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Orthotics and Prosthetics

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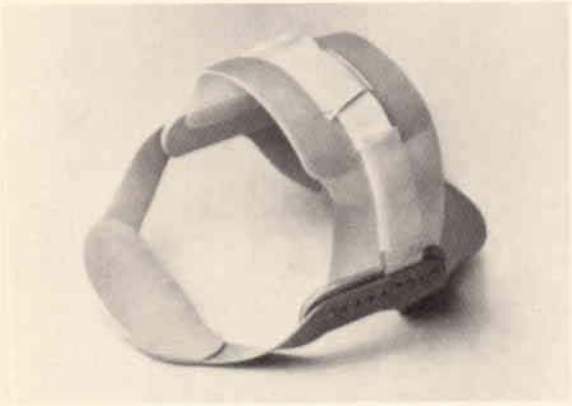

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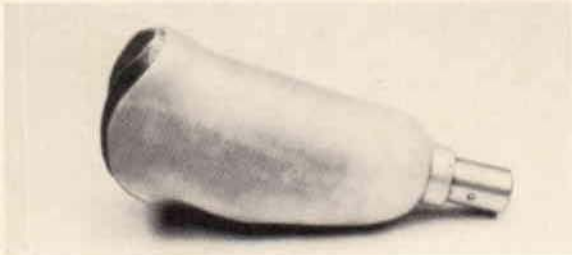

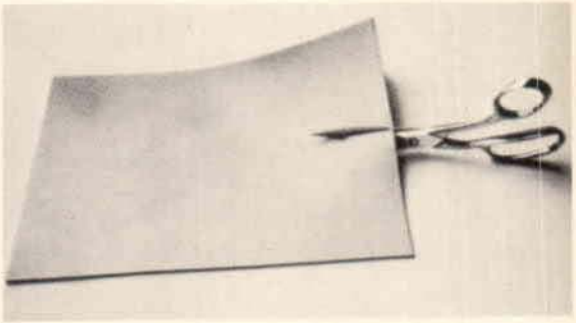

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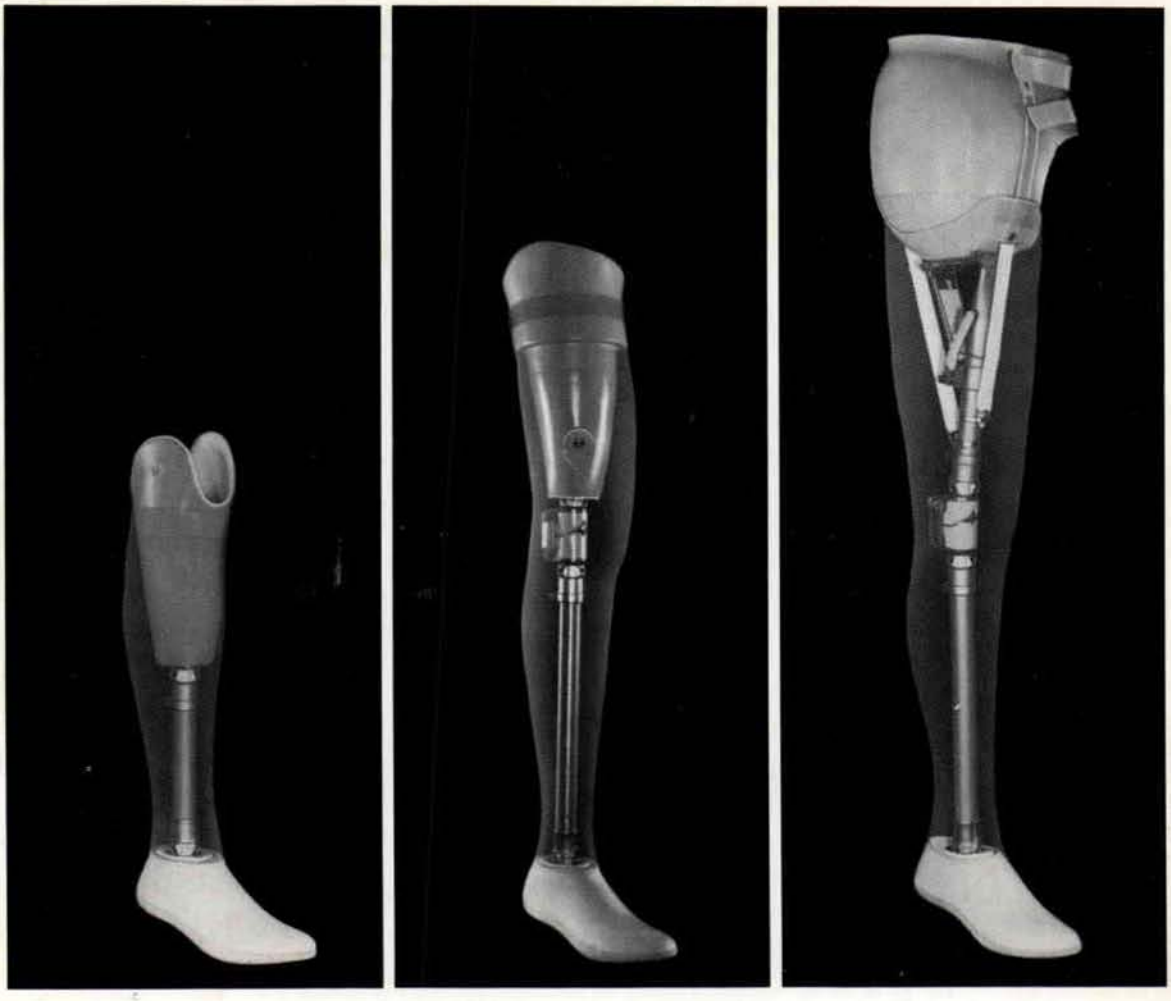

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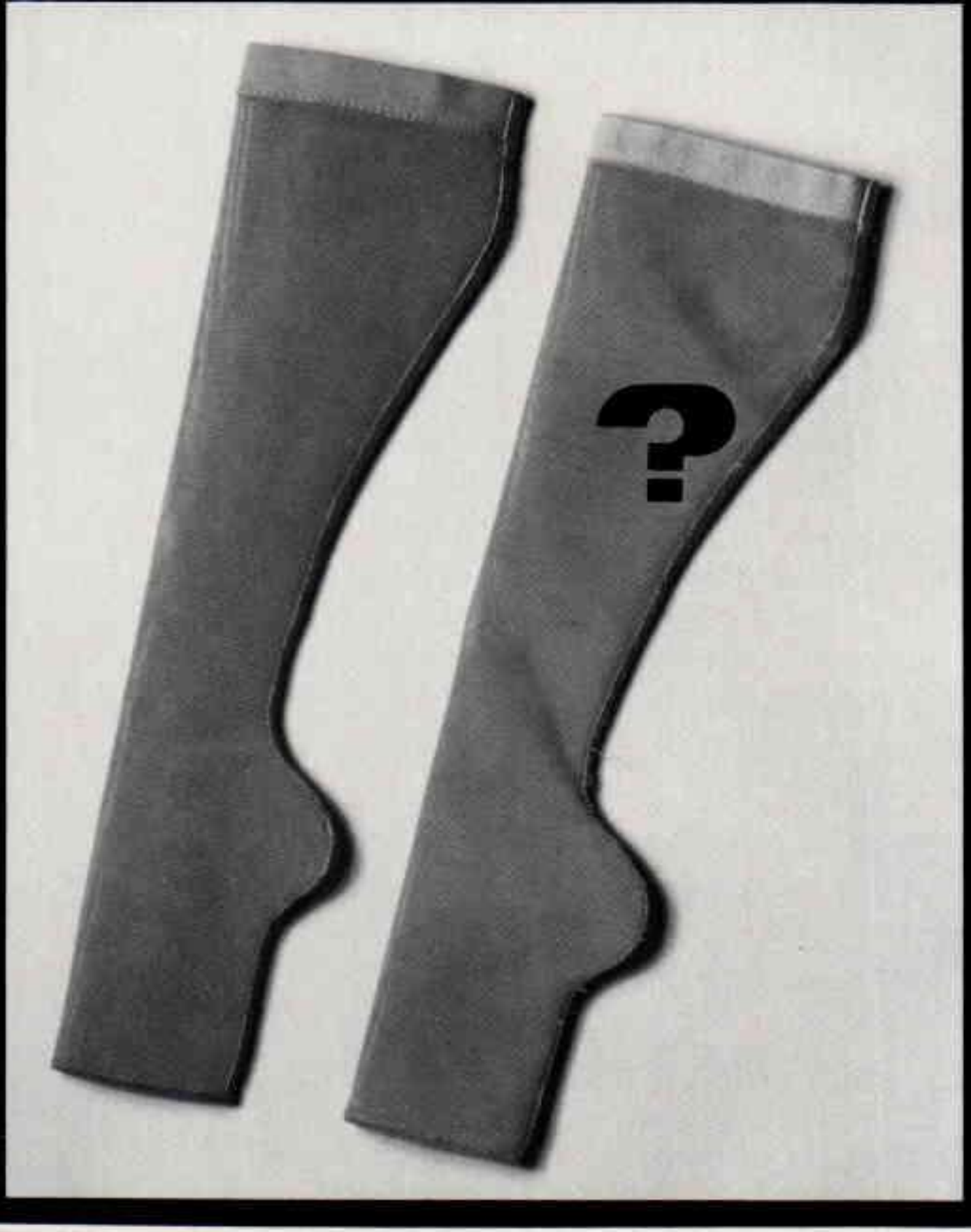

WARNING

Orthotics and Prosthetics

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Spring, 1982 Journal **Volume 36, No. 1**

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1982, June 1-3, Canadian Association of Prosthetists & Orthotists National Convention, Skyline Hotel, Ottawa, Ontario, Canada.

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1982, June 10-13, AOPA Regions II and III Combined Meeting, Claridge Hotel, Atlantic City, New Jersey.

1982, June 17-20, AOPA Region VI and AAOP Midwest Chapter Combined Meeting, Indian Lakes Resort, Bloomingdale, Illinois.

1982, June 22-25, Orthopadie Technik '82 International Congress, Wiesbaden, Germany.

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1982, August 13-14, AAOP Midwest Seminar, College of Health Sciences, University of Kansas, Kansas City, Kansas.

1982, September 8-10, Second Annual Advanced Course of Lower Extremity Prosthetics, Nassau County Medical Center, East Meadow, New York.

1982, October 19-23, AOPA National Assembly, Shamrock Hilton, Houston, Texas.

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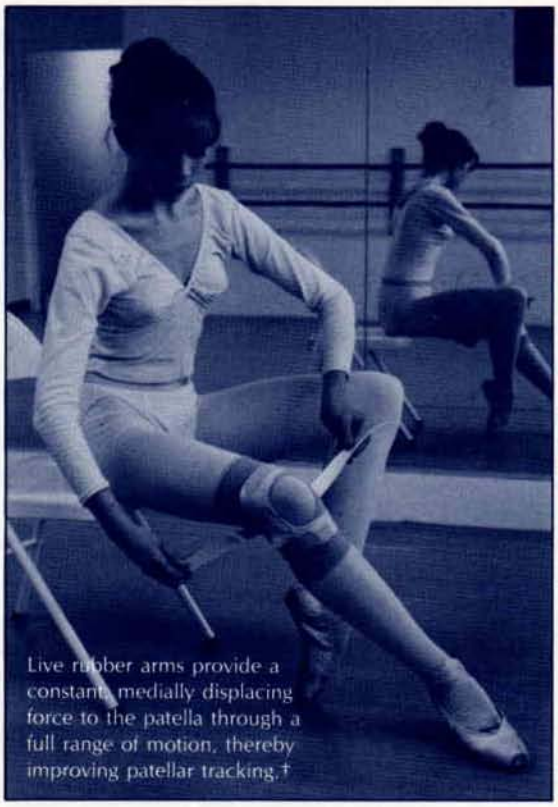

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Static Rotational Control Cervical Orthosis for the Treatment of Congenital Muscular Torticollis and Associated Plagiocephaly and Hemihypoplasia

Barry Townsend, B.S., C.P.O.

