

The "Orthotic Arm": A Case Report

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PATIENT HISTORY

On January 5, 1983, a patient, Mr. C., was referred to the Prosthetics-Orthotics Department of Chedoke-McMaster Hospitals as needing revision to a standard, fabric arm sling. This patient had been involved in a motorcycle accident and had suffered severe avulsion of the fifth, sixth, and seventh cervical spinal nerves. For a number of months after the accident, Mr. C. was unable to walk and was told that he would not regain useful function of his left arm and that he would also suffer impairment of his speech and mental faculties. Contrary to this prognosis, Mr. C., in less than a year, is not only mentally competent and articulate, but has regained a fully functional gait pattern, with no sign of his previous trauma.

The remaining problem, and main focus of this paper, is the patient's left arm. The muscles of the shoulder region are atrophied through lack of innervation. The elbow is likewise similarly affected (Figure 1). This patient is extremely fortunate, however, in that while certain nerves were pinched and destroyed, others were left intact. Mr. C. has very weak wrist extension and weak finger extension. He retains good finger flexion, good thumb control,

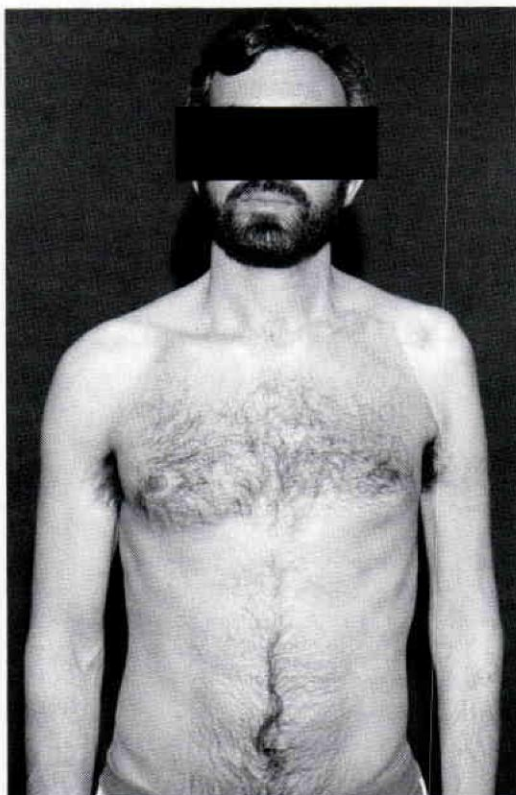


Figure 1. The patient, showing atrophy of left arm.



Figure 2. The patient and orthosis.

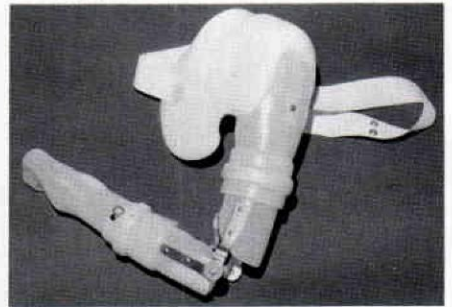


Figure 3. The "Orthotic arm," lateral view complete.

and adequate fine finger movement. Because of the pressure of hand function, it was thought possible that some type of orthotic management would be of benefit to the patient. A series of discussions was initiated with Mr. C. that resulted in a device he calls his "orthotic arm" (Figures 2 and 3).

FUNCTIONAL CONSIDERATIONS

The primary function of Mr. C.'s orthosis is to retain and stabilize the head of the humerus in the glenoid fossa. This prevents stretching and damage to the nerves which allow the patient near normal use of his hand. Critical stability was particularly hard to achieve as the patient exercises strenuously and enjoys such activities as swimming, jogging, and tennis.

The orthosis' secondary function is to act as a stable, variable positioning agent for Mr. C.'s hand. For this reason, even the most elaborate of conventional cloth arm slings would not be satisfactory.

RANGE OF MOTION

The device provides positioning within the following range of movements:

- The hand is supported and fixed in 10° of extension at the wrist.
- The forearm can be rotated through 180° to provide full supination and pronation, although most commonly the hand is maintained in either the mid supination-pronation (thumbs up) position or in full pronation.
- The elbow can fully extend and can be locked in any one of seven positions, including approximately 135° of flexion (The Hosmer-Dorrance elbow joint allows a mode of free motion).
- The upper arm rotates through 90° such that when the elbow is flexed at 90°, the forearm can extend forward from the patient's side or be positioned anywhere in an arc terminating with the forearm held across the abdomen. An elastic strap extends around the body below the diaphragm. Fitted with two small straps to secure the forearm, this strap pro-

vides further stability to the arm during strenuous activity.

