

Prosthetic use in adult upper limb amputees: a comparison of the body powered and electrically powered prostheses

S. G. MILLSTEIN, H. HEGER and G. A. HUNTER *

Amputee Clinic, Ontario Workers' Compensation Board

Abstract

Three hundred and fourteen adult upper limb amputees were reviewed retrospectively at the Ontario Workers' Compensation Board. A questionnaire was used to evaluate the use of body and electrically powered prostheses. Follow-up ranged from 1 to 49 years with a mean of 15 years. Results indicated that complete or useful acceptance of an electrically powered prosthesis was reported by 69 of 83 amputees (83%); 199 of 291 amputees (68%) used the cable operated hook, 57 of 291 (20%) used the cable operated hand and 40 of 83 (48%) used the cosmetic prosthesis. The majority of amputees used more than one prosthesis for their functional needs and should be fitted with more than one type of prosthesis. Acceptance of an upper limb prosthesis by 89% (196/220) of below-elbow, 76% (56/74) of above-elbow and 60% (12/20) of high level amputees indicates that for most upper limb amputees, their prostheses are well used and essential to their personal and employment activities.

Introduction

The Amputee Clinic at the Workers' Compensation Board, Downsview Rehabilitation Centre provides Ontario workers who have sustained an amputation in a work related accident with medical, prosthetic, psychosocial and vocational services. The multidisciplinary treatment team consists of a physician co-ordinator, nurse, prosthetist, physiotherapist, occupational therapist, remedial gymnast, social worker, research associate, vocational rehabilitation counsellor, secretary and medical director of the Clinic, who is an orthopaedic surgeon.

All correspondence to be addressed to Ms. S. G. Millstein, Research Physiotherapist, Amputee Clinic, Ontario Workers' Compensation Board, Downsview Rehabilitation Centre, 115 Torbarrie Road, Downsview, Ontario, M3L 1G8, Canada.

The impact on a person due to the sudden loss of a hand or arm cannot be overstated. Prosthetic fitting and training is crucial to successful rehabilitation and reintegration of the amputee into society.

The loss of fine, co-ordinated movements of the hand, tactile sensation, proprioceptive feedback, and aesthetic appearance can only be compensated for to a limited extent by the three types of prostheses that are at present available. These are a body powered and cable operated prosthesis with a split hook or hand as a terminal device; an electrically powered prosthesis controlled by muscle sensors (myoelectric) or by microswitches; and a cosmetic replacement with a passive hand.

The standard practice at this Amputee Clinic is initially to fit and train each below and above-elbow amputee with a cable operated prosthesis supplied with one or more hooks and a hand. Following the evaluation of a request for a myoelectric or cosmetic prosthesis, these prostheses may also be provided. Shoulder disarticulation and forequarter amputees are fitted from the onset of prosthetic training with electrically powered prostheses. The supply of more than one prosthesis has evolved from the recognition that different kinds of prostheses are frequently used in combination by the amputee to meet a variety of functional needs.

Although several research projects, including those at the Downsview Rehabilitation Centre have been undertaken to assess the value of the electrically powered prosthesis, (Herberts et al, 1980; Northmore-Ball et al, 1980; Millstein et al, 1982; Heger et al, 1985), there are very few detailed reports on the acceptance and use of the body powered prosthesis. (Fletcher, 1970; Vitali et al, 1978; Stein and Walley, 1983; van Lunteren et al, 1983; Chan et al, 1984).

* Sunnybrook Medical Centre, Toronto, Ontario.

The purpose of this present review was to assess the use of the various types of body powered and electrically powered prostheses for different levels of upper extremity amputations in adults in order to determine their function and acceptance. Advantages and disadvantages of each prosthesis were examined to determine the factors that influence the amputee's choice of an upper extremity prosthesis over a long period of time.

Patients and methods

The population surveyed included 314 patients, who had sustained a single upper limb amputation in a work related accident and had been treated by the Workers' Compensation Board Amputee Clinic. There were 45 wrist disarticulations, 175 below-elbow amputations, 3 elbow disarticulations, 71 above-elbow amputations, 15 shoulder disarticulations and 5 forequarter amputations.