INTRODUCTION

Numerous theories have been advanced to explain the etiology of Congenital Muscular Torticollis (CMT), also known as Sternomastoid Fibrosis. Most prominent among these theories are molding and positioning of the fetus in late uterine life and injuries sustained to the sternomastoid muscle during birth. In late uterine life, if the fetal head is obliquely constrained for a prolonged time the sternomastoid muscle can be damaged through intermittent venous occlusion.[1] The incidence of obstetrical difficulties and traumatic deliveries is too low to implicate birth injury as a cause for Sternomastoid Fibrosis.[6]

Three forms of Sternomastoid Fibrosis are encountered in pediatric practice; first, a so called sternomastoid "tumor," usually seen in infancy; second, diffuse fibrosis, without localized tumor, also seen in infants; and third, established torticollis seen in older children. Torticollis in older children due to Sternomastoid Fibrosis is most likely the outcome of fibrosis which began in utero.[6]

Histological features of Sternomastoid Fibrosis indicate degenerative changes of muscle fibers with deposition of fibrous connective tissue. The amount of fibrosis within a certain muscle is highly individual and is directly correlated to the severity of the torticollis. Clinically, in 75% of all cases involving sternomastoid tumor, the tumor disappears by six months of age.[6]

DIFFERENTIAL DIAGNOSES FOR TORTICOLLIS

Postnatal torticollis may also result from other differential diagnoses. These are:

1) Postural Torticollis: Probably due to persistence of the position of the fetus in utero. The sternomastoid muscles in this case are normal.

2) Cervical Hemivertebrae: Produces torticollis in which the limitation of rotation is not due to tightness of the sternomastoid muscle. Instead, the limited range of motion is produced by a skeletal vertebral anomaly.

3) Delayed neuromuscular coordination may produce torticollis: This is especially true in infants between three and eight months of age.

4) Cerebral Palsy: With unilateral or regional hypertonia, can cause persistent rota-

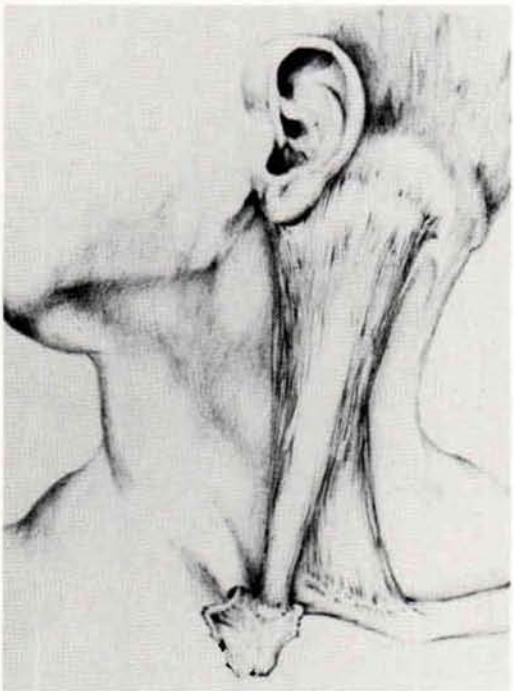

Fig. 1—Sternomastoid muscle showing origin, insertion and action.

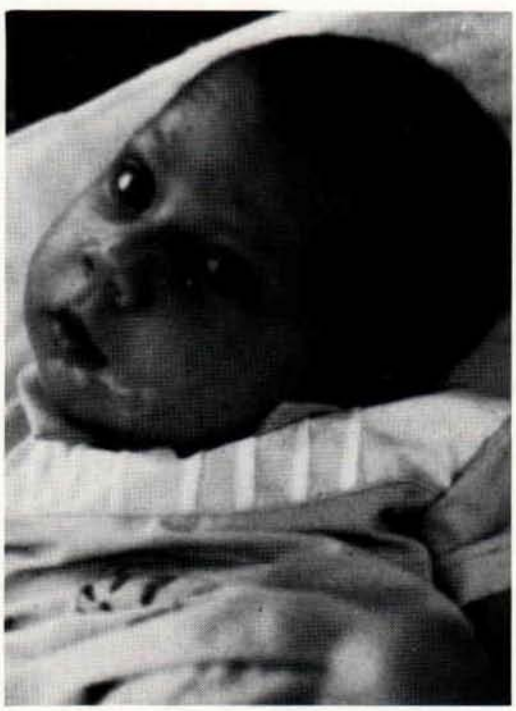

Fig. 2.—This is a one and one-half month old infant suffering from left sternomastoid fibrosis.

tion of the head to one side causing torticollis.

5) Ocular Torticollis: Many different types are seen clinically. This type is not present in early infancy since compensatory postural adaptations normally do not appear before ocular fixation.

REVIEW OF ANATOMY

The sternomastoid muscle is the largest muscle in the neck (Fig. 1). It is thick and narrow at its central part but broader and thinner at either end. It originates at its distal end by two heads. The sternal head has its origin on the anterior surface of the manubrium and the clavicular head on the upper surface of the medial one third of the clavicle. These heads blend below the middle of the neck to form a round thick muscle which inserts on the lateral surface of the mastoid process and superior nuchal line of the occipital bone. The function of the muscle, when it contracts individually, is to laterally flex the head in one direction and rotate it in the opposite direction, pointing the chin cranially.

Figure 2 shows the effects of a shortened, fibrotic, left sternomastoid muscle in a one and one-half month old infant suffering from CMT. Torticollis is defined as being lateral inclination of the head to the affected side and rotation in the opposite direction.

The main consequence of CMT in a zero to six month old infant is the decrease in neck rotational range of motion. This decrease in neck rotation has several secondary effects:

- Wasting of ipsilateral trapezius: may be very marked.
- Plagiocephaly: true facial asymmetry as seen from the vertex.
- Hemihypoplasia: true facial asymmetry as seen from the front.
- Spontaneous Involuntary Compensation: postural adaptations for torticollis.

DEFORMITIES

Figure 3 is a posterior view of a five month old infant suffering from left Sternomastoid Fibrosis. Please note the following conditions:

- Wasting of upper fibers of left trapezius, since the upper fibers of the trapezius laterally flex the head in one direction and rotate the head in the opposite direction. It works in unison with the sternomastoid muscle on that side. Inability to use the sternomastoid muscle results in disuse atrophy.
- Asymmetry of neck folds.
- A bald spot on the infant's right, flattened posterior parietal eminence. When this infant was placed in the supine position, he was constantly bearing weight on this area of the head which caused the hair to be rubbed away.

Figure 4a is a diagram of true plagiocephaly as seen from the vertex. The plagiocephalic skull usually exhibits deformities such as a bulged posterior parietal eminence that is situated more posterior than normal. The ear on the side of the flattened frontal area is also situated more posteriorly. Referring to Figure 4a, A plus B equals the width of the face as viewed from the front. The width of A, the flattened frontal area is usually larger than B, the bulged side. The long axis (P) of the cranium is displaced from the sagital plane, to the right or left, depending on the affected side. It is therefore a quadrilateral asymmetry which involves both right and left hemicrania and both frontal and occipital regions. The flattened frontal area is always on the same side as the affected muscle. For example, this figure is for right Sternomastoid Fibrosis.

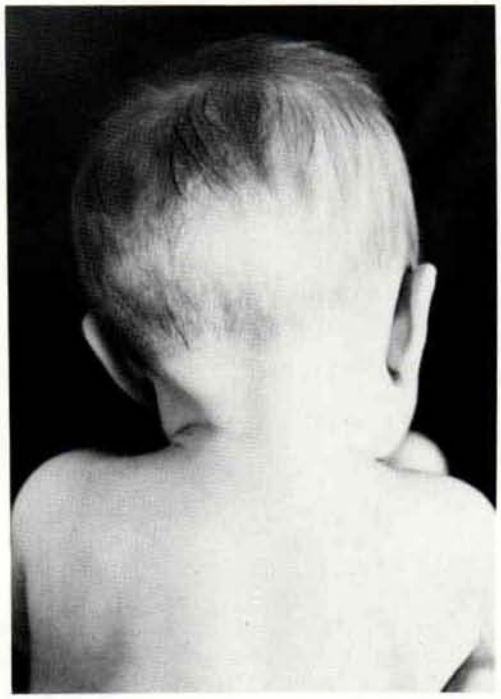

Fig. 3.—Posterior view of a five month old infant suffering from left sternomastoid fibrosis.

Figure 4b shows a photograph of a left Sternomastoid Fibrosis: Note the associated asymmetries.

Plagiocephaly can be congenital, deformational plagiocephaly, or it can be acquired after birth as the result of torticollis. In this latter case, the direction of rotation determines the shape of the cranium.

In the Oxford Child Health Survey[6] plagiocephaly was found in five percent of infants between birth and one year of age. Twenty-one of these infants were reexamined ten years later and in 19 (90%) plagiocephaly of some degree was still present. In an additional study of 35 infants by Peter Jones, plagiocephaly was found to persist in 58% of the infants after a six and one-half year period.[6]

Deformational plagiocephaly will resolve spontaneously in most infants, especially in the absence of torticollis. However, in some cases these deformities may persist into adulthood as a mild to severe cosmetic disability.[3] The removal of postnatal deforming forces such as torticollis will not always ensure a return of craniofacial symmetry. In one long-term follow up study of children treated with surgery for torticollis, early muscle resection did not result in a higher percentage of patients with normal shaped heads.[8]

Dr. Peter Jones offers the following hypothesis as a possible explanation for acquired plagiocephaly.[6] In the first six months of an infant's life, before he can sit erect, the head is constantly in contact with some part of the environment. In an infant with CMT, there is little or no variation in the position of the head. For example, an infant with left Sternomastoid Fibrosis, who cannot rotate his head to the left comfortably, will bear his weight while in the prone position on the left frontal lobe and while in the supine position on the diagonal right posterior parietal

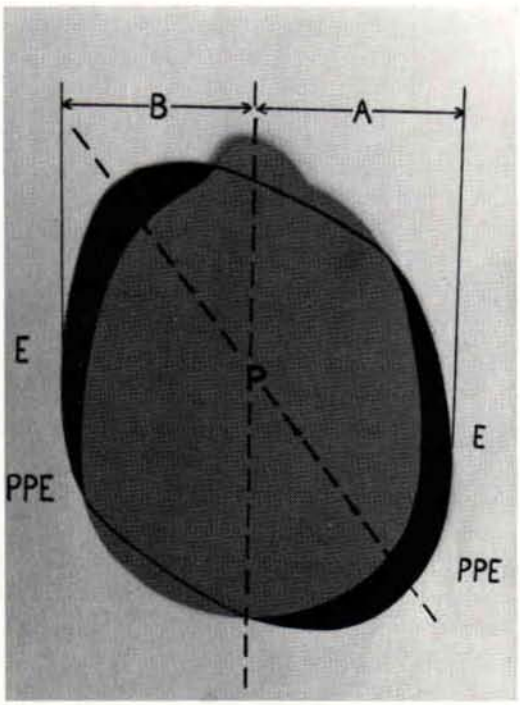

Fig. 4a.—Diagram of true plagiocephaly as seen from the vertex. P: long axis of the cranium; PPE: posterior parietal eminence; E: site of external ear; A and B: width of face as viewed from the front. This diagram shows a normal shaped head in gray and a rhomboid shaped head in black.

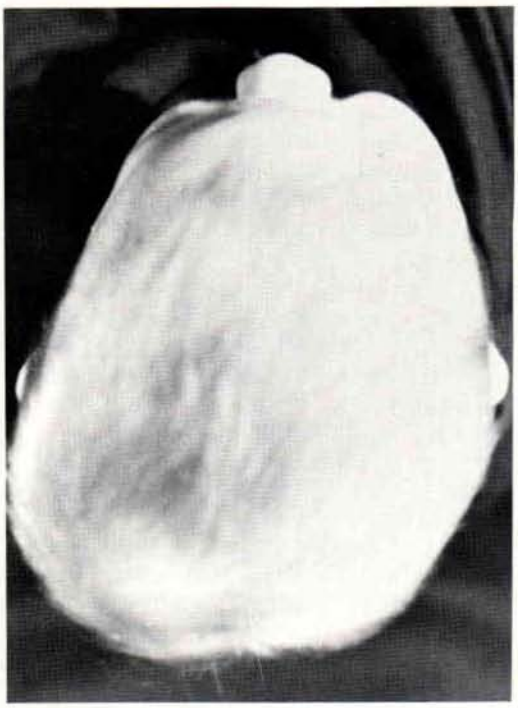

Fig. 4b—Photograph of infant showing opposite isomer. Note frontal and maxillary "horizons" with concordant asymmetry.