In combination, the above positioning capabilities provide the patient with a very wide range of positioning options.

CASTING AND FABRICATION

Initially, two plaster negatives were made. One mold was taken of Mr. C.'s forearm and hand, the other was taken of his humeral section and shoulder, including the pectoral and scapular regions. The mid area of the humeral section mold was modified to provide as perfectly cylindrical a section as possible. The biceps in their flaccid state could easily accommodate this modification, which was necessary to eventually ensure free rotation of the device in this region. The same type of modification was also necessary in the mid forearm to provide unhindered supination and pronation. The shoulder cap was cast with the head of the humerus held well into

the glenoid cavity. Because of atrophy in this area, bony prominences were particularly apparent and the shoulder mold was modified to relieve these areas. Later, a molded thermofoam insert was incorporated in the vacuum forming process to further protect these sensitive areas.

The "arm" was fabricated of 1/4" polypropylene in three distinct vacuum forming operations (Figure 4).

The first vacuum forming was of the patient's forearm and hand. The positive mold was positioned so that the seam from this molding extended along the radial surface of the forearm and, proximal to the thenar eminence, over the dorsum of the hand. This seam was later trimmed and widened to allow the patient's arm to fit into the forearm section of the orthosis. A thermofoam pad over the ulnar styloid was incorporated in the final vacuum forming. The palmar area of this section supports the hand in pronation. A section cupping the hypothenar eminence and lateral border of the hand supports the hand in the "thumbs up" position. In addition, a web bar helps prevent the limb from slipping downward

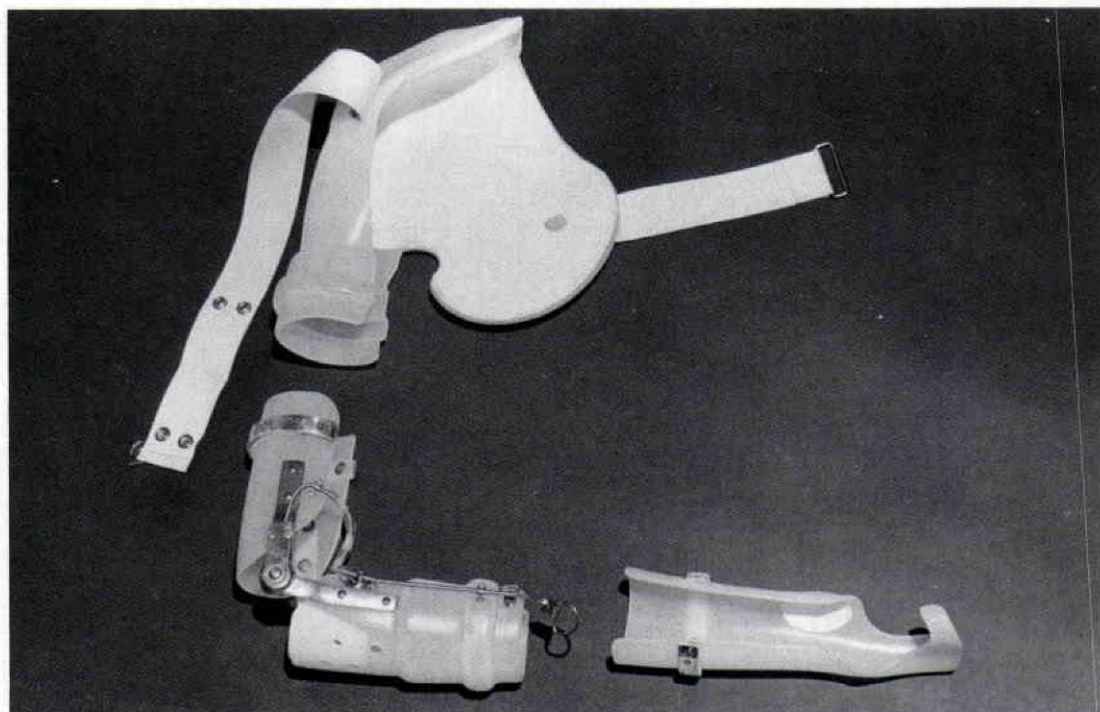


Figure 4. The orthosis, medial view, showing locking elbow and rotating components.

