An Extension Orthosis for the Management of Elbow Flexion Contractures

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INTRODUCTION

Individuals with flexion contractures of the elbow secondary to head injury or spinal cord injury often have serious impairment of function in the upper limbs. In order to retrieve some measure of function, management of elbow contractures must be individually applied throughout the rehabilitation program. If there is persistent spasticity, a program of serial plaster casting, passive/active range of motion, and positioning must be initiated and maintained to keep the extremities free of contractures and to help the individual achieve appropriate balance in motor power.

The clinical picture usually seen in comatose head-injured individuals is a decorticate position with flexion contractures of the elbow. While the individuals are still comatose, elbow contractures can be corrected or prevented by serial plaster casting, thus facilitating maximum use of the upper extremities when function returns. Head-injured individuals treated one year or more post injury may also be managed with serial plaster casting.

Pierce and Nickel[1] in discussing spinal cord injuries (SCI) state that "flexor patterns are more common than extensor patterns, appear earlier following an injury, and usually become increasingly stronger during the first six to nine months." Without proper preventive measures, elbow contractures may be severe for persons with spinal cord injury.

For persons with either spinal cord injury or head injury, the loss of elbow extension may severely limit functional activities of daily living. When appropriate, serial plaster casting has been applied to these individuals to correct the contractures, thus facilitating maximal functional use of the upper extremities. Perry[2] states, "restoration of full elbow extension is a strong challenge, as the flexor muscle mass is large, closely wrapped about the joint, and well endowed with fibrous tissue. For these reasons an intensive short term program with serial plaster-of-Paris casts is often preferred to regain range of motion."

SERIAL CASTING TECHNIQUE

When a program of serial plaster casting is initiated, the plaster cast is changed at least

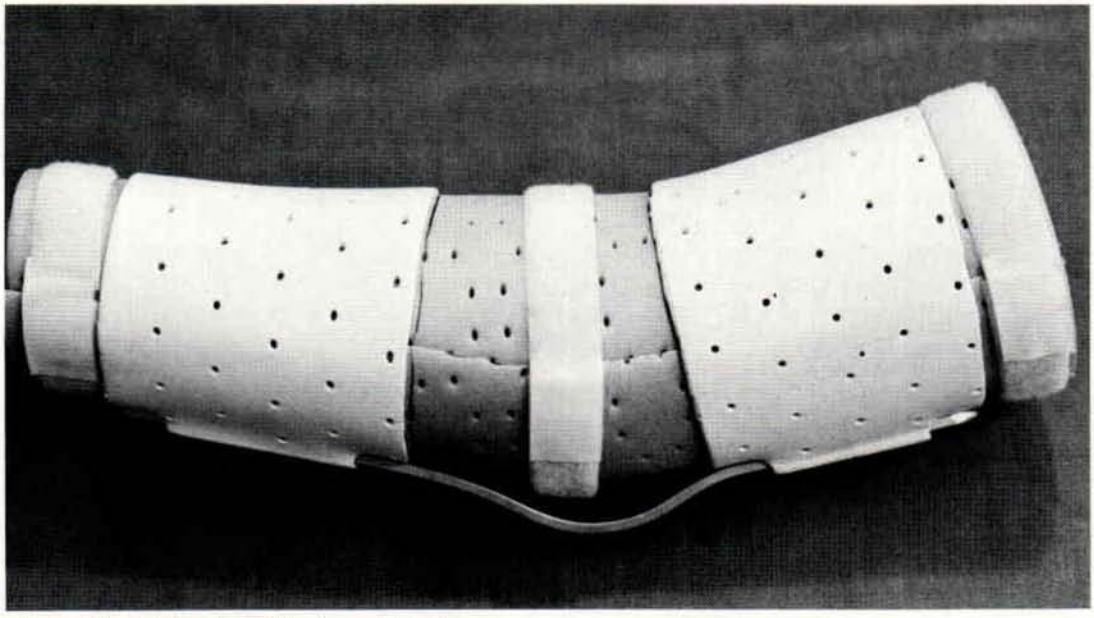

Fig. 1 – Elbow Extension Orthosis, medial view.

weekly, and the degree of increase in passive range of motion noted. For some individuals, this casting will only maintain their current range of motion, and no changes are noticed after application of new casts. Where spasticity is persistent, the results of casting may not be beneficial in increasing range of motion. Furthermore, in some cases, increased range of motion gained following a serial plaster casting program may not be maintained.

For follow-up management, rigid circular plaster casts can be bivalved to form an anterior and posterior shell to prevent the loss of passive range of motion gained from serial plaster casting and to prevent further contracture.

In our two years experience of using the plaster bivalve orthosis we found it to have the following disadvantages:

- difficulty in proper fitting,
- problems with pressure areas,
- softening when wet,
- cracking when used for extended periods,
- difficulty in building wearing tolerance thus causing difficulty in maintenance of passive range of motion,
- body odor retention, and
- weight of the plaster orthosis.

Hoffer et al[3] described the use of plaster casts for head-injured children and reported that the more spastic and profoundly affected children had the greatest deformities. Additionally, they emphasized that plaster bivalve casts were not well tolerated by deformed spastic limbs before correction was obtained.

