioned aspects.

One important aim in prosthetic rehabilitation is to restore a degree of grip function, and if the improvement is relevant in the perspective of disability and handicap a prosthesis may be accepted by the patient. The acceptance of a prosthesis may be regarded as an indication of the benefit for the individual patient, but additional assessment of grip function and the ability to perform relevant, standardised activities may be helpful in the analysis of the more general benefit of the prosthesis. Most standardised indices of activities of daily living (Barer, 1989) relate to activities which are not relevant in unilateral amputation of the upper limb. To describe the disability of these patients, more sensitive and specific tests are required (Stein and Walley, 1983). The test of grip function described by Sollerman (Sollerman, 1980) is a standardised test which is representative for activities of daily living both with regard to the dominant hand and the non-dominant hand.

In patients with different impairments of hand function, Sollerman found a good correlation when the test results of two independent observers were compared (Sollerman, 1980), and this tallies with the results of the present study. Sollerman found a good correlation between the results of two consecutive testing procedures. In this study there was some intra-individual variation in three consecutive tests (Fig. 4) and in 11 of 16 cases the score in the second test was higher than in the first test. With regard to the observed intra-individual variation the best scores for each type of prosthesis, in each patient, were used for comparison.

Table 3. Width of grip (mm) Mean and Range

Type of object	Cylinder	Prism
Adaptive hand	64 (55-75)	59 (40-70)
Non-adaptive hand	94 (80-100)	90 (70-100)

The difference between the two types of prostheses, in the Sollerman test, was statistically significant. Whether this difference is clinically significant cannot be concluded from this study but it seems to be a relevant contributing factor regarding the preference of prosthesis.

The acceptance or rejection of a prosthesis (Childress, 1973) depends on the balance between the benefit and the trouble associated with the use of the prosthesis (Roeschlein and Domholt, 1989). The benefit may depend on the improvement of grip function or ability to perform manual activities and on cosmetic aspects, and in each case this benefit will depend on the environment and the social role of the patient. In general the grip function of a prosthesis is influenced by the technical properties of the prosthesis, the socket fabrication, and the training programme. The observed differences in width and force of grip were statistically significant. Although it is still debatable which technical parameters are clinically significant, the results in this project from the technical test also tallied with the patients' choice of prosthesis. In order to focus on grip function, identical sockets were used for the two types of prostheses. All patients were trained to use a conventional myoelectric prosthesis during their initial rehabilitation programme and their ability to control the adaptive prosthesis was checked at delivery. In order to minimize influence from different individual needs and social roles, each patient was used as his own control when the results were compared.

The usefulness of a prosthetic system, in rehabilitation, will also depend on whether technical service from the manufacturer is available or not. Regarding prototypes and small series, lack of service may limit the clinical usefulness of a prosthesis, despite good results concerning the discussed parameters.

Beside grip function, the subjective benefit of a prosthesis may depend on cosmetic factors. Regarding this aspect most of the patients also preferred the conventional prosthesis. A quantitative comparison of grip function and cosmetic aspects is difficult.

In conclusion, the particular type of adaptive hand that was studied did not appear to increase the functional benefit compared to a conventional myoelectric prosthesis. Thus, it

could not be verified that an adaptive prosthetic hand would be the best technical solution. If a prosthetic system is to be clinically useful, it must provide good grip function and still be simple and reliable enough to use without the facilities of a development laboratory. In order to achieve this balance, a close contact between technical development and clinical rehabilitation may be one of the most important factors.

#### Directory of suppliers

ES Hand (Een and Holmgren Systemteknik Hand), Protesindustri AB, Box, 67 S-751 03 Uppsala, Sweden

Otto Bock Scandinavia AB, Box 623, S-601 14 Norrköping, Sweden

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