The amputee's age at amputation ranged from 14 to 68 years with a mean of 34 years. The average age of the patients at review was 49 years, the oldest being 82 and the youngest 15. There were 302 men and 12 women. The period between accident and follow-up ranged from 1 to 49 years with a mean of 15 years. The dominant side was amputated in 54 per cent of the population. Nine per cent had a revision of their amputation, of these 48% were revised to a higher level and 52% at the same level.

Evaluation included the completion of a standard questionnaire and a review of patients' records. The questionnaire examined the use of the various types of prostheses in activities of daily living, work and recreation. The questions were concerned with the amount of time a prosthesis was actually worn, its use and reliability and the problems the amputee encountered. For those amputees who possessed more than one type of prosthesis, a comparison was made in regard to the time the prostheses were worn and the activities for which they were used. The results of the questionnaire were coded and analyzed using the Statistical Analysis System.

Results

Ninety-six per cent of the amputees reported having a prosthesis at the time of review. Eighty-five per cent had a cable operated prosthesis with hook(s), 55% a cable operated

hand, 10% a cosmetic prosthesis and 25% an electrically powered prosthesis.

At the below-elbow level, 95% (209/220) of the amputees had originally been fitted with a cable operated hook and 69% (145/209) of those amputees fitted were using this prosthesis. At the above-elbow level, 89% (66/74) had been fitted and 73% (48/66) were using it, and at the higher levels, 80% (16/20) had been fitted and 38% (6/16) were using it.

Although the same number of amputees at each level had been fitted with a cable operated hand, there were considerably fewer amputees making use of this prosthesis. Only 21% (44/209) at the below-elbow level, 18% (12/66) at the above-elbow level and 6% (1/16) at the higher levels reported using the cable operated hand.

Considerably fewer amputees had been fitted with a cosmetic prosthesis, but some had converted their cable operated hand into a cosmetic prosthesis with a nonactive hand by disconnecting the cable.

With respect to the cosmetic prosthesis, at the below-elbow level 26% (58/220) had been fitted and 59% (34/58) were using it, at the above-elbow level 27% (20/74) had been fitted and 20% (4/20) were using it and at the higher levels 25% (5/20) had been fitted and 40% (2/5) were using it.

One third (72/220) of below-elbow amputees had been fitted with an electrically powered prosthesis and 82% (59/72) of those fitted reported using it, 9% (7/74) of above-elbow amputees had been fitted and 86% (6/7) were using it and 20% (4/20) of high level amputees were fitted and all (4/4) were using it.

The number of hours of use on an average work day and weekend day indicated that these prostheses were well used. The cable operated hook was used for an average of 8 hours each work day and 7 hours on a weekend day. The electrically powered prosthesis was worn for an average of 8 hours each day throughout the week. The cable operated hand was used for an average of 5 hours each day and the passive cosmetic hand was worn an average of 4 hours each day.

The number of amputees using the various types of prostheses for an average of less than 4 hours per day, 4-8 hours per day and more than 8 hours per day is shown in Figure 1. There is very little difference in usage by time between the cable operated hook and electrically