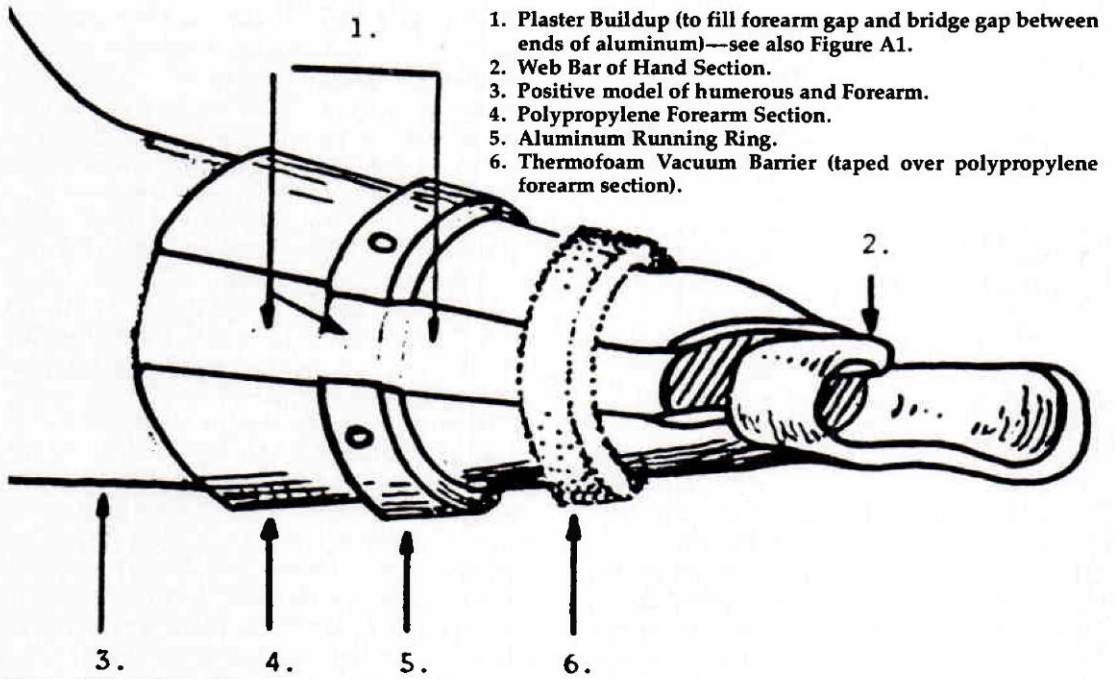


Figure 5. Case Setup for second plastic forming.

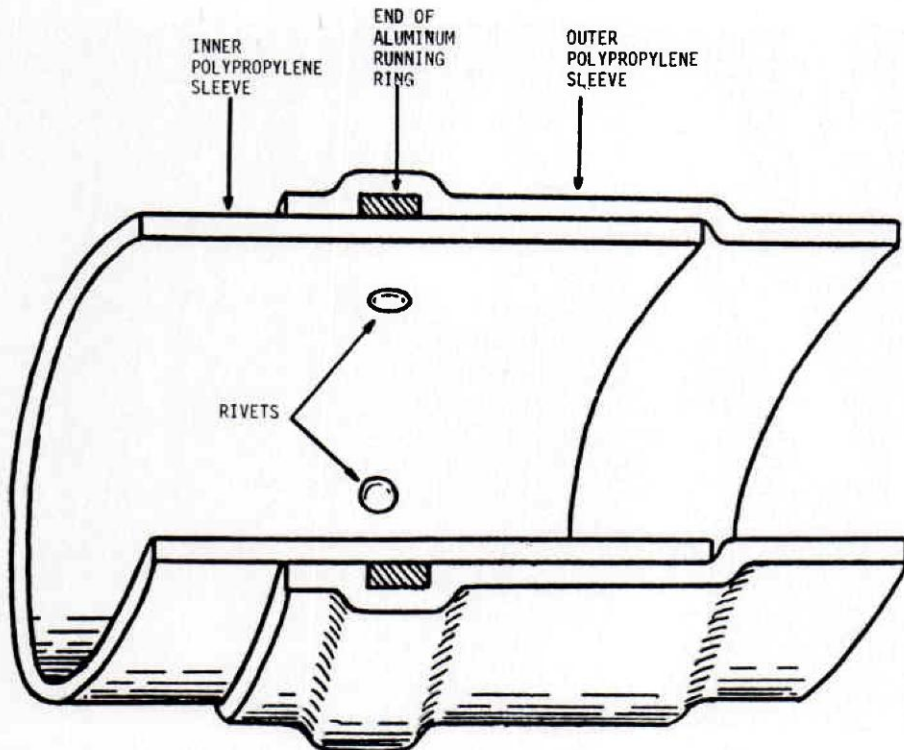


Figure 5A. Cross section of Figure 5 to show plaster build ups.

