Prosthetics and Orthotics International, 1993, 17, 126–129

Clinical note

Lightweight prostheses for bilateral below-elbow amputees

S. N. ROUT

Dept. of Bio-Engineering, National Institute of Rehabilitation Training and Research (NIRTAR), Orissa, India

Abstract

In view of the anticipated activity of the patient and working environment, lightweight prostheses were designed for an adult female, bilateral below-elbow (BE) amputee at NIRTAR to provide the greatest degree of function. The prostheses were fabricated using lightweight materials and new techniques. Depending on the stump length there were two different types of lightweight prostheses designed and successfully used, (1) an endoskeletal BE prosthesis and (2) an exoskeletal BE prosthesis. After periodic follow-up and evaluation the function of the prostheses was found to be most satisfactory. By reducing the weight considerably compared to other available alternatives, it is more likely that the amputee will make use of the prostheses to efficiently perform various activities. The new prosthesis designs may counteract the high rejection rate of old conventional ones and the principle may be applied to the fabrication of all BE prostheses.

Introduction

Bilateral BE amputees are fully dependent upon prostheses to perform most of their activities in contrast to unilateral amputees. Therefore proper prosthetic fitting and suitable prosthetic components are necessary to optimise their performance in various activities. The design must anticipate the activity of the patient and the working environment to provide the greatest function. Reducing the weight of the prosthesis will encourage the patient to perform most activities and also facilitate execution with less expenditure of energy. Taking the above points into consideration new types of lightweight prostheses were designed at NIRTAR for a bilateral BE amputee in an attempt to provide maximum function.

All correspondence to be addressed to S. N. Rout, Lecturer in Prosthetics Dept. of Bio-Engineering, NIRTAR, Bairoi-754010, Cuttack (Orissa), India.

Methods

Subjects

The patient was an adult female bilateral BE amputee who presented at NIRTAR for fitting of prostheses. On the right side she had a very short BE stump of about 6.35 cm (2.5 ins) length and on the left side a long BE stump of about 16.5 cm (6.5 ins) length. Previously she had been provided with bilateral BE prostheses at other limb fitting centres using traditional exoskeletal construction. She had discarded these due to the heavy weight and high energy expenditure incurred in prosthetic operation. The same patient was successfully fitted with the lightweight prostheses developed at NIRTAR.

Fabrication techniques

The prostheses are fabricated using new techniques and lightweight materials.

Right side

The right very short BE prosthesis was designed based on a modular principle to reduce weight.

Socket design: The prosthesis consists of a socket made from polypropylene which encases the stump and a length of aluminium tube joined to the distal end of the socket, representing the forearm section. The distal end of the socket is shaped into a flat surface. The threaded metal insert from a wrist friction nylon (ALIMCO make) is connected at the distal end of the socket by means of three screws. The nylon lined threaded metal insert permits attachment of the aluminium tube (forearm section) to the socket as shown in Figure 1.

Forearm section: Aluminium tube of the desired length (dia 14mm) connects the socket and the mechanical hand. The terminal device (mechanical hand) attachment is direct to the threaded end of the aluminium tube, eliminating the use of a wrist unit and so reducing weight. A small section of M 12 x1.75 threaded stud is used at the proximal end of the aluminium tube to attach it to the distal end of the socket as shown in Figure 1.

Control cable arrangement: To improve cosmetic appearance and maintain a proper cable path for the smooth operation of the terminal device the control cable system is placed close to the aluminium tube. The cable pull of the mechanical hand is altered and brought out at its proximal attachment face which remains inside the cosmetic foam cover and is not visible either on the palmar or the dorsal aspect at the level of the wrist unit. Aligning the cable in this way prevents slipping of the cable from the pulley inside the mechanical hand. A single piece of housing is provided in the control cable system connected to the mechanical hand at the distal end and with the housing crossbar assembly at the proximal end. To maintain the proper cable path a suitable housing anchor point is attached to the aluminium tube and the socket (Fig. 1).