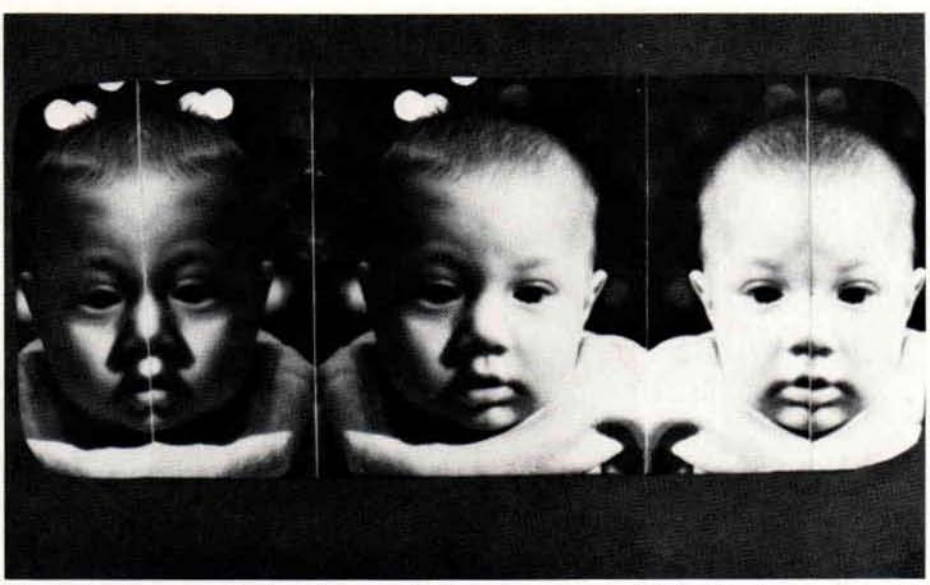

Fig. 5—Photographs of infant showing facial asymmetry associated with plagiocephaly. The middle face (B) is the normal. The right face (C) is a composite of two right halves and the left face (A) is a composite of two left halves.

eminence. The head consequently assumes a rhomboid shape. Clinical observations support Jones' hypothesis because as the infant starts to sit up, the deforming forces, i.e., the effects of gravity, are removed and the head starts to assume a more spherical shape. Dr. Jones also proved that deformation by gravity was possible. He molded one kilogram (kg.) of molding putty into an elliptical sphere resembling the shape of the human cranium. A match was inserted as an anterior midline marker. He then heated the putty to 22° C and placed the mass of putty on an unyielding horizontal surface so that the long axis of the mass inclined 45°. In 15 seconds, the exact shape of a plagiocephalic skull developed.

The brain in the newborn weighs approximately .75 kg. and has even greater plasticity and compliance with gravitational force than putty. The cranium of the neonate is two to three millimeters thick and largely membranous. It is therefore possible that acquired plagiocephaly in infants with persistent rotation of the head to one side may be caused by directing the force of gravity in such a way that pressure is exerted by the brain on a specific segment of the cranium, imprinting upon it the shape of the plagiocephaly from within.

Walter, in other clinical observations in 1929, reported an extraordinary experience with one of his patients with torticollis. In this patient post-operative retention of the head in an over-corrected position in a plaster cast of the head and neck region was unduly prolonged for 17 weeks. As a result, the plagiocephaly and hemihypoplasia were found to have been transferred to the opposite side when the plaster was removed.

It has been suggested in the literature that if the child sleeps prone, facial asymmetry will increase and if he sleeps supine, cranial asymmetry becomes more pronounced.[3] Figure 5 shows the facial asymmetry which is associated with plagiocephaly. Note the flattened left frontal lobe and bulged right frontal lobe and cheek.

The next secondary effect of torticollis is hemihypoplasia. This term is defined as true facial asymmetry on the side of the affected muscle. The contour of the cheek is flatter, and the vertical height of the face is diminished while the horizontal width is usually greater. Plagiocephaly contributes to the width and horizontal aspects while hemihypoplasia contributes to the vertical aspect. The height of the face is defined as being the distance between the supraorbital ridge and the maxillary alveolus, i.e., eyebrow to top teeth (Fig. 6).

The mechanism by which sternomastoid torticollis produces hemihypoplasia has not been explained. Hemihypoplasia usually develops in patients whose torticollis persisted beyond the age of six months. The earliest age at which true facial hemihypoplasia was seen to develop was seven to eight months. There is not a close correlation between the severity of torticollis and the degree of hemihypoplasia. This condition does improve after surgery and no improvement in facial asymmetry is to be expected after the age of 18–20 years.

The last deformities seen in CMT are postural adaptations or spontaneous involuntary compensation for torticollis. Between

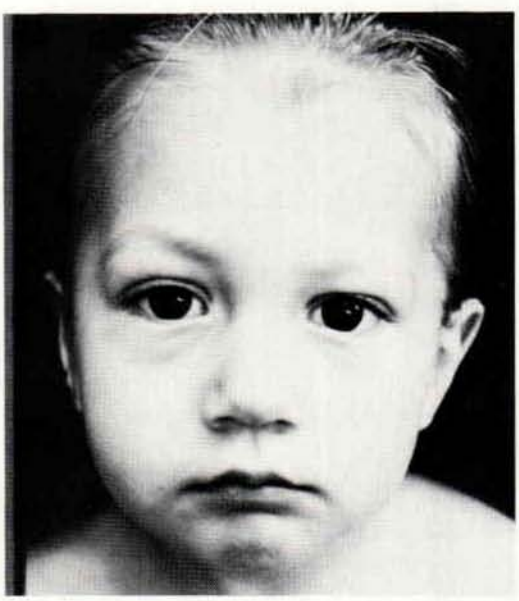

Fig. 6 – A photograph of hemihypoplasia in a two year old infant suffering from left CMT.

four and six months of age as the infant begins to sit erect a lateral inclination of the head is seen. As the infant develops there are two ways in which spontaneous involuntary compensation for sternomastoid torticollis could occur:

1) elevation of the affected shoulder and
2) lateral shift of the head towards the affected side (Fig. 7a and 7b). Both of these maneuvers are an attempt to relieve the tension on the sternomastoid muscle.

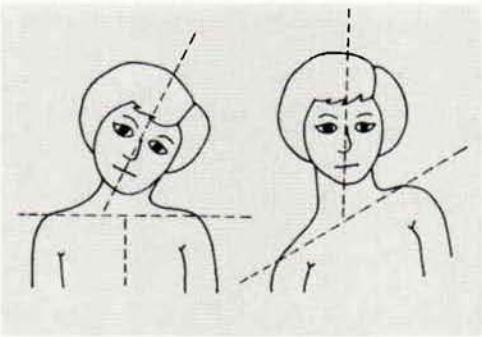

Fig. 7a – Elevation of affected shoulder.

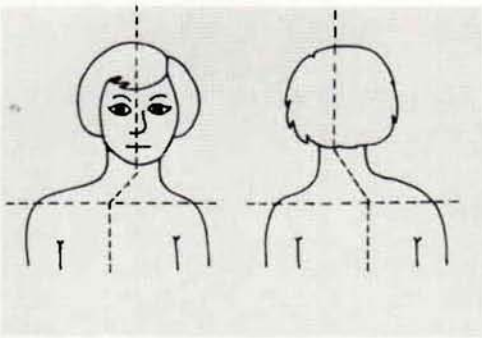

Fig. 7b – Lateral shift of the head toward affected shoulder.

ORTHOSIS DESIGN

A static rotational control cervical orthosis has been designed to stretch a fibrotic sternomastoid muscle (Fig. 8). There are two sections to the static rotational control cervical orthosis. The head section has asymmetrical trim lines which are dictated by the side the affected sternomastoid muscle is on and the thoracic section which is trimmed in a symmetrical fashion. The head section of the orthosis has an anterior projection on the side opposite the affected muscle. The projection functions to push on the xygomatic arch of the bulged side and not to push on the mandible on that same side. The head section of the orthosis also incorporates a posterior projection on the same side as the affected muscle. The anterior and posterior projections work together to prevent the infant from rotating his head in the direction of the affected sternomastoid muscle.

The head section and the thoracic section are interlocked in virtually any degree of rotation by a ring of ⅝" wide Velcro (Figs. 9a and 9b). This freedom of rotation allows treatment to begin in a neutral rotation position, and progressively stretches a tight sternomastoid muscle by slowly increasing rotation. In addition, while the child is lying prone or supine he will pick up weight bearing on the bulged posterior parietal eminence and the bulged anterior frontal lobe and face thereby allowing the effects of gravity to successfully remold the plagiocephalic head into a more normal shape.

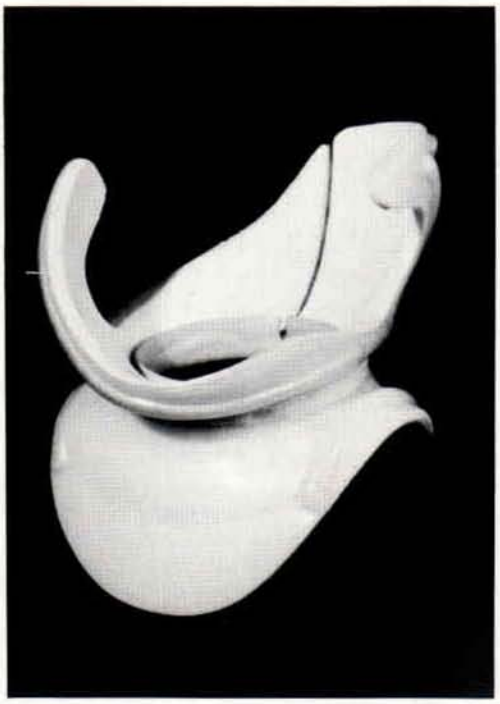

Fig. 8 – Static rotational control cervical orthosis.

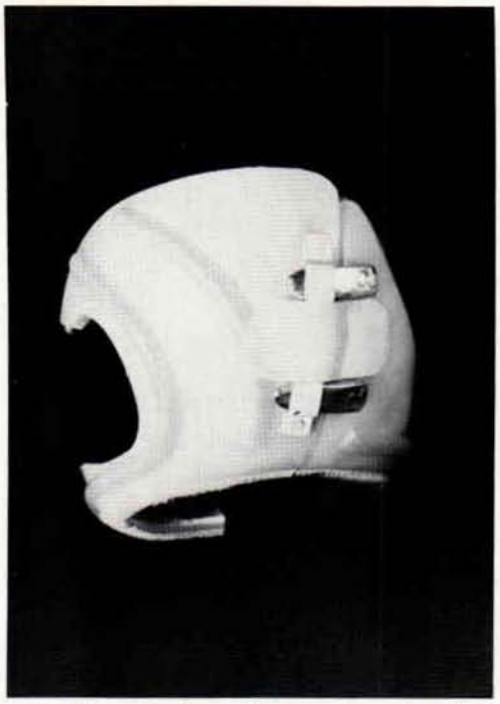

Fig. 9a – Posterior view of head section of orthosis showing slide interlock keepers and ring of Velcro.

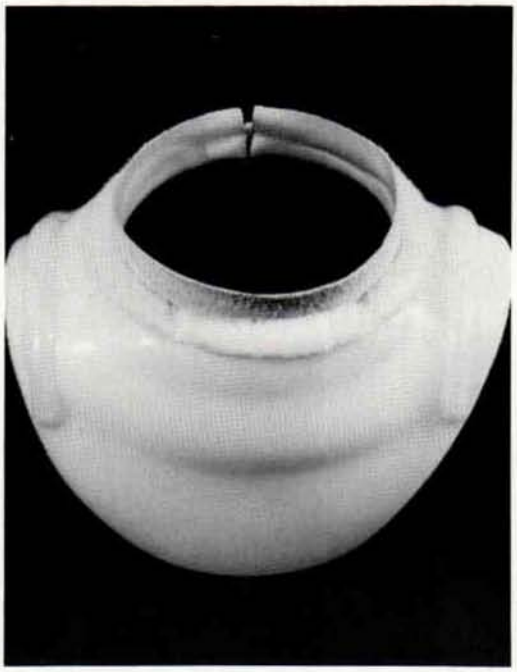

Fig. 9b – Anterior view, thoracic section. Shows ring of Velcro and Kip leather glued to the inside of the thoracic section. This leather functions to protect the patient's skin when the head section is rotated on the thoracic section.