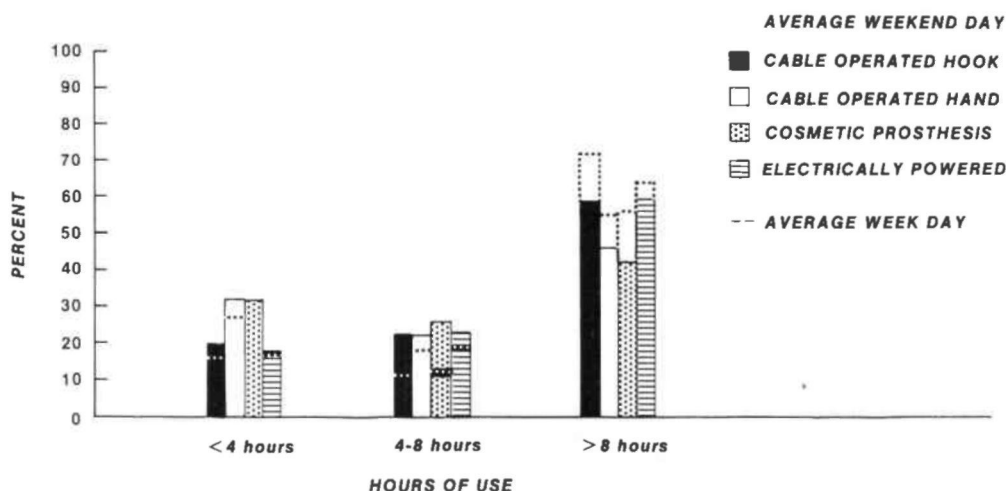


Fig. 1. Prosthetic use on average week day and weekend day.

powered prosthesis or between the cable operated hand and cosmetic prosthesis. During the week, (as indicated by the broken black line), the cable operated hook and electrically powered prosthesis were used the most often for over 8 hours and the cable operated hand and cosmetic prosthesis were used for the least number of hours.

For the cable operated hook as many as 73% of amputees reported they used it more than 8 hours on an average work day (Fig 1.). For the electrically powered prosthesis, 64% used it more than 8 hours during the week, 55% for the cable operated hand and 56% for the cosmetic hand. On the weekend, there was a change in the pattern of use of all types of prosthesis. More amputees were using their prostheses for shorter periods of time (less than 8 hours) rather than for longer periods of time (more than 8 hours) as

was the case during the week. On the weekend 58% of amputees reported using the cable operated hook more than 8 hours, 59% of amputees used their electrically powered prosthesis, 46% used the cable operated hand and 42% used the cosmetic prosthesis.

Those upper limb amputees who reported rarely or never using their prosthesis, identified pain with limited function as the principal reasons. Other reasons included harness and stump problems. The percentage of nonusers was 11% (25/220) at the below-elbow level, 24% (18/74) at the above-elbow level and 40% (8/20) at higher levels (Table 1).

Prosthetic activities of use

Amputees were asked to indicate for what activities they used a prosthesis and which type of prosthesis they used for that particular

Table 1. Prosthetic use of body powered and electrically powered prostheses.

	Below-elbow		Above-elbow		High level		Total	
	Number	%	Number	%	Number	%	Number	%
Cable-operated hook exclusively	70	32	28	38	4	20	102	32
Cable-operated hand exclusively	14	6	2	3	1	5	16	5
Cosmetic prosthesis exclusively	13	6	4	5	1	5	18	6
Electrically-powered exclusively	22	10	2	3	3	15	27	9
Combination of prosthesis	76	35	20	27	3	15	100	32
No prosthesis	25	11	18	24	8	40	51	16
Total	220	100	74	100	20	100	314	100