Cosmetic covering: The modular BE prosthesis is finally covered with a soft foam cover. Then two more layers of coloured nylon socks are applied to cover the entire prosthesis. This not only improves the cosmetic appearance but also provides a feel like natural soft tissue. Finally a cosmetic glove is applied over the mechanical hand. This also covers some parts of the forearm section and provides a good, aesthetic appearance.

Left side

The left side long BE prosthesis is designed based on the double wall exoskeletal principle, but the socket and the forearm shell are made separately using polypropylene and joined together by riveting.

Socket design: The long polypropylene socket not only facilitates snug fitting of the stump for the effective transmission of residual mobility but also permits flexibility at the brim for comfort. The socket is prepared by drape moulding using 6 mm thick polypropylene sheet. After the socket is prepared it is suitably trimmed to allow comfortable mobility (Fig. 2).

Preparation of forearm shell: To match the right side forearm plaster of Paris is built up at the end of the socket. The end of the build-up is

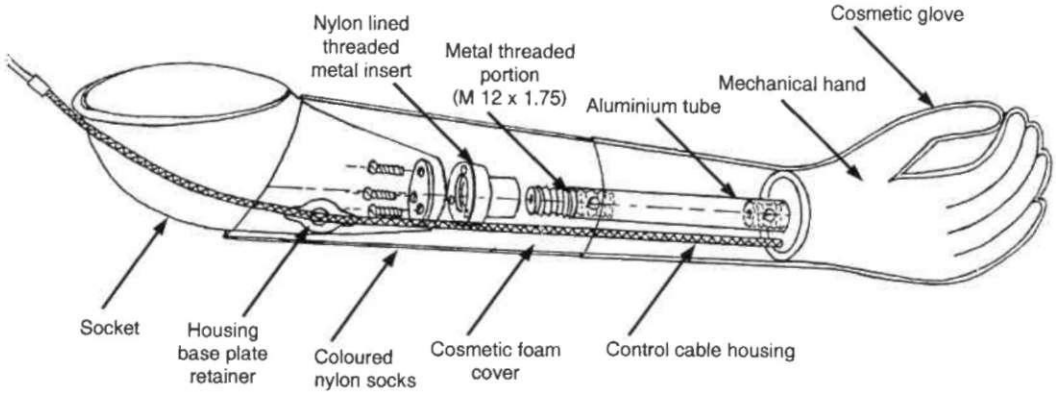

Fig. 1. Right below – elbow prosthesis

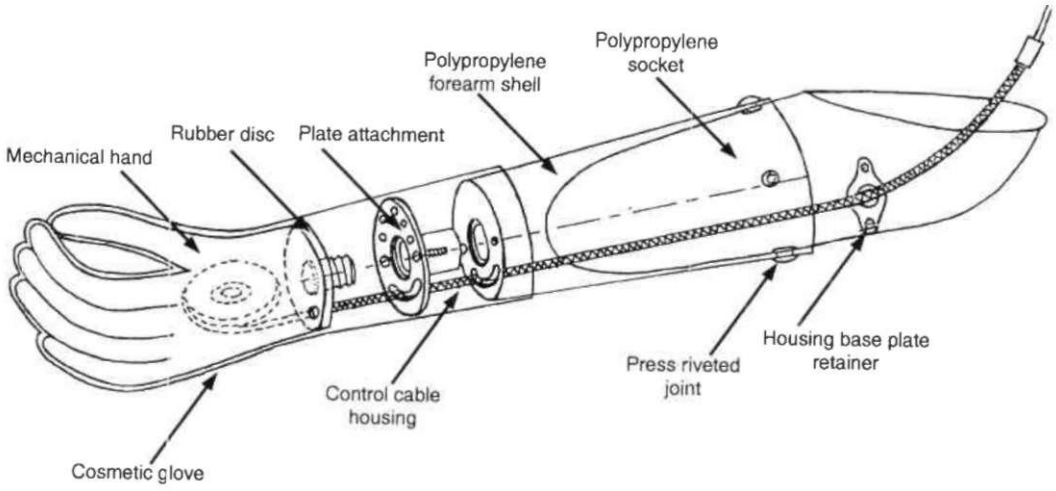

Fig. 2. Left below – elbow prosthesis.