in the orthosis when the arm is fully extended by the patient's side. The web bar thus helps maintain the humeral head in the glenoid fossa. To guide rotation and yet maintain stable length of the "arm," an aluminum ring was bent around and fastened to the forearm section of the orthosis. Copper rivets were used, countersunk on the anterior of the plastic forearm section and ground flush on the outer surface of the aluminum band. This completed plastic section was replaced on the patient's positive mold (Figures 5 and 5A).

It was necessary, at this point, to bridge the gap in the polypropylene forearm section with plaster and to extend a plaster build up between the two ends of the aluminum ring. This would prevent the second vacuum formed section of the arm from entering the gap and thus locking the arm. By presenting a continuous cylindrical surface, full rotation of the first polypropylene sleeve was permitted within the second (Figure 6).

The second vacuum formed section, forearm, and arm was trimmed and the elbow joints attached using copper rivets. The areas of the olecranon and cubital fold were trimmed to allow full flexion and extension of the elbow. The lateral areas were left as long as possible to accommodate the elbow unit side bars. The elbow locking unit was located medially so that the actuating cable would extend as unobtrusively as possible along the volar surface of the forearm. As the patient is required to position the arm by grasping it near the wrist, the cable was anchored to this point (above the rotating wrist section) and terminates with a thumb ring. Mr. C. preferred this arrangement to a nudge control.

It is important to realize, in the original positioning of the aluminum running-ring on the cast, that enough room must be left proximally to allow for the attachment of the elbow joint side bars. Conversely, enough room must be left distally so that the rotating inner sleeve has enough bear-

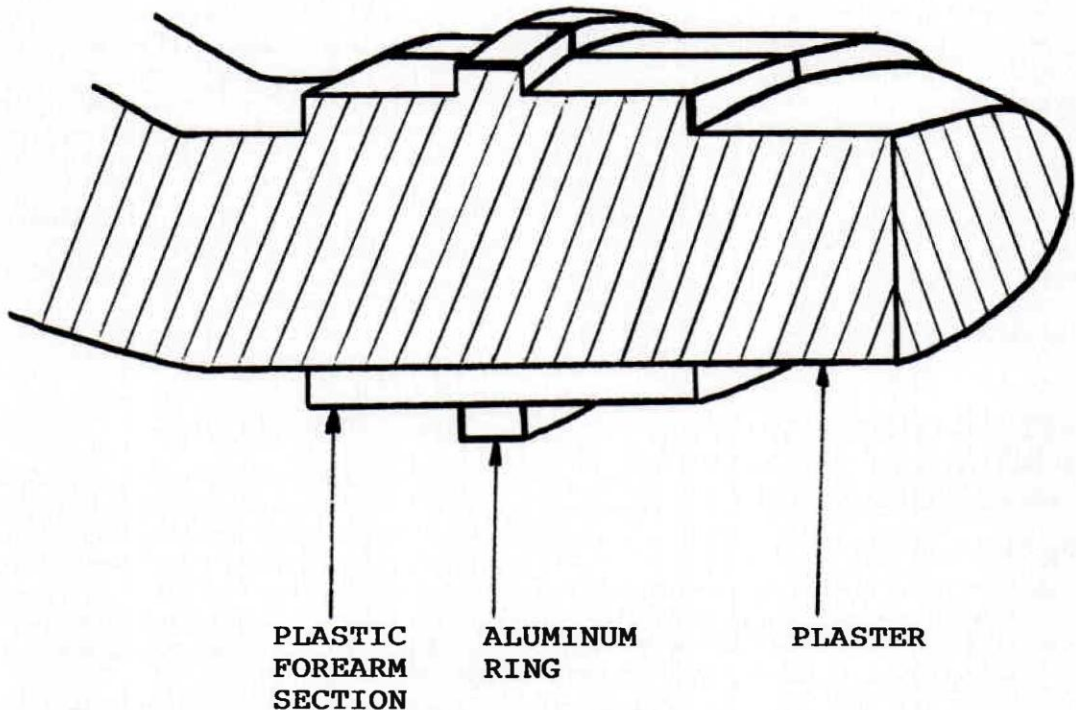


Figure 6. Plastic rotating mechanism.

ing surface to remain stable (through its long axis). These considerations also apply to the rotating section of the arm.