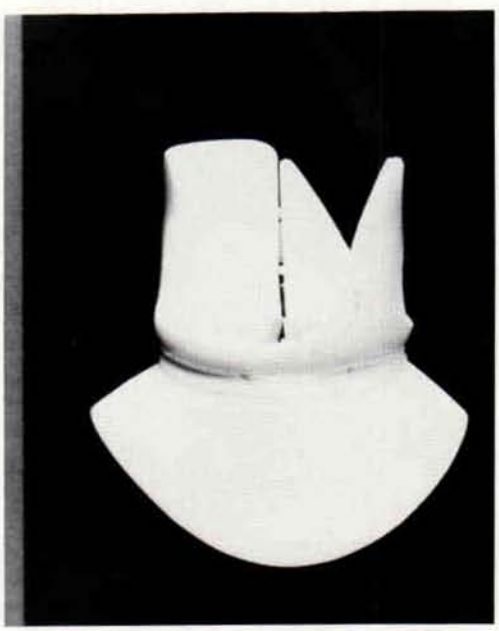

Fig. 10 – Anterior view cervical orthosis without reinforcing corrugations.

Design Modifications

Some changes were made to the original design to create the current orthosis. The first design incorporated three-sixteenths of an inch cotton rope to make reinforcing corrugations on the head anterior and posterior projections (Fig. 8). The original theory was that the sternomastoid muscle would have to be forcibly stretched. However, after treatment of one infant it was found that this is not the case. A second orthosis was fabricated without corrugations and this modification made fabrication easier and did not hinder the effectiveness of the overall treatment (Fig. 10).

Two modifications to the anterior projection were made in the second design which makes treatment much more effective. Figure 11 shows the removable anterior projection with its slide interlock keepers and Velcro straps. The anterior projection is removed when the child lies in the prone po-

sition making him bear weight on the entire aspect of his face and frontal lobe. This, in theory, should cause the anterior craniofacial deformities to disappear more quickly. At this point, the orthosis has lost one of its counter rotation projections and if the infant can rotate out of the orthosis he will have to have his sleeper firmly pinned to this mattress to limit movement during sleep.

Figure 12 shows the second design modification of the anterior projection. This cervical orthosis was prescribed for a four year old male who has spasmodic torticollis of unknown etiology. The forces required to stretch a spasmodic sternomastoid muscle are much greater than the forces needed to stretch a fibrotic sternomastoid muscle. The anterior projection is reinforced with one-eighth inch thick aluminum. The reinforced anterior projection can be contoured in such a fashion that the patient is assured of receiving rotational corrective forces on the xygomatic arch only and not on the mandible of the same side.

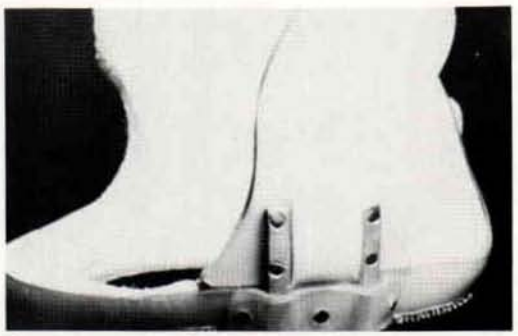

Fig. 11 – Anterior lateral view showing removable anterior projection.

After the first static rotational control cervical orthosis had been in use it became readily apparent that a final modification was necessary to aid in the donning and doffing of the orthosis. The head and thoracic sections were cut into two equal halves in the mid-sagittal plane. Four piano hinges were then attached to the posterior aspect of the head and thoracic sections (Fig. 13). Slide interlock keepers and Velcro closures were attached to the anterior aspects of both head and thoracic sections (Fig. 12).

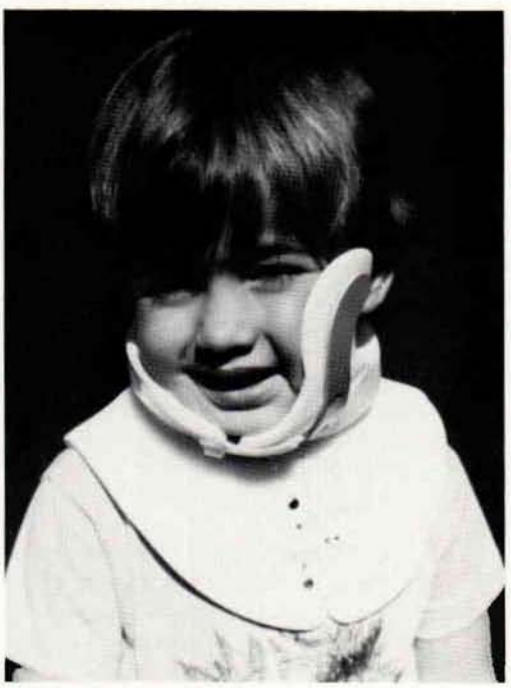

Fig. 12 – Anterior view cervical orthosis showing reinforced anterior projection, slide interlock keepers and Velcro straps.

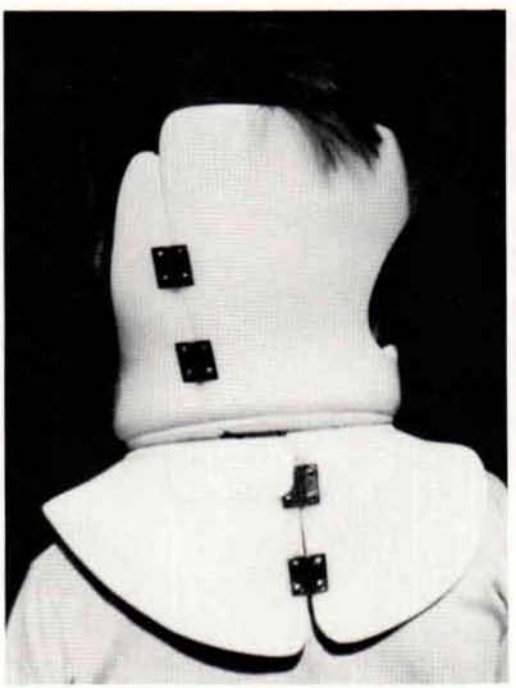

Fig. 13 – Posterior view of static rotational control cervical orthosis showing four piano hinges.

NEGATIVE IMPRESSION PROCEDURE

If possible, the infant should be sedated prior to casting.

To obtain a cast impression for the cervical orthosis, a modified turtle neck shirt was fabricated and worn by the patient. A piece of one-quarter inch thick cotton felt, three-quarters of an inch wide, was placed on the neck of the patient and stapled posteriorly. A cast removal strip was applied posteriorly. The proximal right and left anterior sections of the sock were then stapled together (Figure 14). The shirt was made long enough so the distal anterior and posterior sections could be stapled together between the patient's legs. The following landmarks were then identified with a transfer pencil: right and left cars, clavicles, and right mandible.

To obtain a negative impression, circumferential wraps of elastic plaster bandage were molded on the head and neck areas of the patient. An effort was made to keep the wraps distal in the anterior left section and more proximal in the posterior left and anterior right sections. Flexible plaster splints twelve inches long and three layers thick were applied from anterior to posterior to continue the mold distally to obtain an impression of the shoulder and thoracic areas. Care was taken to assure that the infant's head and neck were held in a neutral position (Fig. 15). Finally, Figure 16 shows the impression removed and plaster trim lines kept proximal in the anterior right and posterior left regions.

Fig. 14 – Infant in modified turtle neck shirt.

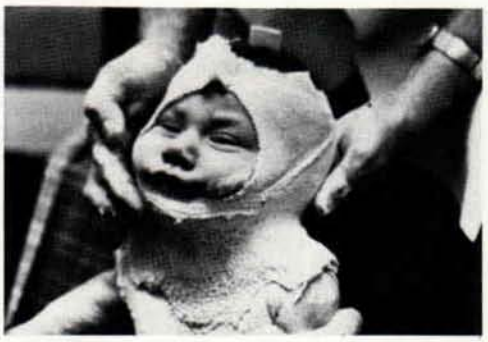

Fig. 15 – Infant in plaster. Every effort should be made to take the negative impression with the head and neck held in neutral position.

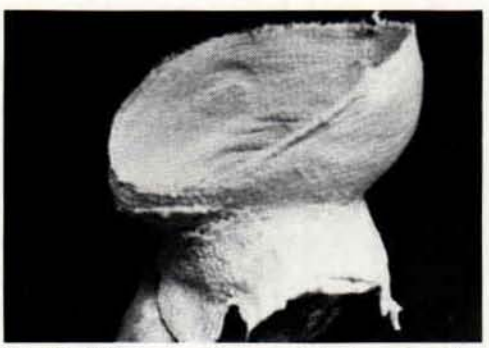

Fig. 16 – Efforts should be made to keep the plaster wrap proximal in the areas where the anterior and posterior projections are to be located.

POSITIVE MODEL MODIFICATIONS

Remove the neck ring (cotton felt) from the negative impression. Fill the impression with plaster of paris. Place the pipe mandrel in the thoracic section of the model; it should not extend proximally into the neck region of

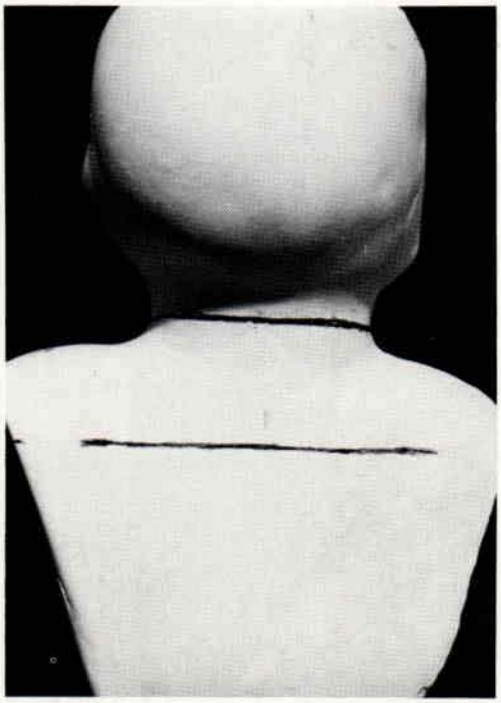

Fig. 17a,b,c – Transverse plane is identified in mid-neck region of positive model.

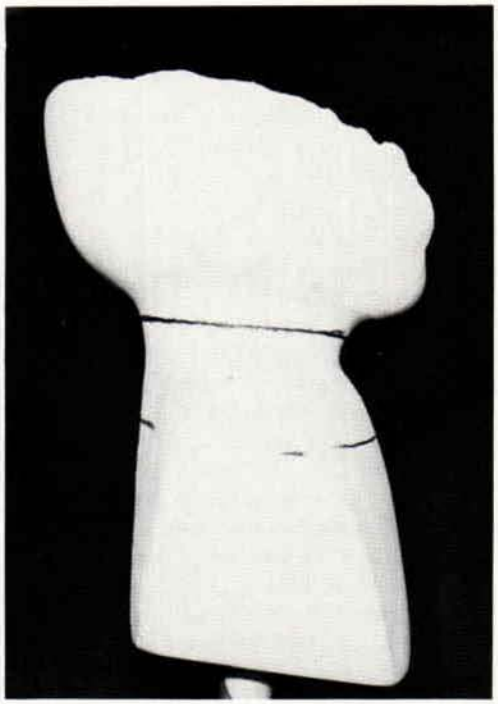

Fig. 17b

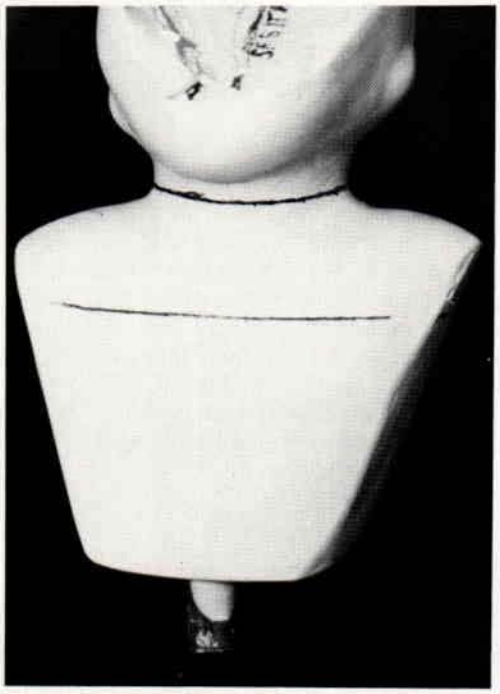

Fig. 17c

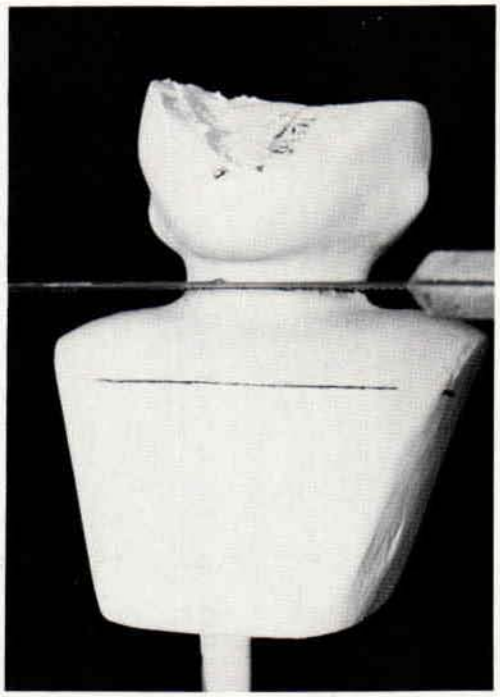

Fig. 18 – The positive model is bisected in the transverse plane.