shaped into a flat surface to match the diameter of the plate attachment. Using drape moulding the polypropylene is moulded over the build-up to prepare the extended forearm shell. It is finally trimmed slightly proximal to the expected joint with the socket. At the distal end of the shell a suitable diameter hole is drilled at the centre, to insert the stud of the plate attachment. The plate attachment is firmly fixed with the polypropylene shell using screws and nuts as shown in Figure 2. The plate attachment is used for the terminal device to eliminate the use of a wrist unit.The forearm shell prepared by this method is very light in weight.

The shell is then firmly united with the socket by riveting (using press rivets) on four sides i.e. anterior, posterior, medial and lateral.

Control cable arrangements: The control cable was positioned inside the forearm shell and brought out near the junction between the socket and shell to maintain the proper cable path while improving cosmetic appearance. A single piece of housing is provided in the control cable system which is anchored distally by the housing baseplate retainer fixed on the antero-lateral aspect of the socket and proximally by the housing crossbar assembly fixed on the triceps pad. By using a single housing the control cable path is properly maintained during the full range of elbow flexion and greater cable excursion is available for terminal device operation.

Cosmetic covering: After assembling the mechanical hand the cosmetic glove is finally applied over the prosthesis covering the mechanical hand and also a portion of the forearm shell to improve the aesthetic appearance. The control cable remains inside the forearm shell and is not visible near the wrist joint on either the palmar or dorsal aspect.

Results and conclusions

Because the wrist unit is eliminated and lightweight materials are used for fabrication of both prostheses, the weight of each prosthesis is about 0.610 kg as compared to 1 kg for a conventional prosthesis. Because the stump length is not the same on both sides two different types of lightweight prostheses were designed. Depending on stump length either type may be fitted to the bilateral BE amputee. After fitting the patient was able to open the terminal device at any desired position of elbow flexion and to peform the following activities efficiently:

1) donning and doffing the prostheses easily and independently;
2) drinking water while holding the glass in one hand and operating the water tap with the other;
3) controlling the movement of a spoon and eating freely as normal;
4) manipulating the prosthesis while writing with one hand and stabilizing the paper

with the other. (She graduated using these prostheses);

5) (since she is interested in becoming a teacher) holding the chalk and writing freely on a blackboard by lifting the prosthesis above her head for long periods;
6) exercising good control for manipulating the prostheses to perform various daily living activities i.e., using cosmetics, lipsticks etc;
7) performing ordinary household activities like sweeping etc;

The patient acceptance is very good and encouraging.

Advantages

1) They are very light in weight, more efficient in function and have a superior cosmetic appearance.
2) By using the lightweight prostheses, the patient activity sphere increases and thereby is helped to perform various manipulative activities efficiently with minimum energy expenditure.
3) Fabrication time required for the lightweight prosthesis is less compared to the conventional and also there are economies in eliminating the use of a wrist unit and avoiding laminating procedures.
4) The fabrication method is very simple, therefore care and maintenance is also very easy.

Disadvantages

During follow-up and evaluation after using the prostheses for a period of about 6 months, no specific disadvantage has been noticed except some minor adjustment in the harness system to improve function. Interchanging the terminal devices is not possible, however, it is believed that most of the amputees particularly ladies, do not prefer to interchange terminal devices.

Acknowledgement

I would like to extend my gratitude to my Director, Wing Commander S.N. Mohanty, and my Head of the Department, Mr L. T. Iyer, who always inspired and encouraged me to take up new challenges in design and to develop suitable prostheses for problem cases.

REFERENCES

Sturup J, Thyregod HC, Jensen JS, Retpen JB, Boberg G, Ramussen E, Jensen S (1988). Traumatic amputation of the upper limb: the use of body-powered prostheses and employment consequences. *Prosthet Orthot Int* **12,** 50–52.

Roeschlein RA, Domholdt E (1989). Factors related to successful upper extremity prosthetic use. *Prosthet Orthot Int* **13,** 14–18.