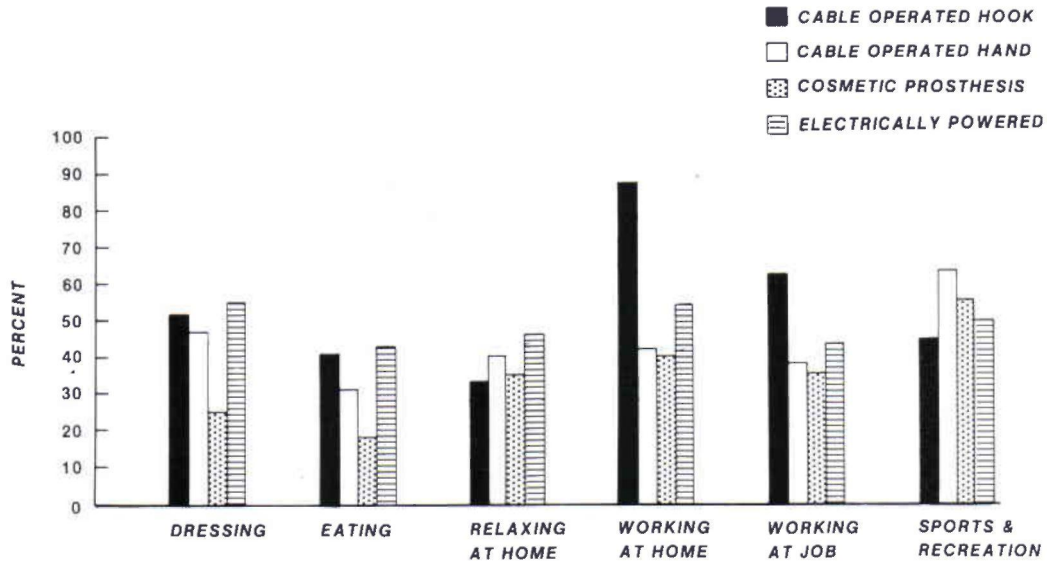


Fig. 2. Prosthetic use-functional activities.

activity. Figure 2 reflects a wide range of responses indicating a very varied preference by amputees.

At work

Sixty-six per cent of upper limb amputees reported using their prostheses at work. The choice of using a cable operated hook/hand, cosmetic prosthesis or electrically powered prosthesis depended on the requirements of the amputee. Amputees who used the electrically powered prostheses primarily had jobs that involved office work, supervisory work or contact with the general public. They were able to utilize the electrically powered prosthesis in their work tasks because of their light activities in a relatively clean environment. Those amputees who used a cable operated prosthesis had jobs that required heavy lifting or their work environment was unsuitable. It was generally dirty, materials to be handled were greasy or sharp and the danger of damaging the glove or prosthesis was high. For these jobs, the cable operated hook was more suitable because of its ruggedness and durability.

Exposure to extremes of weather can be a problem with the electrically powered prosthesis. Very cold weather will interfere with the function of the battery, and outdoor work in winter time can be uncomfortable because the stump may become very cold. Hot humid

weather conditions or working strenuously can cause excessive sweating, leading to the loss of myoelectric control.

Activities of daily living

The extent to which body powered or electrically powered prostheses were used for activities of daily living was quite diverse. Below and above-elbow amputees found both types useful for eating, personal care and dressing. However, most high level amputees found their prosthesis less useful and used it only occasionally for activities of daily living.

Recreational use

Both body powered and electrically powered prostheses were used for a variety of sports and recreational activities. The most popular activities for which prostheses were beneficial included golf, fishing, gardening and minor home and car repairs.

Some amputees played baseball, broomball, or pool, while some were active in camping, canoeing, hunting and curling or hockey. The cable operated hook was preferred for heavier and more vigorous activities and some used the cable operated hand for specific sports.

Social use

The amputees liked the cosmetics of the electrically powered prosthesis and wore it for

many social events. It was found to be considerably more acceptable in the social sphere than the cable operated hook. It was quite often not noticed or if noticed, it elicited amazement, interest and more positive comments than the hook. The electrically powered prosthesis was used most often for eating, holding objects and occasionally driving a car. High level amputees tended not to make active use of it often in a social setting as they felt the use would lead to greater attention directed toward them. However, they appreciated the availability of function when they desired it, combined with increased comfort. A few amputees did not mind wearing their cable operated hook in a social setting. However, many preferred using the cable operated hand and cosmetic prosthesis rather than the hook if they did not possess an electrically powered prosthesis.

In an attempt to ascertain which prosthesis satisfied our amputees' needs the most, calculations were made to determine how many amputees used one prosthesis exclusively and how many used a combination of two or more prostheses (Table 1). Approximately 1/3 (102/314) of amputees used the cable operated hook exclusively and approximately 1/3 (100/314) used a combination of more than one prosthesis.