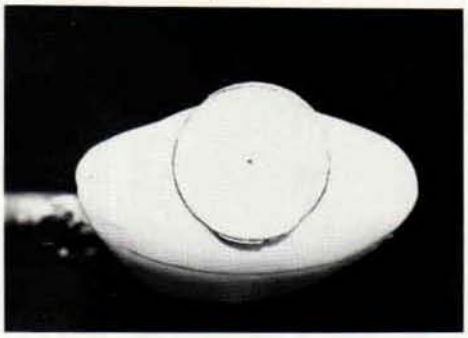

Fig. 19a,b – Vertex view of transverse plane on thoracic section and (b) head section.

the model. Smooth the positive model and add reliefs to the clavicular and mandibular and chin areas. A generous relief is needed in the mandibular area and slight build-ups are needed in the other areas.

Modify the neck section of the positive model as round as possible and bring it to the average dimension between the patient's neck M-L and neck A-P measurements plus three-eights of an inch; this is the inside neck measurement. A wire of solder wrapped around the neck area gives an exact shape of the model.

Remove additional plaster from the bulged posterior parietal eminence. In the mid-neck area of the model the transverse plane must be identified and marked with an indelible pencil (Fig. 17 a, b, c). The transverse line previously drawn acts as a saw line and the neck section of the model is separated from the head section (Fig. 18).

The exact centers of the neck areas are identified on the thoracic and head sections. A circular compass is used to scribe a circle of equal radius on both thoracic and head sections (Fig. 19 a and b). This line functions as a guide when modifying the positive model impressions into two equal circles. These are equal to the inside neck measurement.

A transverse plane slice approximately one-eighth of an inch thick is removed from the thoracic and head sections of the model. Removing this plaster allows for the thickness of the Aliplast lining and plastic cover (Fig. 20).

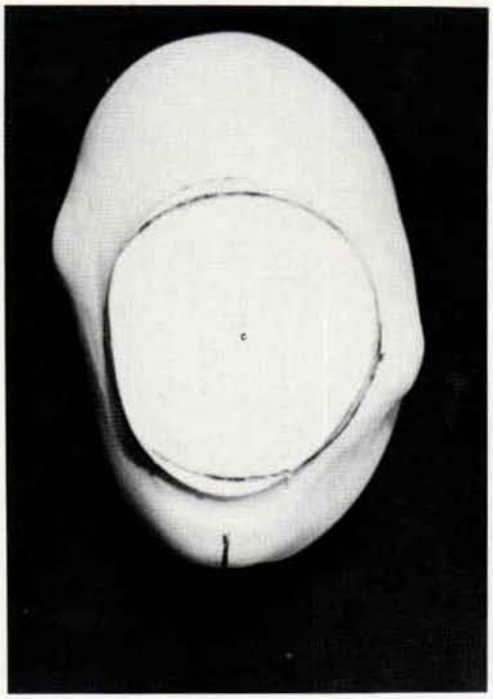

Fig. 19b

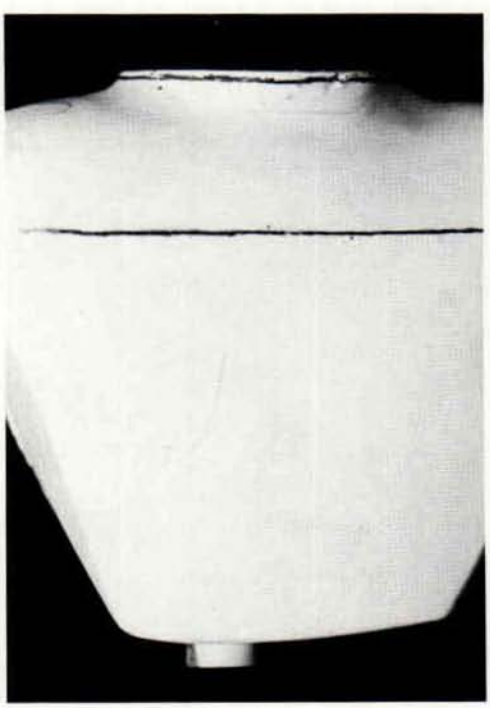

Fig. 20 – 1/8" of plaster is removed from transverse plane on both thoracic and head sections.

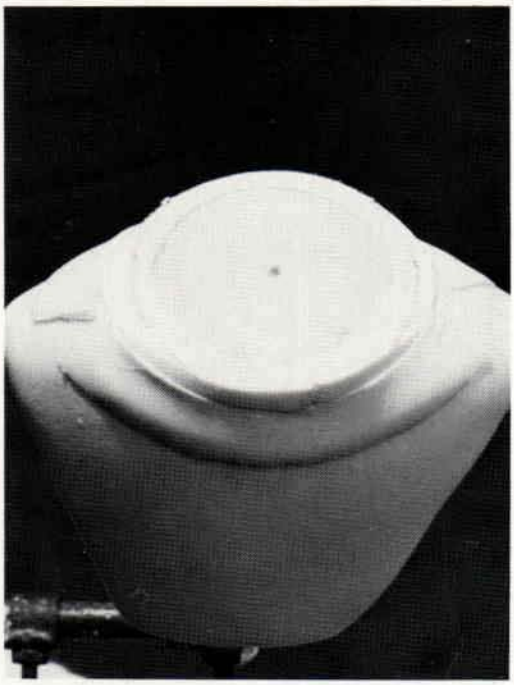

Fig. 21—Three or four layers of 1/4" thick Aliplast are successively glued around the anterior, posterior and lateral aspects of the positive model.

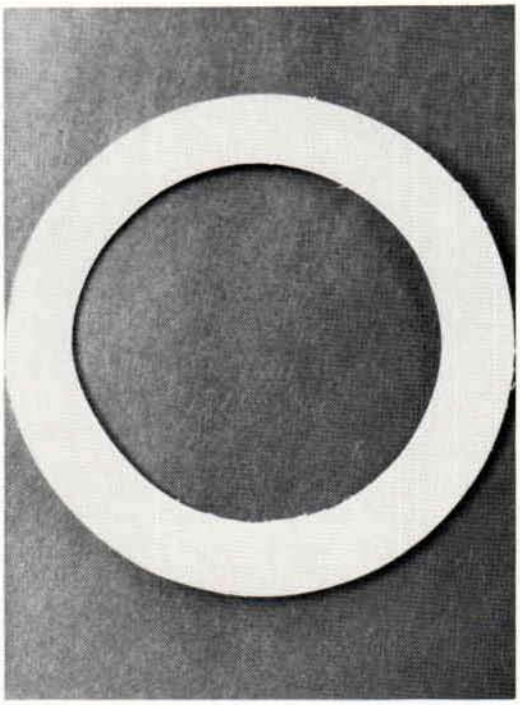

Fig. 22—This picture shows a circle of 3/4" wide, 1/16" thick high density polyethelene with the inside neck diameter equaling the inside neck radius of the model. This plastic is glued to the vertex aspect of the thoracic and head sections.

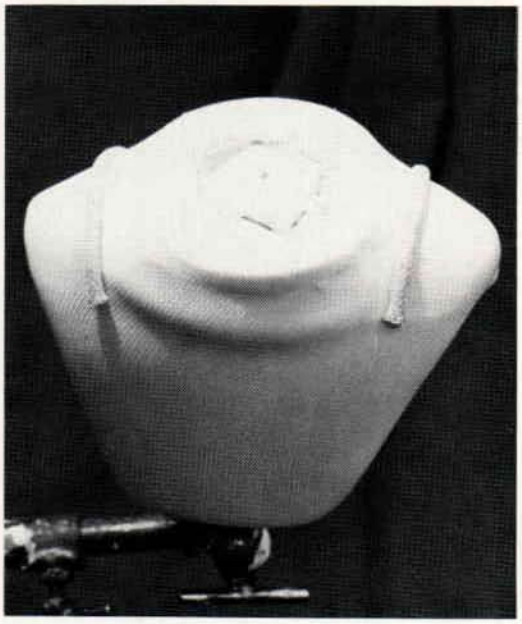

Fig. 23—The model is now ready for vacuum forming.

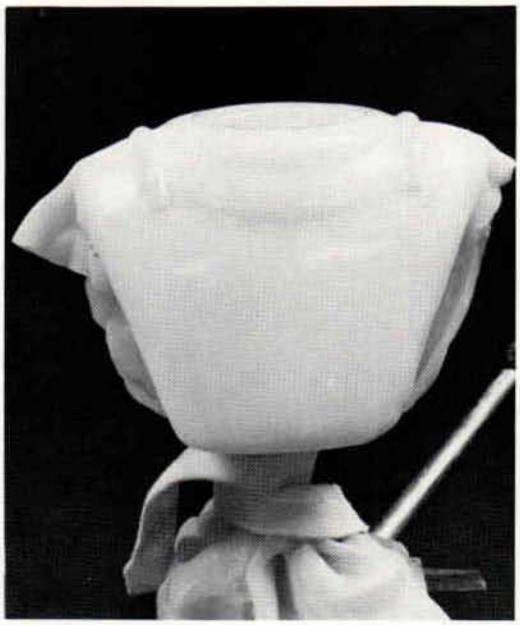

Fig. 24—1/8" thick low density polyethelene is vacuum formed over the model.

Thoracic Section Fabrication

Aliplast lining (⅛″) is heated in the oven and pulled over the thoracic section of the model, after which the lining is built up with three or four layers of ¼″ Aliplast. These successive layers of Aliplast provide a build up which is approximately ¾″ larger in radius than the inside neck radius that was previously drawn. This build-up is then ground parallel to the transverse plane and made as flat and as thin as possible (Fig. 21).

Cut out a circle of ¾″ wide and 1/16″ thick high density polyethelene with the inside diameter equaling the inside neck measurement of the model (Fig. 22). Center this plastic and glue it with polyadhesive to the proximal aspect of the model. The function of this plastic ring is to keep the ¾″ Aliplast build-up from collapsing when the model is finally draped and vacuum formed.

White tube-gauze stockinette is stapled in the center of the neck region and then pulled over the model and secured to the mandrel which has been prepared for vacuum forming (Fig. 23). In the initial orthosis design 3/16″ cotton rope was used as corrugation material; this step is not necessary. Next, ⅛″ low density polyethylene is vacuum formed over the model (Fig. 24).

Head Section Fabrication

To accommodate a pipe mandrel, a ¾″ hole is drilled in the center of the vertex aspect of the head section. One-quarter inch thick Aliplast is then heated in the oven, pulled over the model, and stapled into position.

Build up three layers of ¼″ Aliplast around the neck region to equal a circle exactly ¾″ larger in radius than the actual inside neck model measurement. This build-up is then ground parallel to the transverse plane. The additional Aliplast material, which is located outside the ¾″ build-up is removed by using a felt cone (Figs. 25 and 26).

Cut out a circle of ¾″ wide, high density polyethylene with the inside diameter equaling the inside neck measurement of the cast. This is glued with polyadhesive to the model. Tube gauze or white IPOS stockinette is then pulled over the model and secured to the pipe mandrel which has been prepared for vacuum forming. Vacuum form ⅛″ high density polyethylene over the model.