DESCRIPTION

An elbow extension orthosis has been developed as a supplement when desired extension cannot be achieved through serial plaster casting alone and also serves as a maintenance orthosis to preserve gains made by casting (Fig. 1 and Fig. 2). The orthosis was designed and developed by Northwestern University Rehabilitation Engineering Program and the Occupational Therapy Department of the Rehabilitation Institute of Chicago. The elbow extension orthosis is custom fabricated and fit to each subject's involved limb. Within a two year period this elbow extension orthosis has been used successfully with six subjects with a diagnosis of traumatic head injury and one subject with a diagnosis of C5 quadriplegia. Each person made initial gains from serial plaster casting,

noted by an increase in passive range of motion. After a time, their range of motion plateaued using serial plaster casting. The method and materials used to fabricate the elbow extension orthosis are found to be beneficial to the wearer. Adjustments can easily be made to the "Plastazote" (polyethylene foam) liner of the orthosis to prevent pressure problems and discomfort. The initial cost of materials and labor necessary for providing an elbow extension orthosis is greater than that of a plaster bivalved orthosis, however, initial cost of the elbow extension orthosis would be offest by the expense to refabricate several plaster bivalve orthoses.

The major advantages of this new elbow extension orthosis include the following:

- fabrication and fitting by the occupational therapists or orthotist within the treatment setting,
- maintenance of passive range of motion,
- ease in proper fitting,
- total weight is reduced by approximately one half when compared to a plaster bivalved cast of the same size,
- sufficient padding to prevent skin breakdown,
- ease of adjustability to accommodate arm volume changes,
- adjustability by the occupational therapist permitting change in the degree of elbow extension,
- durability when worn for extended periods,
- easy removability, allowing the individual to participate in a program of exercise with passive/active range of motion and to wear the orthosis as a night splint and,
- easy care of the orthosis.

The disadvantages of the Elbow Extension Orthosis include:

- difficulty in fitting elbow flexion contractures of eighty degrees or more,

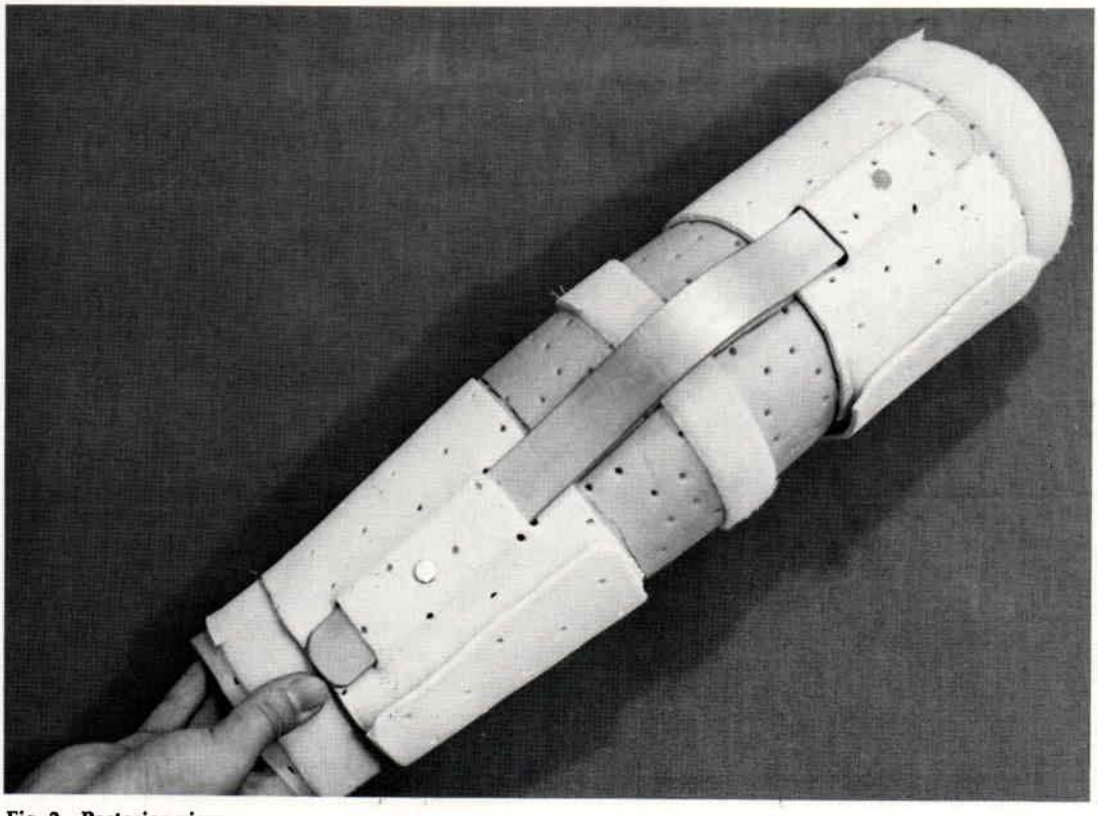

Fig. 2—Posterior view.