Although only 9% (27/314) of amputees used the electrically powered prosthesis exclusively, the majority of amputees have been fitted with cable operated hook/hands whereas considerably fewer have been fitted with

electrically powered prostheses. Amputees predominantly used the cable operated hook and electrically powered prosthesis in combination relative to their functional requirements. Only 5% (16/314) and 6% (18/314) respectively of amputees used the cable operated hand and cosmetic prosthesis exclusively.

Acceptance

For any prosthesis to be accepted and used by the amputee, it must be comfortable, functional and have a pleasing appearance. Other contributing factors that influence acceptance, are the quality of the stump, the level of the amputation, manual dexterity and motivation of the amputee.

Complete or useful acceptance of an upper limb prosthesis was reported in 89% (196/220) of below-elbow amputees, 76% (56/74) of above-elbow amputees and 60% (12/20) of high level amputees. The majority of amputees used more than one prosthesis for their functional needs at work, home, recreation and social events.

Amputees indicated that the most preferred prosthesis was the electrically powered prosthesis. The cable operated hook was the second most favoured followed by the cosmetic and cable operated hand.

Figure 3 illustrates the acceptance and use of the four types of prostheses. Since the majority of amputees have more than one prosthesis, there were multiple responses to this question.

For the cable operated hook the acceptance

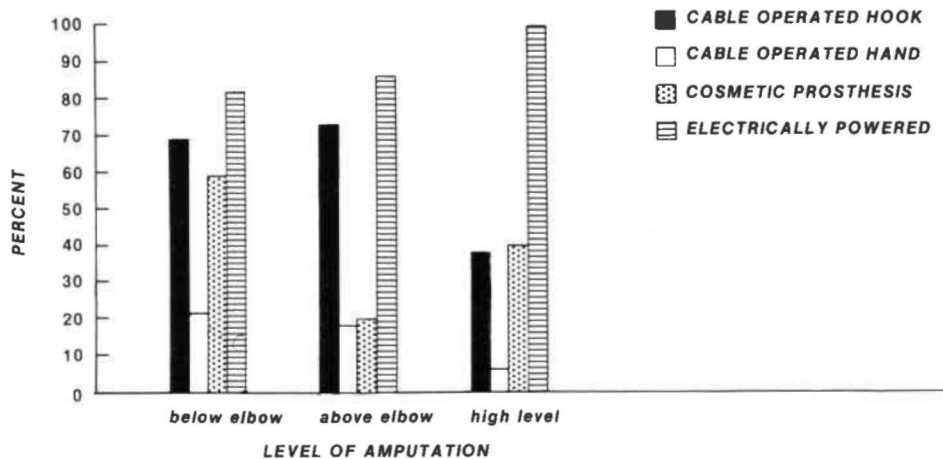


Fig. 3. Acceptance of body powered and electrically powered prostheses.

rate was 69% (145/209) at the below-elbow level, 73% (47/64) at the above-elbow level and 38% (6/16) at higher levels. The low acceptance rate by high level amputees is due to the high energy expenditure necessary to achieve limited function with a cable operated prosthesis. A wide range of acceptance rates for body powered prostheses exists in the literature from 34% (73/213) at the below-elbow level and 28% (29/103) at the above-elbow level by Vitali et al, (1978) to 90% (18/20) by Chan (1984).

The cable operated hook is especially advantageous for hobbies and jobs which require manual skills because of the following properties: it provides good sight of the grasped object; it is not easily damaged; it is designed for rugged conditions; it is easy to clean. An obvious disadvantage of the cable operated hook is the lack of cosmetic appeal. It is also difficult to stabilize some objects with the split hook, due to its shape and sometimes insufficient gripping force. To overcome some of these shortcomings, amputees may interchange their split hook with other hooks or terminal devices that have been designed for use in specific tasks or hobbies.

The cable operated hand has a very low acceptance rate at 21% (44/209), 18% (12/66) and 6% (1/16) for the various levels. Amputees have found the hand difficult to operate, awkward, and heavy. It is not durable and has a weak grip. This prosthesis is occasionally used for specific sports or work activities or as a nonactive prosthesis for cosmesis.

