RECENT ADVANCES IN THE DEVELOPMENT OF PARTIAL HAND PROSTHESES

Edmund Biden, D.Phil., F.C.S.M.E., Greg Bush, B.A., C.P.(c),
Murray Olive, Machinist, and Walter Young, Prosthetic Research Technician
Institute of Biomedical Engineering, University of New Brunswick

INTRODUCTION:

Recently, two patients have presented with partial hand amputations in which the digits and distal ends of the metacarpals were missing, but the thumb was intact. One of these was a child with a congenital absence and the other an adult with loss of digits through a farming accident.

The child has been fitted with two different systems, the first based on the motor and finger group of an Otto Bock size 5 Electrohand 2000, and the second based on our own, in-house, design. The adult has been fitted with mechanical fingers having multiple locking positions. The prostheses have been used extensively.

MECHANICAL DESIGN AND PROSTHETIC APPROACH:

The first powered partial hand prototype:

The original fitting of the child was done by building up a powered finger unit from the motor and finger block of the Otto Bock size 5 Electrohand 2000. The hands wrist attachment, thumb, and related linkages between the thumb and fingers were removed leaving a unit approximately 1.2 mm in diameter and 45 mm long. This was then laminated to a socket which left the thumb exposed and free to move. Otto Bock 13E125 electrodes, a VASI digital bridge, and a Steeper external 6V battery pack were used. The electrodes were placed over the thumb flexors/adductors and the extensors/abductors so that as the thumb was flexed or extended, the finger group mimicked the motion.

The control method worked well, and the action of fingers and thumb together gave a natural grip which was easy to learn to control.

The motor end of the finger unit was laminated rigidly into the prosthesis with the moving finger unit left free to move. The modification to the hand lead to problems with the brushes losing contact, and bending of the gearbox relative to the motor and base due to the removal of the linkage to the thumb. The child using the system was enthusiastic and an active user and eventually these modifications lead to failure of the drive. This is in no way a criticism of the Otto Bock hand which was being used in a way for which it had simply not been designed.

The second redesigned powered partial hand:

To address these problems we have built a second unit around a MicroMo 1319 electric motor and a 246:1 gearbox. As illustrated in figure 1, the unit is built so that the sleeve holding the fingers is attached to the output shaft of the gearbox with a setscrew on the closed end. The open end projects back over the gearbox housing and rides on a pair of Teflon bushings. The fingers themselves are brass rod inserted into projecting mounting block on the finger unit. The casing, in which the motor and gearbox are mounted, is laminated into the prosthesis and the motor and is attached to the gearbox housing as well. By means of this, the gearbox housing carries the load of the fingers and removes the problem of the gearbox bending relative to the motor. The leads from the motor are brought out the end of the unit and two Otto Bock 13E125 electrodes, a VASI digital bridge, and a Steeper remote 6V battery pack complete the system.

The unit has a range of finger motion of approximately 60 degrees, and opening and closing for the unloaded unit is approximately 200 milliseconds. The stall torque is 9 inch-pounds. The unit was provided