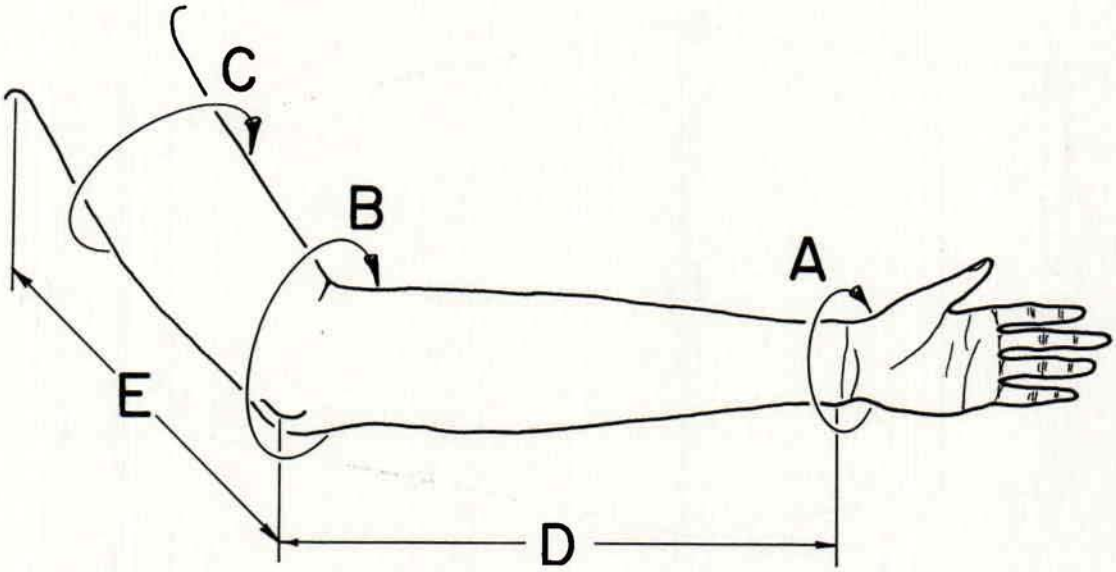

Fig. 3—Measuring diagram. Circumferences: A) Wrist, B) Elbow, C) Arm. Lengths: D) Ulnar Styloid to Olecranon, E) Olecranon to Axilla.

- difficulty in fitting Plastazote liner on limbs having severe wrist and hand contractures,
- some users reported their arm felt noticeably warm when wearing the orthosis.

The elbow extension orthosis is easily donned or doffed. This is a major advantage to the user and the people involved in the management of their elbow flexion contractures as wearing tolerance must be monitored to prevent skin breakdown and high localized pressure areas. The instructions for donning the elbow extension orthosis are:

- apply stockinette over length of arm,
- don Plastazote liner and fasten Velcro closures, and
- place Orthoplast shell over Plastazote liner and fasten Velcro closures.

The user is given an extra stockinette so that one may be laundered while the other is worn. The Plastazote liner may also be washed using mild soap and warm water and it will still maintain its shape (caution: hot water may deform the Plastazote liner).

FABRICATION

Tools

- oven
- bandage scissors
- tape measure
- contouring iron
- contouring fixture
- leather punch—25 millimeter wide wide slot and punch pad
- electric frying pan or hydrocollator
- two blocks clean wood or formica covered pressboard (25mm thick × 50 mm wide × 20 mm long)
- drill
- 1/8″ bit
- hack saw
- hammer
- rivet
- anvil

Materials

- 12.7 mm perforated Plastazote sheet
- Permabond adhesive
- cotton stockinette
- elastic bandage
- Velcro—25 mm wide
- Velcro—50 mm wide
- aluminum bar 4.8 mm thick × 25.4 mm wide (type 2024–T4 alloy)
- perforated Orthoplast sheet
- medium length speedy rivets
- talc powder

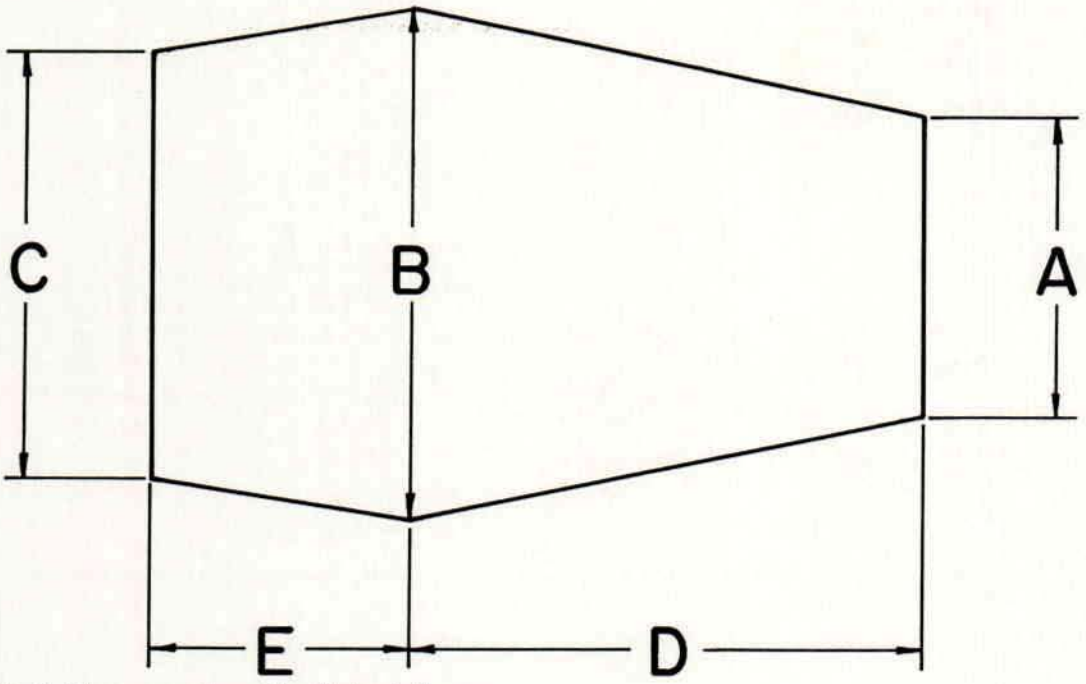

Fig. 4—Measurement layout for Plastazote liner.