The acceptance of the cosmetic passive prosthesis covers a wide range from 59% (34/58) for below-elbow amputees to 20% (4/20) for above-elbow and 40% (2/5) for high levels. Amputees reported using this prosthesis primarily for social events. It is gradually being discarded in favour of the electrically powered prosthesis which offers cosmesis combined with function.

The high acceptance rate of 82% (59/72) at the below-elbow level, 86% (6/7) at the above-elbow level and 100% (4/4) for high level amputations for the electrically powered prosthesis is very positive (Fig 3), and it appears that amputees strongly favour this prosthesis, especially high level amputees. However, as yet, at this Centre only 33% of below-elbow amputees, 9% of above-elbow amputees and 20% of high level amputees have been fitted with the electrically powered prosthesis. A review at

this Centre that followed up all 164 amputees fitted with electrically powered prostheses, resulted in an 80% (104/130) acceptance rate at the below-elbow level, 69% (11/16) at the above-elbow level and 72% (13/18) at the high level. (Heger et al, 1985). A Chi² test was done and the difference between acceptance rates for the three levels of amputation between the two studies was not statistically significant. Our acceptance rate at the below-elbow level compares favourably with the acceptance rates reported by Herberts (1980) and Stein and Walley (1983), who reported 37% (14/38) and 60% (14/23) at the below-elbow level respectively.

The advantages of electrically powered prostheses are:

1. Increased comfort because of lack of harness suspension for below-elbow amputees and simpler harnesses for higher level amputees.
2. Cosmetic acceptance by amputees and the general population. Although for some amputees, the lack of a large-sized prosthetic hand in comparison to the amputee's hand (largest available size is 8) may lead to unsatisfactory cosmetic appeal.
3. Superior pinch force (15 to 25lbs.) compared with the cable operated hook (7 to 8lbs.).
4. Control of the myoelectric prosthesis is more natural and less strenuous; movements of the hand and elbow units are independent of the position of the body.
5. For high level amputees, whose physical impairment is severe, the electrically powered prosthesis is a viable alternative to the cable operated prosthesis, because it provides a greater range of function and requires less energy expenditure.
6. Some sensory feedback has been reported by some amputees between the stump and prosthesis, the vibration of the motor and controlling muscle contraction.
7. Short below-elbow stumps can be provided with good function through skillful fitting of the Muenster socket.

The disadvantages of electrically powered prostheses at the present time are:

1. High cost factors in initial fitting (approximately twice as expensive as cable operated) and ongoing repairs (average of two repairs per year for our amputees).

2. Myoelectric service must be carried out in a specialized Centre.
3. The electrically powered prosthesis is not as durable as the cable operated prosthesis because it has not been designed for heavy work in regard to its suspension, wrist connection, handframe and glove. Many amputees were reluctant to use the electrically powered prosthesis for some specific activities for fear of damaging the glove or its components. The current electric elbows have been criticized because they are too noisy, have limited strength, and move too slowly for functional purposes.
4. The shape of the hand makes some precise tasks more difficult.
5. The prosthesis requires more maintenance, eg. recharging the battery regularly and cleaning the glove.
6. The suspension of the Muenster socket and resultant weight distribution may cause discomfort and magnify the apparent weight of the prosthesis for some amputees.

The acceptance of prosthetic devices by upper limb amputees is a very complex process in which several important factors interact. Prosthetic fit and reliability are of special importance, but psychological and socioeconomic factors play important roles. Another review at this Centre on employment patterns of industrial amputees included the 314 upper limb amputees in this study. It was found that 88% of these upper limb amputees were employed at the time of review (Millstein et al, 1985). Prosthetic use by upper limb amputees was positively associated with return to work. Our experience shows that good acceptance figures for body powered and electrically powered prostheses can be obtained if prosthetic fitting and training is combined with the services of a multidisciplinary team. Patients must be followed up regularly and prosthetic fitting changed according to the changing needs of patients.