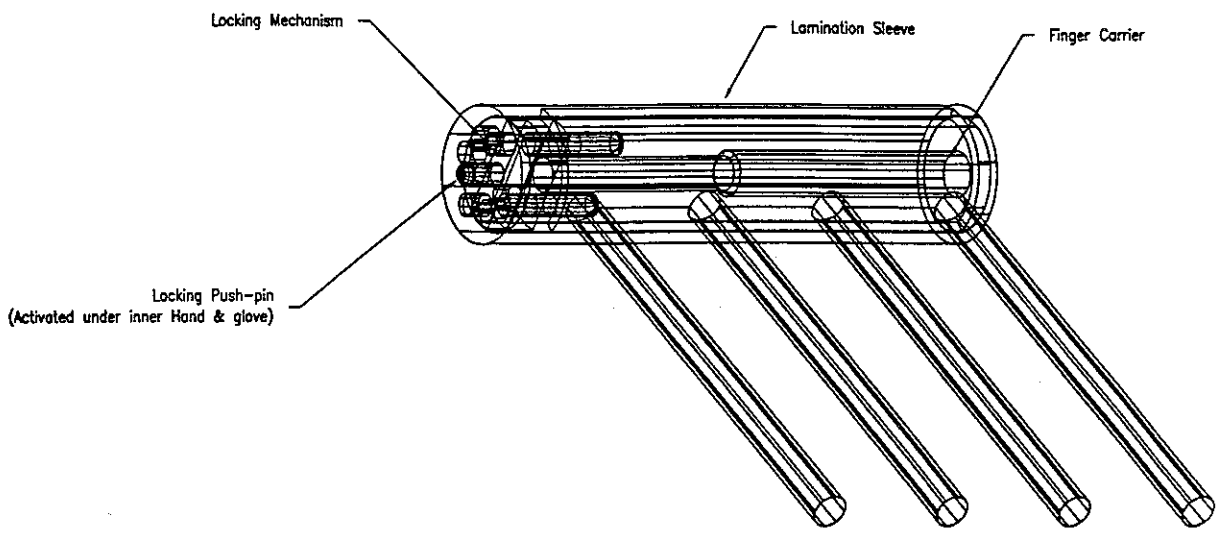

Figure 1: Adult articulated mechanical partial hand

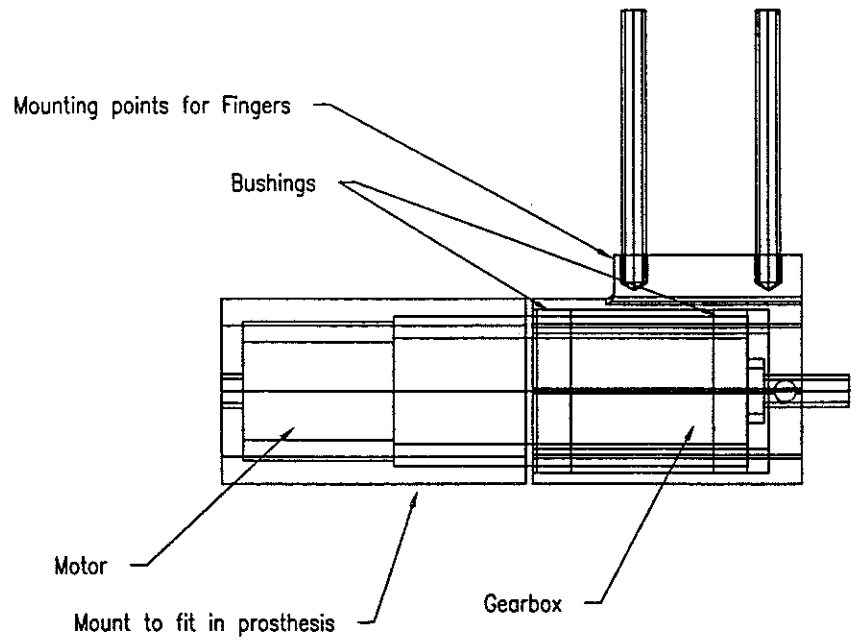

Figure 2: Powered partial hand design

with a rubber bumper system to cushion the end points of the finger travel and reduce impact loads on the motor.

The size of this unit is slightly larger than the original modified size 5 Electrohand 2000, it is size appropriate and also has adequate pinch.

The glove to cover the fingers has the thumb cut out. The glove also required a substantial amount of stretching to allow the fingers full range of motion. The prosthesis extends to approximately the mid forearm and is self suspending.

Adult articulated mechanical partial hand:

The adult size mechanical hand was built to provide a robust device for a farmer, and also in order to be able to get the individual back to planting in the spring of 1997. Finger unit is shown in figure 2. It consists of a sleeve and core rather than the motor unit in the hand described above. All four fingers are attached to the core which also has a three position lock which is activated by pressing on a button through the cosmetic cover. The range of motion is limited by the size of the "window" left in the sleeve. The fingers have a range of approximately 90 degree with the locked positions being with the fingers fully extended, partly flexed, and flexed to 90 degrees so that the thumb can come into contact. The fingers were covered with an Otto Bock inner glove and then covered with an outer glove with the thumb removed. The finished prosthesis ends just distal to the wrist allowing relatively unrestricted wrist motion.

RESULTS AND DISCUSSION:

As noted above, the original child size, powered prosthesis was used actively until it wore out. The second unit has also had active use although some modifications will be made when it is returned for repair, or when the child is back for a clinic visit. The digital control system in a hand which is as fast as this one has meant that the child has difficulty getting to intermediate positions in the range of the fingers. We believe that a proportional control will solve this problem.

The glove restricts the motion of the fingers and much of the power output of the motor is used to move the glove. We will explore alternative ways of stretching the glove, or using some other glove to reduce this problem.

The cosmetic result is very good and the child is an active user.

The adult size, mechanical hand has worked well in the field. It has been used actively.

A problem with both devices has been the attachment of the fingers. We used a threaded base for the fingers which has proved to be a poor choice since the fingers have to be threaded in first and then bent to their final form since the bent fingers interfere with one another when they are being rotated to thread them into the attachments. Subsequent units will use some alternative attachment method.

FUTURE DIRECTIONS:

Both of these fittings have been successful, and the mobile fingers have worked well and been very functional for this particular form of partial hand amputation.

The basic powered design can be scaled up to produce a larger hand, although an adult size hand for heavy work would likely need to incorporate a clutch or locking system to prevent backdriving of the unit.

The mechanical mobile fingers can also be scaled up or down to accommodate different hand sizes.

These fittings have given us reason to believe that prosthetic management of partial hand amputations as described is technically feasible and proving to be very functional for these clients.