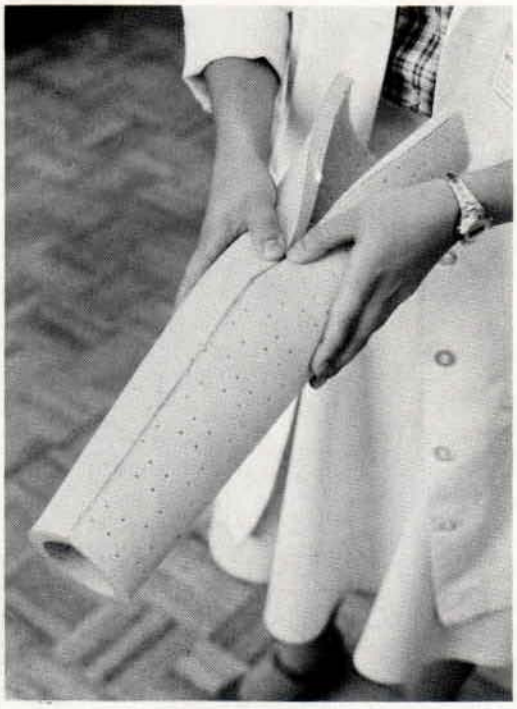

Fig. 5—Form Plastazote tube.

Plastazote Liner

The first component of the Elbow Extension Orthosis (EEO) fabricated is the *Plastazote liner*. The liner is form-fitted directly to the wearer—no plaster impression is required.

1. Make the following measurements and add length as noted to compensate for Plastazote thickness. (Fig. 3).
   - Measure circumference at the styloid processes. Add 40 millimeters to this dimension.
   - Measure circumference at the epicondyles. Add 40 mm to this dimension.
   - Measure the largest circumference over biceps. Add 40 mm to this dimension.
   - Measure the distance between the ulnar styloid and medial epicondyle.
   - Measure the distance between the medial epicondyle and axilla.
2. Layout the measurements on a 12.7 mm thick piece of perforated Plastazote as shown (Fig. 4).

Fig. 6 – Prepare arm with two layers of cotton stockinette to protect it from the heat of the Plastazote.

3. Cut out the Plastazote liner using sharp scissors or knife.
4. Form a tube by applying "Permabond" or similar adhesive to the edges of the Plastazote that follow the axis of the arm (Fig. 5). This tube is to be warmed and slipped over the wearer's arm.
5. Cover the arm with two layers of cotton stockinette. The stockinette is left to extend 600 mm from the end of the hand to act as a guide in sliding the Plastazote tube over the arm. The cotton stockinette also helps protect the arm from hot spots in the liner and compensates for shrinkage of the Plastazote as it cools. (Fig. 6).
6. Insert a layer of cotton stockinette into the Plastazote tube and pull it back over the liner to form a cuff at each end. This layer of stockinette will serve as a pulling point when the liner is slipped over the arm. The liner is placed in an 200° F oven until it is softened.
7. Remove the liner from the oven and slip the extended end of the stockinette through the tube. A "Handi-reacher" or tongs may help in threading the stockinette through the tube (Fig. 7).

Fig. 7 – Direct stockinette through liner tube of Plastazote which has been heated in a 200 degree oven.

Fig. 8—Liner in position on arm. Set elbow to maximum extension at this point and wrap it with an elastic bandage.

8. Pull the Plastazote tube on the arm by standing behind the patient. An assistant stands in front of the person and holds the limb while pushing the liner on the arm (Fig. 8).
9. Pull the Plastazote liner to the axilla, then immediately wrap it circumferentially with an elastic bandage. *Hold the arm at the desired angle of extension while the liner cools.*
10. Remove the elastic bandage when the liner is cool and use bandage scissors to cut the liner along the longitudinal axis on the medial aspect of the extremity. An opening on the medial side eases donning (Fig. 9).
11. Smooth the distal and proximal inside edges of the liner using a belt sander to form a skived edge. Do not skive the longitudinal seam.
12. Bond three Velcro pile strips, 25 mm wide, with hook Velcro ends (50 mm long) sewn on, circumferentially to the Plastazote liner at the proximal and

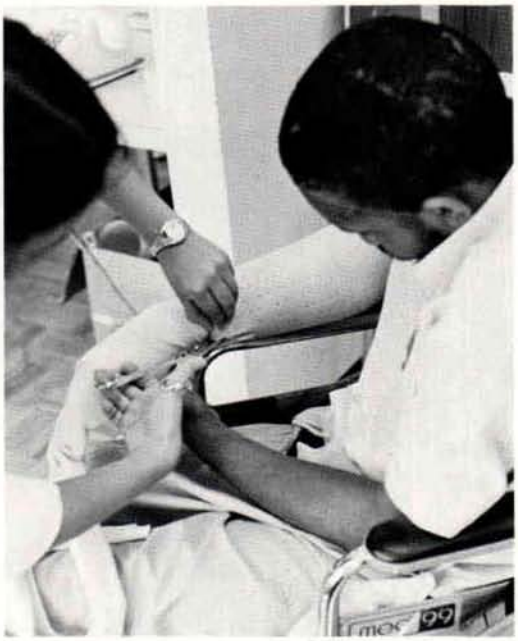

Fig. 9—Cut liner opening on medial side to ease donning.