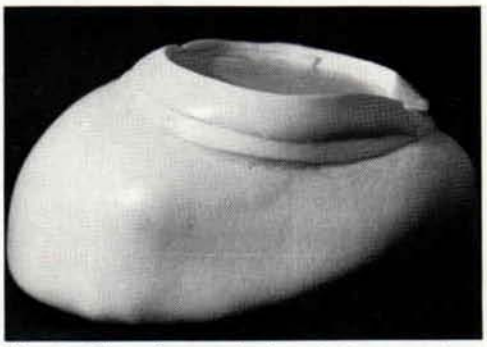

Fig. 25 – Three layers of 1/4″ Aliplast are glued around the anterior, posterior and lateral aspects of the model.

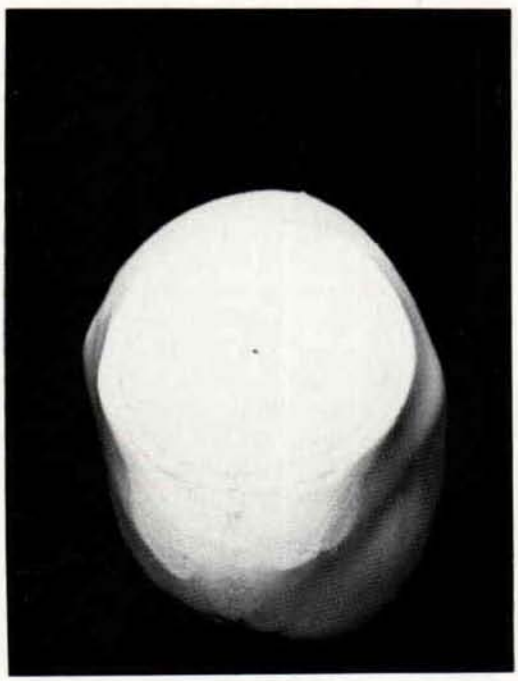

Fig. 26 – The excess material is ground flat and parallel to the transverse plane.

Trim Lines for Head and Thoracic Sections

Locate the anterior projection of the proximal section so it will press on the xygomatic arch and avoid pressure on the ear. Trim the

lower portion of the anterior projection so as not to cramp the mandible on that side.

Trim the posterior projection as close to the ear as possible since the ear on that side of the orthosis is sometimes located more posteriorly, and, with correction, will move anteriorly. As the ear moves anteriorly, modifications to this area of the orthosis may be necessary to keep an intimate fit. The posterior trim line on the posterior projection swings distally just after the mid-sagittal line.

Trim the thoracic section in a symmetrical fashion without inhibiting any horizontal glenohumeral flexion. Leather (Kip or Elk) may be glued to the inside thoracic neck section. This functions to protect the infant's skin from being scratched when the head section is applied and rotated.

CASE REPORT

TJT is a male Caucasian. He was born healthy via an uncomplicated vertex delivery. When TJT was about two weeks old the mother noted that he preferred to sleep in the prone position with his head rotated to the right. At five weeks the mother observed a lump in the left side of the baby's neck. At five and one-half weeks the pediatrician found a small, hard tumor in the left sternomastoid muscle. The tumor was one centimeter in length and width and occupied only part of the muscle. Torticollis was present at this time with passive rotation to the left reduced to 40° (normal is 90°). Plagiocephaly was noted and stretching exercises were prescribed.

At 11 weeks TJT was seen by an orthopedist and X-rays were taken to determine if a hemivertebrae condition existed; it did not. At this time there was no marked increase in rotation to the left and plagiocephaly had increased. The parents were instructed to put the infant down to sleep on either side alternately, avoiding the supine and prone positions.

The parents were also instructed to always approach the infant from his left side thus making him rotate his head to the left, stretching the tight left sternomastoid muscle. The stretching exercises were continued.

At 16 weeks, passive rotation to the left increased to approximately 45°-50°, while the plagiocephaly was much the same. A prescription was given for a static rotational control cervical orthosis.

At five months of age, the cervical orthosis was applied to TJT. At this time passive rotation to the left had increased to 50° while the plagiocephaly stayed much the same.

Initially, the cervical orthosis was worn by the patient while supine and sleeping in a neutral rotation position. Wearing time was dictated by the patient's tolerance for the orthosis. As TJT's tolerance for the cervical orthosis grew, his ability to accept stretching of the sternomastoid muscle also increased. Consequently, rotation to the left was increased daily. After wearing the orthosis for one week, TJT's passive rotation had increased to 65°-70°. At the end of the first week of wear, TJT contracted a low grade intestinal flu which caused him to vomit occasionally. As a result, the orthosis was removed for the duration of the sickness.

As orthotic treatment progressed, TJT's rotation in the orthosis increased until he achieved almost full rotation while wearing the orthosis (Fig. 27). At approximately seven

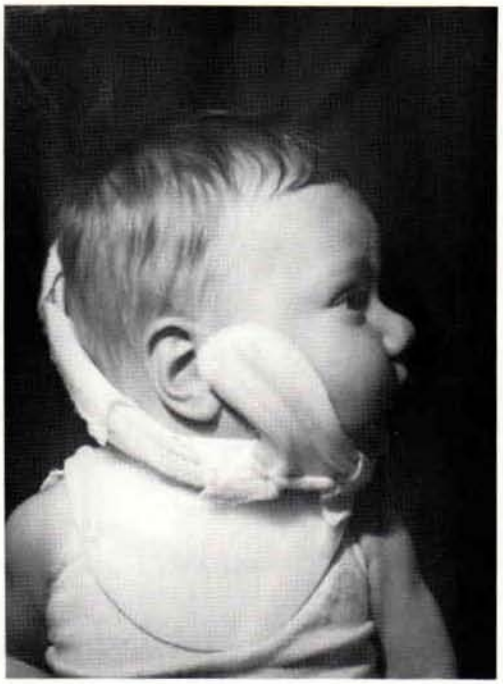

Fig. 27 – Picture showing infant at six months of age (one month into brace treatment) fully rotated towards the affected side.

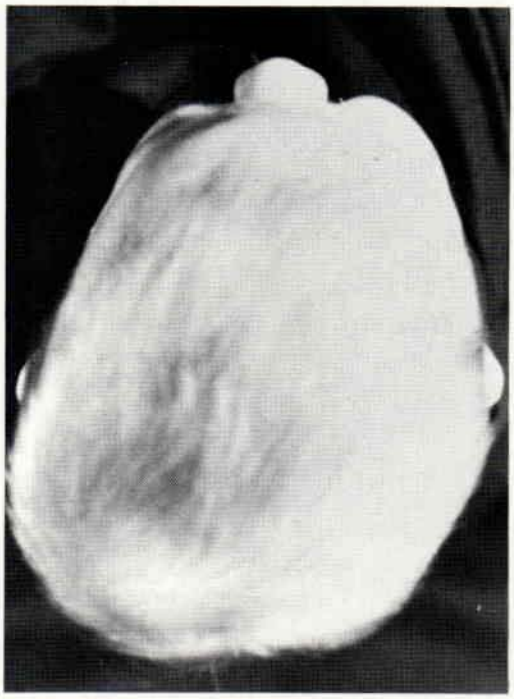

Fig. 28a – Comparative photos before and after treatment with the static rotational control cervical orthosis.

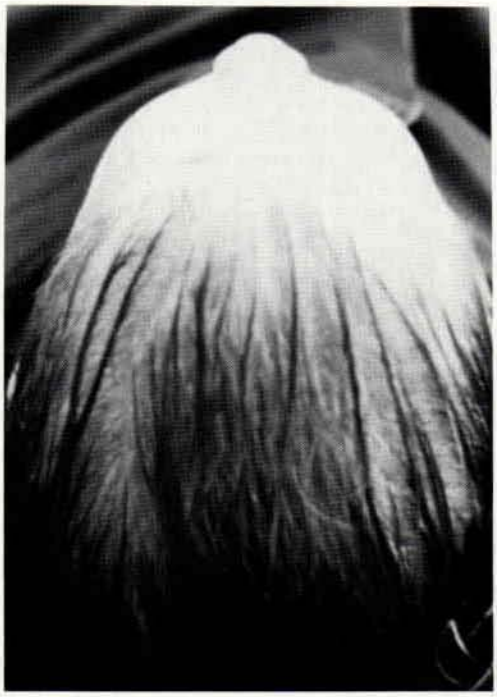

Fig. 28b – Left. Patient TJT at nine months of age, when orthotic treatment was terminated. Right, at two years of age only mild facial asymmetry is seen.

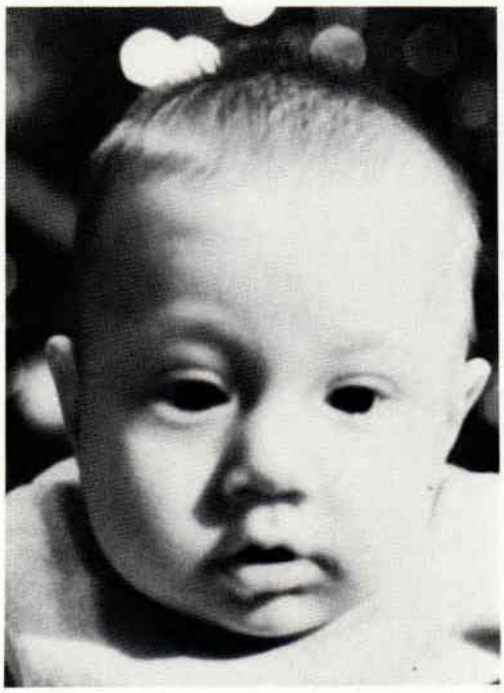

Fig. 28c

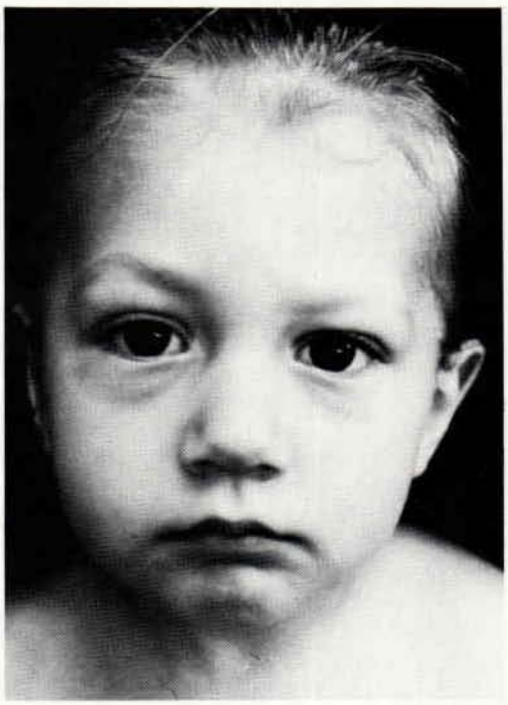

Fig. 28d

months of age TJT began balding on his left bulged posterior parietal eminence, and at eight months he began to show signs of an ulcer on this spot. Rotation was consequently changed periodically, i.e., maximum rotation applied one night and decreased to 40° the next night. The bald spot and ulcer were an indication that the cervical orthosis was indeed changing the weight bearing pattern on TJT's skull. This ulcer and bald spot could have been prevented if the removable anterior projection had been incorporated into his orthosis design and if he had been alternately placed in the supine and prone positions every other night.

At nine months of age, TJT began to roll from the supine to prone position while wearing the orthosis. Since it was undesirable for the infant to lay on the anterior projection the orthosis was removed and treatment was completed. At this time, cranial symmetry was achieved. Mild facial asymmetry did persist as can be seen in comparative photographs of the infant at two years of age (Figs. 28 a-b, c-d, and e-f).

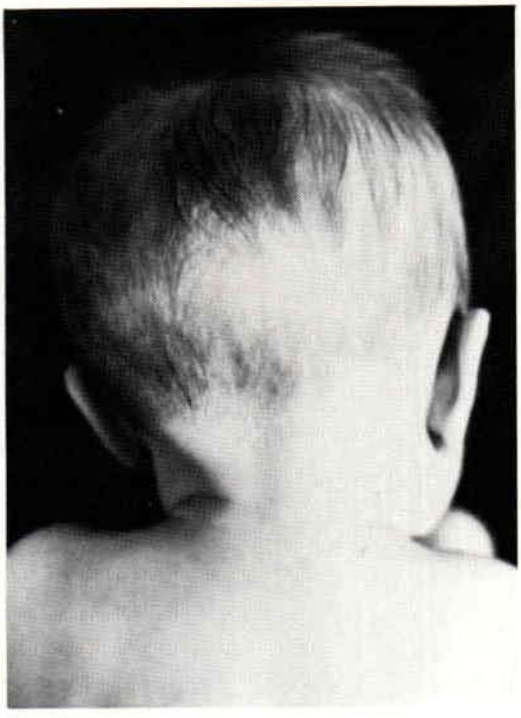

Fig. 28e

CONCLUSION

In this initial study, treatment has been safe and effective. In a patient undergoing static rotational control treatment between five and nine months of age, correction occurred within four months. In older infants, longer treatment periods should be anticipated because the skull is becoming less cartilagenous in nature.