Conclusions

The findings of this review of 314 upper limb amputees confirm that complete or useful acceptance of an upper limb prosthesis was reported in 89% of below-elbow amputees, 76% of above-elbow amputees and 60% of high level amputees. Prostheses are well used and essential

to the amputees' personal and employment activities. Most upper limb amputees should be fitted with both a body powered and electrically powered prosthesis to meet their various functional requirements. The benefits of these prostheses far outweigh their costs.

The cable operated hook is well accepted and used by the majority of amputees for heavy work and precision tasks at work and at home. It provides good sight of the grasped object, is not easily damaged and is easy to clean. The cable operated hand and cosmetic prosthesis are used by a small number of amputees primarily for cosmesis at social occasions. In spite of the high initial cost and continued maintenance and repair, improvement in comfort, cosmesis and function have led to good levels of acceptance of the electrically powered prosthesis. For high level amputees, it provides better function, superior pinch force and requires less energy expenditure than the body powered prosthesis.

The multidisciplinary team approach, at the Amputee Clinic, patient follow-up and service have contributed to the very positive results of this review. These findings, combined with daily interaction with patients at the Amputee Clinic, suggest that upper limb amputees have the motivation and the ability to overcome the loss of a hand.

Acknowledgements

It is a pleasure to thank and acknowledge the skill of the prosthetists Mr. William Burt of the Ontario Workers' Compensation Board and Mr. William Sauter of the Ontario Crippled Children's Centre, who have fitted and serviced these prostheses.

The authors would further like to thank Mr. George Suranyi M. Sc. of the Policy Planning Secretariat at the Ontario Workers' Compensation Board for his assistance.

The financial support of the Ontario Workers' Compensation Board which has allowed review of these patients is much appreciated. Dr. R. I. Mitchell, the Executive Director of Medical Services warrants special recognition for his support of the Amputee research.

REFERENCES

- CHAN, K. M., LEE, S. Y., LEUNG, K. K., LEUNG, P. C. (1983). A medical-social study of upper limb amputees in Hong Kong — a preliminary report. *Orthot. Prosthet.* **37**(4), 43-48.

- LONDON, P. S., (1970). Upper limb amputations. *Br. J. Hosp. Med.* **4**, 590-595.
- HEGER, H., MILLSTEIN, S., HUNTER, G. A. (1985). Electrically powered prostheses for the adult with an upper limb amputation, *J. Bone Joint Surg.* **67B**, 278-281.
- HERBERTS, P., KORNER, L., CAINE, K., WENSBY, L. (1980). Rehabilitation of unilateral below-elbow amputees with myoelectric prostheses. *Scand. J. Rehabil. Med.* **12**, 123-128.
- MILLSTEIN, S., BAIN, D., HUNTER, G. A. (1985). A review of employment patterns of industrial amputees: factors influencing rehabilitation. *Prosthet. Orthot. Int.* **9**, 69-78.
- MILLSTEIN, S., HEGER, H., HUNTER, G. A. (1982). A review of the failures in use of the below-elbow myoelectric prosthesis. *Orthot. Prosthet.* **36(2)**, 29-34.
- NORTHMORE-BALL, M. D., HEGER, H., HUNTER, G. A. (1980). The below-elbow myoelectric prosthesis: a comparison of the Otto Bock myoelectric prosthesis with the hook and functional hand. *J. Bone Joint Surg.* **62B**, 363-367.
- STEIN, R. B., WALLEY, M. (1983). Functional comparison of upper extremity amputees using myoelectric and conventional prostheses. *Arch. Phys. Med. Rehabil.* **64**, 243-248.
- VAN LUNTEREN, A., VAN LUNTEREN-GERRITSEN, G. H. M., STASSEN, H. G., ZUITHOFF, M. J. (1983). A field evaluation of arm prostheses for unilateral amputees. *Prosthet. Orthot. Int.* **7**, 141-151.
- VITALI, M., ROBINSON, K. P., ANDREWS, B. G., HARRIS, E. E. (1978). *Amputations and prostheses*. London: Bailliere Tindall, 10.