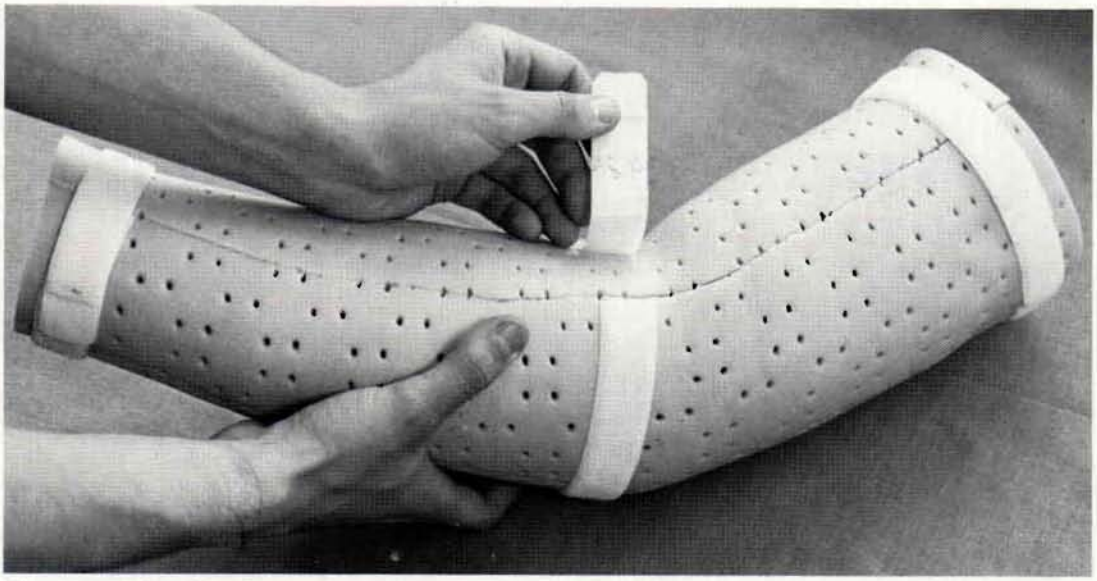

Fig. 10—Attach Velcro closures after the distal and proximal edges have been skived on a sander.

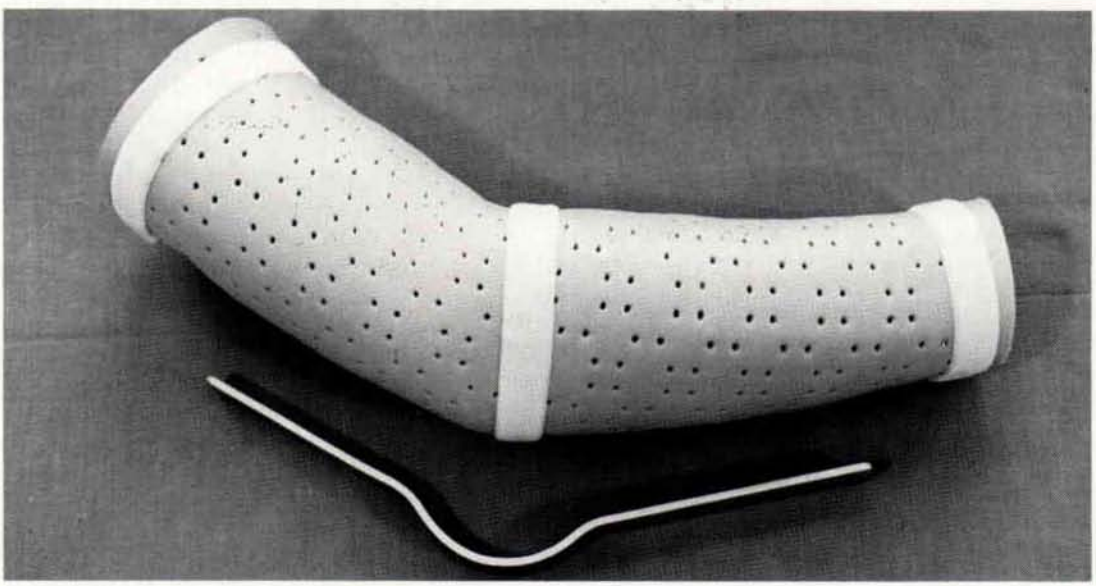

Fig. 11—Determine dorsal bar angle and contour a relief for the olecranon.

distal ends, and over the elbow area (Fig. 10). The Plastazote liner is now complete. Minor adjustments may be made with a heat gun, for relieving pressure areas.