It will not be known if the treated patient would have eventually spontaneously resolved his plagiocephaly. However, after removing the orthosis which TJT had worn for four months, very little spontaneous resolution has occurred. It is also believed that any remaining facial asymmetry could have been prevented by incorporating the removable projections into the original orthosis design.

A suggestion for the future is static rotational control treatment for all infants suffering from severe plagiocephaly and also for those in whom more moderate deformities persist for several months without any apparent spontaneous improvement. The orthosis may also be used in conjunction

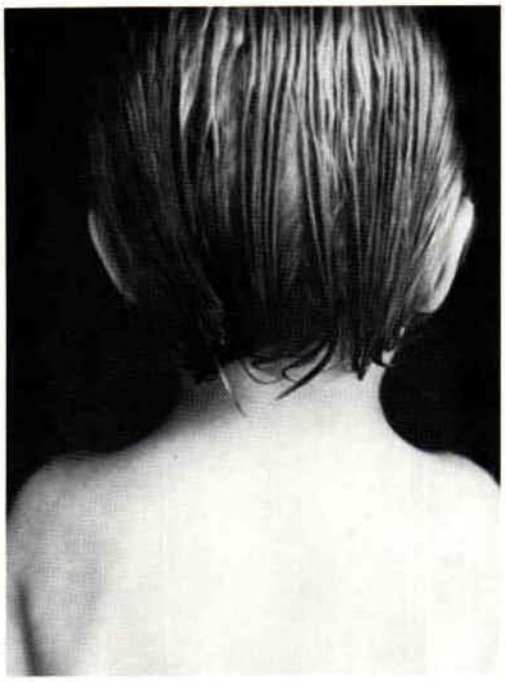

Fig. 28f

with surgery to improve the plagiocephalic condition.

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Comparing the Effectiveness of Elastic Bandages and Shrinker Socks for Lower Extremity Amputees

Kathleen J. Manella, B.S., R.P.T.

Delaying prosthetic fitting because of inadequate shrinkage of the residual limb is detrimental to and discouraging for the amputee. The delay is especially frustrating when the patient displays the ability to wrap the limb well and is conscientious about following the treatment program. This study was designed to evaluate the comparative effectiveness of elastic bandaging and elastic shrinker socks in decreasing residual limb volume.

Early prosthetic application and the prevention of contractures are the foremost priorities in the rehabilitation of the amputee.[1] In order to begin prosthetic rehabilitation, the residual limb must be well healed and nonedematous. Adequate supportive bandaging during the postoperative period should

1) act as a dressing.
2) remain securely positioned despite movement of the limb.
3) hold tissue to control edema, and
4) mold tissues to facilitate prosthetic fitting.

Optimum pressure gradients can be exerted that will control edema, support circulation, and minimize inflammatory reactions, all of which promote healing and are significant in the shaping of the residual limb.

Among civilians, the majority of lower extremity amputations are performed on elderly patients. Of these, 85 percent are secondary to ischemia produced by vascular disease.[1] The healing process in these patients is slow, and breakdown of the tissue further prolongs hospitalization and delays prosthetic rehabilitation.

Swelling is common and, in a postoperative limb, inevitable. However, the presence of swelling and the failure of the swelling to subside unfavorably influence rehabilitation. Compression of tissues is desirable; one of the greatest problems is the unavailability of an efficient dressing that will support, compress, and protect the limb.

Four basic types of compressive bandaging have been investigated:

1) soft dressings,
2) pneumatic appliances,
3) semirigid dressings, and
4) rigid dressings.

The elastic wrap bandage is a commonly used soft dressing. It is inexpensive and readily available. It has traditionally been

used despite its inability to maintain continuous snugness and the difficulty encountered in applying the wrap. The usefulness of this type of dressing in amputation management is controversial. The patient's application of such a bandage often leads to poor results and may have negative effects such as compromised venous flow and thromboembolism. Other types of soft dressings have been studied. Dowie investigated the plastic vinyl chloride bag as a primary dressing.[2] Sher recommended the shrinker sock as a secondary dressing.[3]

Various types of pneumatic devices have been developed in recent years. A pneumatic device permits adjustment of externally applied pressure as well as accessibility of the operative site for inspection. These devices have been recommended as an alternative dressing for cases in which a rigid dressing cannot be applied.[3-5]

Semirigid dressings include the use of a gel-impregnated dressing[6] and supportive bandaging described by Puddifoot and associates.[7] The application of a rigid plaster dressing immediately after surgery is widely supported as a method that hastens residual limb shrinkage and shapes the limb for prosthetic fitting.[8]

Of primary importance when considering a compressive bandage is the amount of externally applied pressure possible without compromising vascular supply. Husni and associates found that maximal venous acceleration and minimal inflow obstruction were attained at pressures of 15 to 20 mmHg.[9] Kosiak demonstrated marked susceptibility of tissue to relatively low constant pressures for short periods of time.[10] He observed microscopic evidence of edema and cellular infiltration when 50 mmHg was exerted over a two-hour period. Furthermore, sustained pressures in excess of 25 mmHg are potentially harmful.[11]

Husni and associates found that pressures of elastic bandages greater than 10 mmHg simulated a major venous occlusion, whereas, with an air splint, pressures up to 20 mmHg could be safely applied. This result was attributed to the tourniquet-like effect produced by the elastic bandage.[9]

Several studies have compared the effectiveness of various bandaging methods. Mooney and associates found that the greatest delay in prosthetic fitting occurred among amputees who used elastic bandages rather than rigid plaster casts.[12] The failure rate (limbs requiring below-knee revision) for the elastic bandage group was 22 percent, compared with 6 percent for the plaster cast group. Isherwood and associates[11] attempted to ascertain pressure distributions beneath the elastic wrap, the bandage described by Puddifoot and associates,[7] and the pneumatic application. The elastic wrap exhibited the greatest range of pressures (23–72 mmHg) as well as the majority of highest readings. Elastic bandaging, therefore, is unreliable and potentially dangerous in terms of pressure and pressure distribution.[11]

METHODS

Subjects

The subjects were 12 amputees with below-knee residual limbs. The five men and seven women ranged in age from 12 to 88 years. The mean age was 56 and the median was 63. Four basic criteria for acceptance were developed:

1) a well-healed incision,
2) a score of 9 on a 10-point scale of proper wrapping technique (Fig. 1),
3) availability for weekly measurements for four consecutive weeks, and
4) not more than 2.25 kg (5 lb) of weight change over the four-week test period.

The 10-point rating scale of wrapping technique was developed by the clinical staff therapists (Fig. 1). These 10 items were used to evaluate independence in wrapping procedures. During each week of the test period each item that the subject could perform independently was checked off. A total score was obtained by adding the number of checks recorded. The subjects were weighed at the beginning and end of the test period to ascertain maintenance of a stable weight throughout the four-week test period.

Of the 12 limbs, 10 (83%) had required amputation because of ischemia caused by diabetes mellitus or vascular disease. This proportion of amputations resulting from

ischemic disease closely parallels the percentage previously reported in the general population.[1]

The subjects were randomly assigned to two groups. One group used elastic bandages wrapped above the knee, the other group wore elastic shrinker socks* that extended above the knee. Instructions given to each subject were uniform and consistent. Each subject using the wrapping technique was instructed to begin the wrap at the lateral side of the limb and proceed anteriorly to the medial, distal side of the limb (Fig. 2). All items on the 10-point rating scale (Fig. 1) were emphasized. The instruction session was concluded when the subject consistently performed the steps of proper wrapping technique. The subjects using shrinker socks were instructed in their proper application. Total contact and proper suspension were emphasized. All subjects were instructed to reapply the dressing at least every four hours, and more often if necessary.

Procedure

An anthropometric technique designed to calculate segmental leg limb volume[13] was used to determine residual limb volume. The residual limb was partitioned into truncated cones (Fig. 3). The formula for volume of a truncated cone using circumference and height measurements is:

$$\text{Volume} = h/12\,\pi \times [C_1^2 + C_2^2 + (C_1)(C_2)]$$

For each truncated cone, C_1 is the proximal circumference, C_2 is the distal circumference, and h is the height (Fig. 3).

The total length of the below-knee residual limb was determined with a modified straight-edge ruler using the medial tibial plateau and the end of the tissue as the proximal and distal landmarks, respectively. These landmarks are easily palpable and correspond to those used to determine limb length for fabrication of a below-knee prosthesis.[8]

Circumferential measurements were recorded with Jobst† measuring tapes. The first tape was placed at the site of the medial tibial plateau. These tapes are spaced at a distance of 4 cm (1.6 in); therefore, the height of each

DATE				
1. Pressure decreases from distal to proximal				
2. Uses figure of 8 and oblique wraps only				
3. Even distribution of layers of wrap				
4. All areas are covered				
5. Wrap is secure and is properly anchored above the knee				
6. No wrinkling of bandage				
7. Re-wraps every 4 hours (patient report)				
8. No areas of highly concentrated pressure (redness)				
9. Pressure is *not* directed at the cut end of tibia				
10. Patient wraps independently				
TOTAL SCORE				

Fig. 1—Ten-point rating scale for evaluating independence in elastic bandage wrapping technique.

1. Begin at lateral side of limb.
2. Bring first wrap anteriorly to medial side of limb just superior to end of tibia.
3. Use figure of 8 wraps.
4. Anchor by continuing wrap above knee.
5. Re-wrap at least every 4 hours, and more frequently if wrap becomes loose.

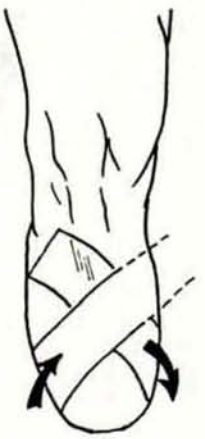

Fig. 2—Description and schematic depiction of appropriate wrapping procedures.

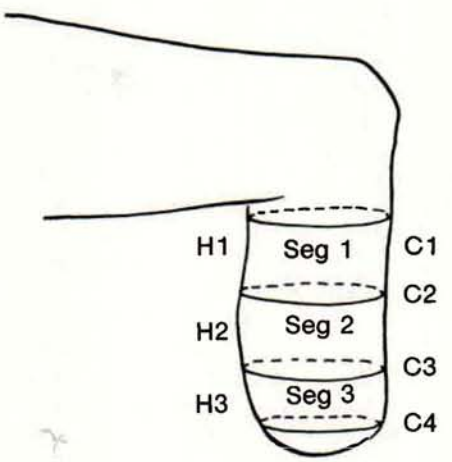

Fig. 3—Below-knee residual limb partitioned into truncated cones. Each cone is measured circumferentially at its top (C_1) and base (C_2) and height is defined as the distance between these two points.

truncated cone was 4 cm. If the height of the most distal cone was less than 4 cm, its height was then determined by subtracting the sum of the heights of the proximal cones from the total length of the limb. The tape for the distal circumference of this cone was placed as close to the end of the limb as possible. All measurements were taken while the subject was sitting with the knee relaxed and flexed to 90 degrees.

RESULTS

Table 1 presents the demographic description of both samples. Note that the shrinker group was older (although not significantly so) and had more vascular disease than did the bandage group. No difference in residual limb length was noted.

By summing the volumes of each truncated cone, a total volume for the limb was determined. Table 2 presents the average (± SEM) volume determinations (cm^3) for each wrapping method over the four-week test period. Note that there was an average increase (from week 1 to week 4) of 16.5 cm^3 ($t = 0.32$, NS) for the bandage method, whereas there was an average decrease bordering on significance of 63.6 cm^3 ($t = 1.67$, $p = .08$) for the elastic shrinker sock method. Comparing these two averages for the two methods revealed that the elastic shrinker method produced a significantly larger decrease in volume ($t = 2.10$, $p = .03$) after four weeks than did the bandage method.