The final stage of fabrication was the vacuum forming of the shoulder cap. In order to maintain a large, intact surface both over the shoulder and in the pectoral and scapular areas of the orthosis, the positive mold was positioned so that the seam line for this forming would run inferior to the axilla and along the medial aspect of the arm. Next, the partially completed lower section of the device was pushed onto the humeral section of the positive mold. It was necessary to be very careful, at this stage, to achieve a proper arm length, again, in order to maintain the head of the humerus as firmly as possible in the glenoid fossa. The same plaster modifications used to ensure full rotation of the forearm section were used to allow rotation of the humeral section. One quarter inch polypropylene was vacuum formed over the positive mold and upper section of the attached orthosis. The shoulder cap was trimmed.

Only one strap is needed to securely retain the "orthotic arm" on the patient. This is a two inch dacron stap with Velcro® and a pull back loop which runs from the pectoral plate, inferior to the axilla, and over the patient's back to the scapular plate. One additional strap of elastic webbing, mentioned previously, holds the arm against the abdomen when the patient is jogging or participating in other activities that involve flexion at the waist. In this way, the strap immobilizes the arm rotation and supplements the function of the scapular plate.

PREPARATION & VACUUM FORMING OF ROTATING FOREARM ASSEMBLY

Figure 5 and 5A

- A. Wrist and hand section of orthosis pushed onto forearm positive mold.
- B. Gap in radial area of the device (necessary for donning the "arm") built up with plaster. Area between ends of aluminum rotator ring

bridged with plaster. A continuous, cylindrical surface is presented. The wrist-hand portion of the device will freely rotate within the forearm section which is vacuum-formed over it.

- C. A nylon stocking is pulled over the positive mold and orthosis. It terminates proximally to the wrist and is taped around the wrist using plastic-electrical tape at this point. The nylon stocking is lightly adhered to all areas where bridging occurs, i.e. sides of ring and proximal border of orthosis.
- D. Double faced tape is applied over the electrical tape.
- E. A strip of thermofoam is wound around the tape. When the hot sheet of polypropylene is vacuum formed over the cast and proximal portion of the orthosis, the thermofoam, in melting to the hot plastic, forms an air tight seal. A cord wrapped around the plastic ensures a tight seal with the thermofoam and this second vacuum forming will draw intimately to the positive mold and inner sleeve which would otherwise have to be draped over the extreme end of the hand section. Complicated trimming of excess plastic is also avoided. The hot polypropylene neither adheres to, nor marks, the cold piece over which it is vacuum formed.

This method of set up and vacuum forming was used to produce the rotating mechanisms of the forearm and humeral section (Figure 6).

FURTHER CONSIDERATIONS

Since the patient has returned to work as a computer programmer, a detachable dorsal spring wire radial assist has been added to the hand portion of the orthosis. This attachment supplements the weak extension of the third, fourth, and fifth digits that affects the hand after several hours of work.

Perspiration has been a problem with the orthosis, particularly in view of Mr.

C.'s athletic pursuits. As a consequence, ventilation holes have been drilled in the pectoral plate and extensively along the volar aspect of the forearm. The aluminum running rings, especially that of the forearm rotator, have become encrusted with salt deposits. For this reason, plastic should perhaps be used for the rotator rings.

The delicate nature of the Hosmer-Dorrance elbow locking joint is also a problem. When such an orthosis is made in the future, it might be advantageous to fabricate a stainless steel, plunger type locking joint. It would be waterproof, simpler, and more durable. Internalizing the elbow unit side bars would be possible using a heavier gauge of steel (for tapping) than is available in the commercial elbow joints.

SUMMARY

In conclusion, it must be pointed out that, as with any orthosis, the success of the device depends heavily on the attitude and enthusiasm of the patient. It was only because of the apparent and consequent determination of Mr. C. to use such a device, that the "arm" was made and employed successfully.

AUTHOR

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