The Dorsal Bar

1. Use the Plastazote liner as a guide to determine the correct angle of the dorsal bar (Fig. 11).

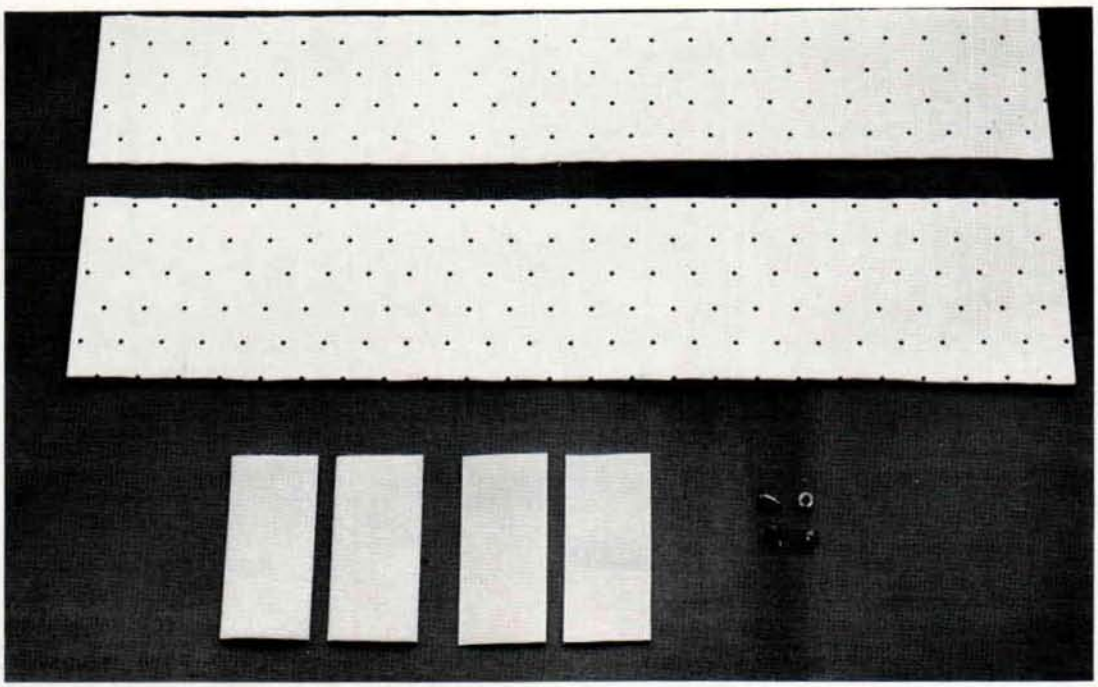

Fig. 12—Components of Orthoplast cuffs.

2. Contour an aluminum bar (type 2024–T4 alloy) 4.8 mm thick × 25.4 mm wide × 381 mm long to form an angle for the desired amount of elbow extension. The bar is contoured over the olecranon to form a loop, or pressure relief. When the bar is placed on the liner, it should not touch the olecranon area. A dorsal bar was chosen because experience shows that it protects the wearer's elbow when in this position. Fabrication and adjustments of the dorsal bar are made with a contouring iron and a contouring fixture. The length of dorsal bar should not extend past the edges of the liner.

Orthoplast Humeral and Forearm Cuffs

1. The following materials are required (Fig. 12):
   - 4 pieces Velcro hook and pile, 50 mm wide × 114 mm long.
   - 2 pieces perforated Orthoplast sheet, 114 mm wide; length to be determined.
   - 4 pieces, medium length "Speed Rivets."
2. Use circumferential measurements taken over the liner to size the humeral and forearm cuffs. Measure the largest circumference on the liner over the respective areas and add 64 mm to each circumference to allow enough Orthoplast for the overlapping Velcro closure flap.
3. Determine the position of the dorsal bar attachment slots on the humeral Orthoplast cuff. Draw a line 76 mm from an end of the Orthoplast strip (Fig. 13). Measure 20 mm from each edge on the line just drawn, this is where the slots will be punched for positioning the dorsal bar on the humeral cuff. Repeat step 3 for attachment slots on the forearm cuff.
4. Punch slots into the Orthoplast cuffs for the dorsal bar attachment. The Orthoplast is heated until it is soft enough to be punched with a 25 mm wide slot; leather-punch over the marks drawn in step 3 for the slots. The Orthoplast can be heated in hot

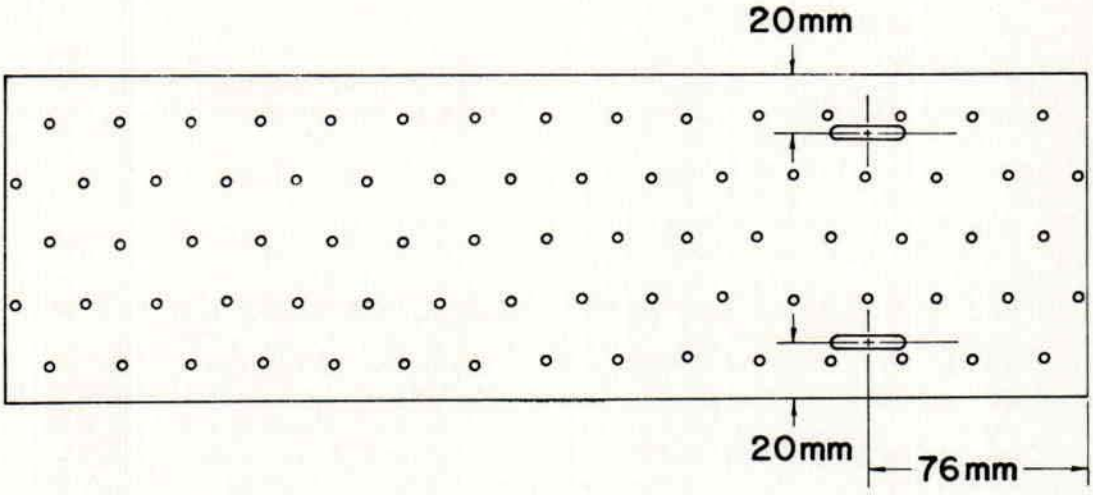

Fig. 13—Measurements for slots for the dorsal bar attachment.

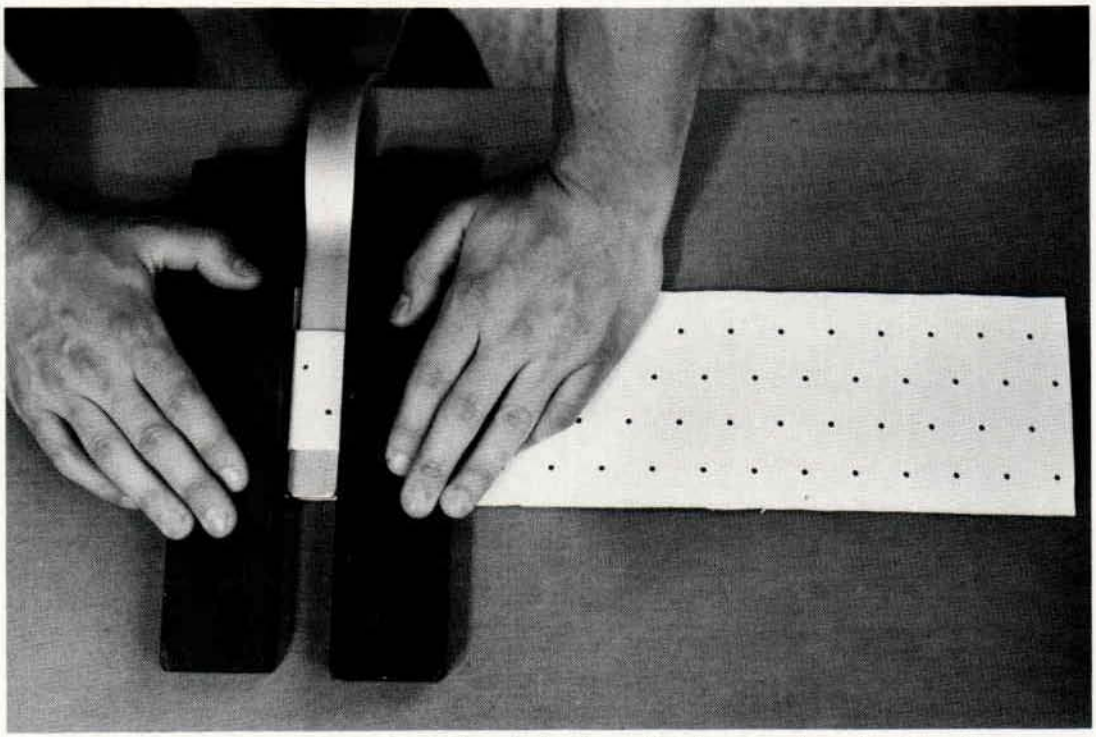

Fig. 14—Fit dorsal bar to cuffs by slipping it through the slots, which have been heated, and pressing down on both sides.

water using an electric frying pan, hydrocollator, or spot heat using a heat gun.

5. Fit the dorsal bar to the cuffs. Heat the Orthoplast using hot water in a hydrocollator or large frying pan until softened. The dorsal bar is slipped through the cuff slots as shown (Fig. 14) and placed on a counter top dusted with talc powder to reduce sticking. Two pieces of clean wood pressboard (Formica covered pressboard from a countertop cut-out was used) are placed adjacent to the bar and pressed down to form an impression of the bar into the Orthoplast. This impression will provide a smooth surface on the Plastazote liner where the cuffs are attached. Repeat this process for the forearm cuff. *Make sure the dorsal bar is slipped into the slots with the closure edge on the lateral side of the bar*. Dust the cuffs with talc powder for the next step.
6. Form the humeral and forearm Orthoplast cuffs to the Plastazote liner. While the Orthoplast is still softened from the above step, place the dorsal bar with attached humeral and forearm cuffs in position on the liner. (An assistant may be needed for this step). While holding the softened forearm cuff in position, firmly wrap an elastic bandage circumferentially around the cuff (Fig. 15). Continue to wrap the elastic bandage until both cuffs are covered. The Orthoplast may need to be reheated and rewrapped to improve the fit. A heat gun may be used for minor adjustments to the cuffs, such as trimming the closure ends. Caution should be taken not to apply excessively hot Orthoplast cuffs to the Plastazote liner for long durations because changes in the liner fit may occur. This problem may be prevented by immersing the entire orthosis into a sink of cool water.

Fig. 15—Wrap Orthoplast cuffs over liner and hold in place with an elastic bandage until it cools.

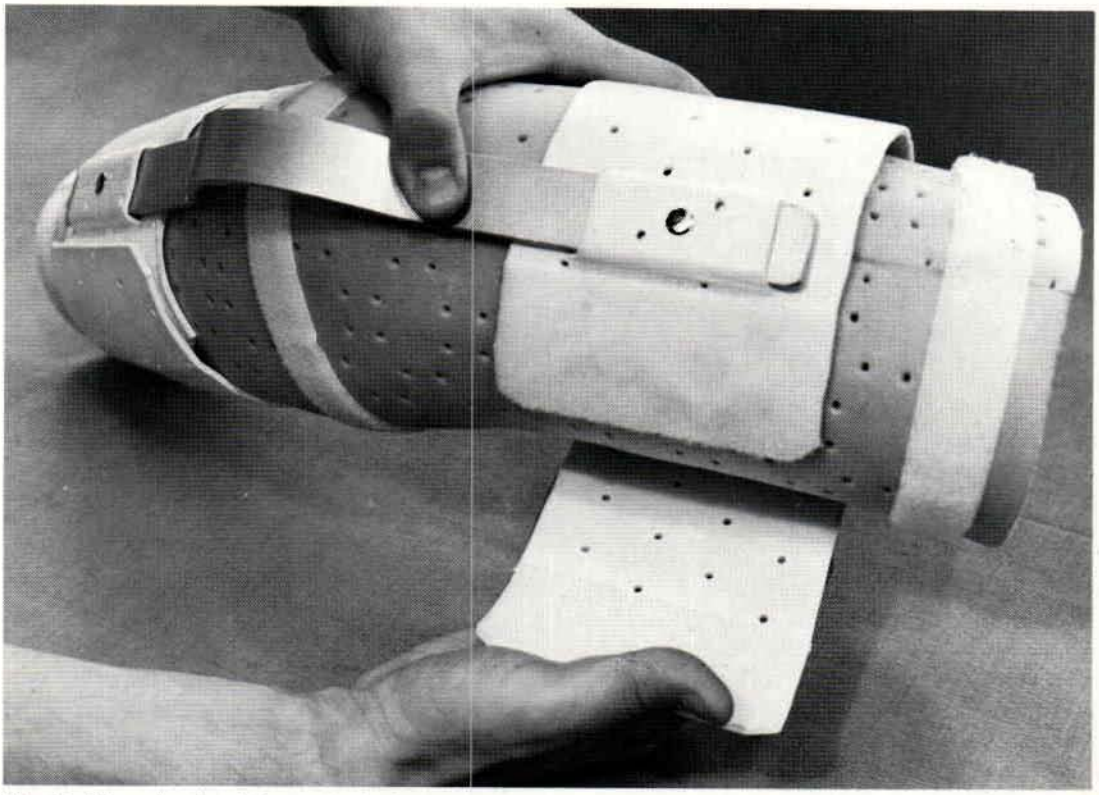

Fig. 16 – Rivet the dorsal bar to the Orthoplast cuffs and attach the Velcro closures.

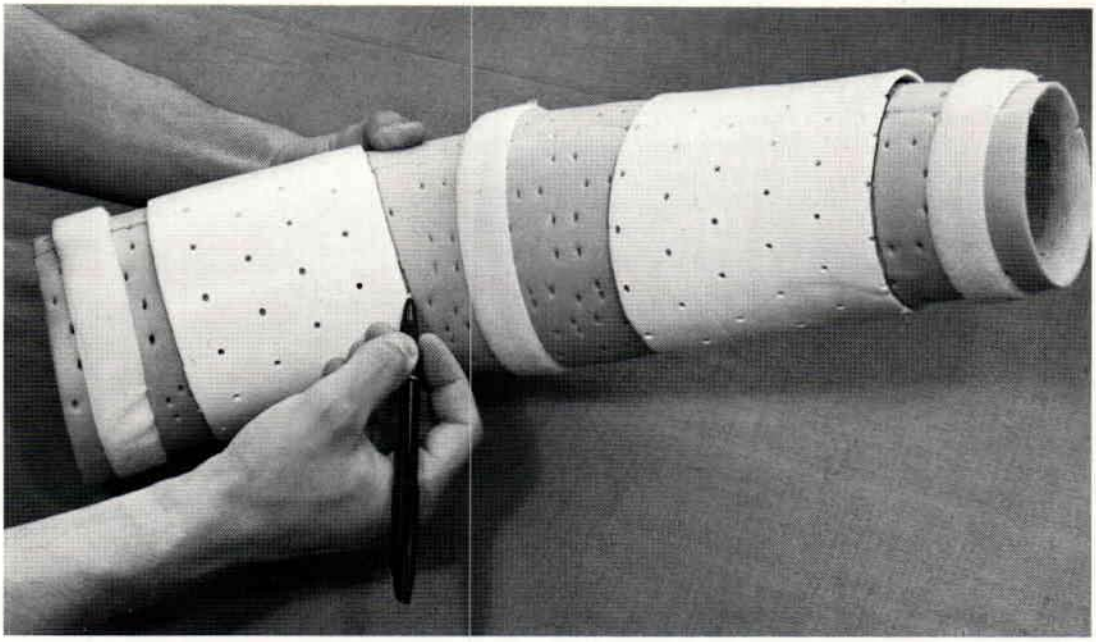

Fig. 17 – Trace position of cuffs onto liner.

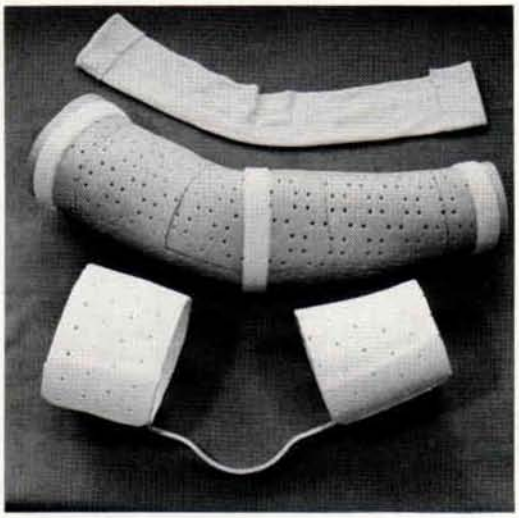

Fig. 18—Completed components of elbow extension orthosis.

7. Rivet the dorsal bar to the Orthoplast cuffs. A 4 mm diameter hole is drilled into the Orthoplast cuff directly over the midpoint where the dorsal bar is positioned underneath. A medium size "Speedy Rivet" is used to fasten the bar to each cuff.
8. Attach Velcro closures to the Orthoplast humeral and forearm cuffs. The Orthoplast should overlap itself by 50 mm for placement of the Velcro. Velcro 50 mm wide is attached to the cuff closure with Permabond or similar adhesive. It is recommended that the Velcro hook be positioned on the flap portion of the Orthoplast closure because if the closure does not overlap precisely the hook will face upward and may snag clothes and bedding (Fig. 16).
9. Reference lines are traced on the Plastazote liner around the Orthoplast cuffs and dorsal bar to aid in proper donning (Fig. 17).
10. The completed orthosis includes: cotton stockinette, Plastazote liner, and Orthoplast cuffs with dorsal bar (Fig. 18).

SUMMARY

The elbow extension orthosis is designed to supplement serial plaster casting. The occupational therapist can monitor the effects of casting throughout the individual's rehabilitation. With the seven subjects involved in this program, the elbow extension orthosis was applied when passive range of motion of the elbow had reached a plateau, and no further correction could be obtained from casting. Based on the clinical course and results of serial plaster casting, the occupational therapist could then appropriately time the application of the elbow extension orthosis. The elbow extension orthosis had been effective in maintaining range of motion, and with the decrease of spasticity a simple adjustment of the metal bar could be made to increase elbow extension. The subjects reported the elbow extension orthosis offered improved durability and more consistent fit compared to the plaster bivalved orthosis.

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