TABLE 1

Demographic Description of Sample

	Bandage (n = 6)	Shrinker (n = 6)
Sex		
Male	3	2
Female	3	4
Age (yrs)	50.5 ± 27.6*	62.0 ± 17.0*
Limb Length (cm)	18.5 ± 5.5	18.7 ± 3.8
Disease		
Diabetes Mellitus	3	3
Vascular Insufficiency	1	3
Cancer	1	0
Congenital (revision)	1	0

* Mean ± standard deviation.

DISCUSSION

This study indicated that the elastic shrinker sock method was significantly better than the bandage method in reducing residual limb volume (Tab. 2). This result appears not to be attributable to length of the residual limb, inasmuch as average limb lengths were equal in the two groups (Tab. 1). This result could be attributed, however, to the increased percentage of ischemic disease in the shrinker sock group, inasmuch as this type of disease may create a greater potential for shrinkage. Assuming that younger patients might respond better than older patients to wrapping, it is indeed surprising that no change was observed in the bandage group despite the fact that it was composed of the youngest subjects in the sample.

These statistical results confirm our clinical observations noted during treatment of these and other patients not reported here. In general, we had believed that shrinkers were more effective; consequently we had substituted them for bandaging in many cases.

TABLE 2

Mean (± sem) Volume Determinations for Each Method Over the Four Week Test Period

Week	Bandage (n = 6) Mean Volume (cm^3)	Shrinker (n = 6) Mean Volume (cm^3)
1 (pre-treatment)	1357.7 ± 179.7	1537.4 ± 142.4
2	1386.2 ± 173.6	1507.5 ± 205.2
3	1457.2 ± 164.2	1488.4 ± 190.7
4 (post-treatment)	1347.2 ± 169.3	1473.8 ± 153.5
Average change (post-pre)	+16.5 ± 50.8[a]	−63.6 ± 38.1[b]

[a] $t = 0.32$, NS against a one-sided alternative

[b] $t = 1.67$, $p = .079$ against a one-sided alternative

CONCLUSION

We recommend the use of an elastic shrinker sock as the method of choice in treating the below-knee amputee. In this study elastic bandaging was not effective in decreasing residual limb volume and, therefore, its use must be reevaluated, especially for patients with vascular disease.

Ms. Manella was Supervisor of Orthopedics, Neurology, and Rehabilitation, Department of Physical Medicine and Rehabilitation, University of Illinois Hospital, Chicago, IL, when this study was done. She is now Supervisor of Education, Department of Therapies, Orthopedic Hospital, Los Angeles, CA 90060 (USA).

Preserved as an original investigative study at the Fifty-fourth Annual Conference of the American Physical Therapy Association, Las Vegas, NV, June 1978.

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* Truform, 3960 Rosslyn Dr., Cincinnati, OH 45209.

† Jobst Institute, Inc., Box 654, Toledo, OH 43694.

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The String Casting Technique for Below Elbow Amputations

Timothy B. Staats, M.A., C.P.

INTRODUCTION

The String Casting Technique+ is a method of casting the below elbow amputee for a socket that provides good range of motion, self suspension and very high trim lines.

The principles of self suspension of below elbow sockets became largely acceptable with the introduction of the Muenster Casting Technique.[1] The Muenster Technique involves a hand holding technique for casting that results in good suspension but normally has a limited range of motion (Fig. 1 and 2). As the residual limb is flexed, the anterior trim line, by design, impinges on the cubital fold area thereby preventing full flexion.

Billock[2] described a self suspension casting technique which provides an excellent range of motion, supra-epicondylar suspension, and has an identifiable trim line which sweeps distally on the anterior surface of the socket (Fig. 3). Billock maintains that research has shown high trim lines are not necessary because the major weight distribution in the below elbow amputee occurs in the distal 1½" of the residual limb. The Billock technique does not attempt to encapsulate the residual limb during casting and a classic bulging normally appears about the cubital fold.

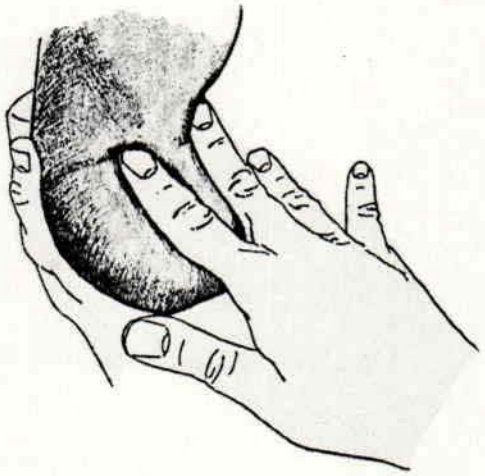

Fig. 1 – The Muenster casting technique utilized proper hand positioning to determine the anterior trim line. From the New York University manual.

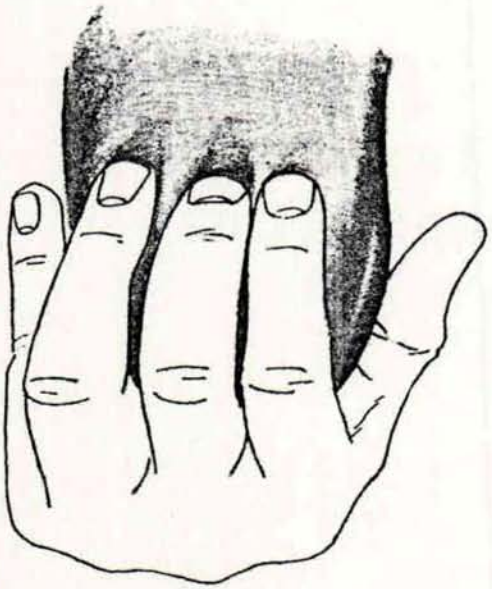

Fig. 2—The Muenster technique determined the posterior trim line and olecranon relief by proper hand cupping and finger pressure proximal to the olecranon.

The German casting technique[3] involves the use of two types of plaster and cut patterns to create classical shapes and excellent results exhibiting good range of motion, high trim lines, self suspension and good stability. In the German technique the hands are held in a manner that greatly reduces flexion impingement, however both hands must remain on the cast and extra steps of plaster casting are involved.

In 1980 the String Casting Technique was developed at the U.C.L.A. Prosthetics-Orthotics Laboratory as a simplification of the German casting technique. It clearly achieves the same result as the German technique but is faster, easier to control and not quite so messy. The following is a description of the casting and mold modification technique.

The principle of the String Casting Technique is to wrap the plaster bandage on the below elbow amputation with the elbow held in full flexion. As the plaster sets a string or cord is held in the cubital fold to create a thin anterior trim line that will natu-

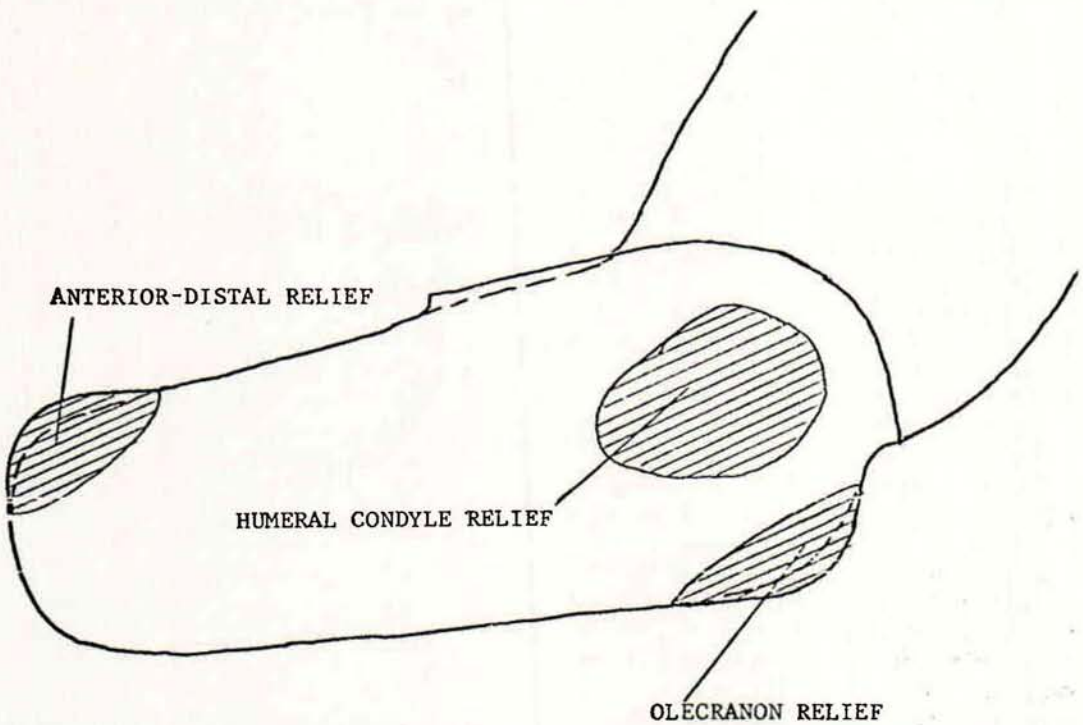

Fig. 3—Northwestern self suspending socket (Billock) features a low anterior trim line to allow use by mid-forearm and longer amputations.

rally conform to the cubital shape as flexion occurs without impeding elbow flexion range of motion.

The String Casting Technique simplifies the German technique but incorporates its cast modification principles. Advantages of high trim line in the below elbow amputee is for distribution of forces over the greatest surface area of the residual limb, particularly during flexion activities with a very short amputation and during lifting procedures where the mid-forearm is used, and with myoelectric prostheses where electrode placement is critical.

NEGATIVE IMPRESSION PROCEDURE

The String Casting Technique steps are as follows:

1. Apply two layers of tube gauze over the below elbow residual limb. Secure with tape or elastic webbing.
2. Apply elastic plaster bandage with turns of plaster around the length of the amputation. Usually two layers are sufficient (Fig. 4).
3. Continue with circular coverings with the residual limb in increasing flexion.

Fig. 4—Two layers of tube gauze are applied to the residual limb and elastic plaster is used to begin the impression. The plaster should extend to the cubital fold.

4. Care is taken *not* to allow multiple layers of plaster to accumulate in the area of the cubital fold. Excess plaster in this area will limit motion of the elbow flexion.
5. Complete the plaster wrap with careful coverage of the residual limb.
6. Place a string or cord (⅛″) across the cubital fold area (Fig. 5), catching the leading edge of the plaster bandage in the cubital fold. Plaster should not extend beyond the crease of skin in the cubital fold but should extend above the humeral epicondyles by about ½″ to ¾″.

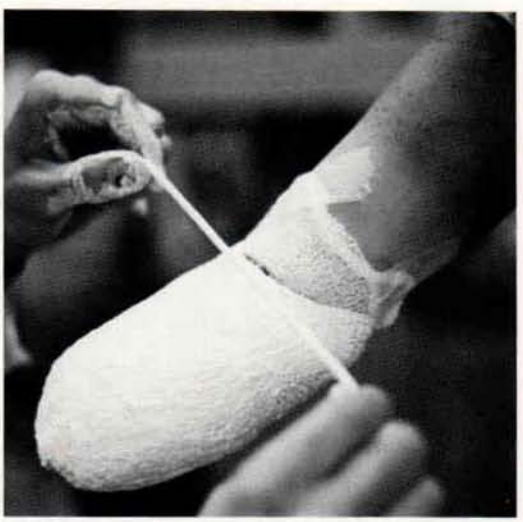

Fig. 5—A string, or cord, of 1/8″ thickness is placed on the plaster at the leading edge of the cubital fold.

7. The string is pulled into the crease of the cubital fold (Fig. 6) from a point 6″ behind the elbow. The string must be pulled posteriorly and above the medial and lateral epicondyles of the humerus. The angle of the string must not cross these bony prominences otherwise impingement and unacceptable results will occur. If the string is held tightly around the circumference of the humerus rather than 4″–6″ away, a constriction will occur on the cast and removal or reapplication will be difficult. In a modification of the String Casting Technique developed at the

Child Amputee Prosthetic Project at U.C.L.A., Baron & Moseley use a technique that does constrict as a special requirement of the child amputee where no condyles are present.

Fig. 6 – The string is held together six inches behind the arm and pulled so that it does not impinge on the epicondyles.

Fig. 7 – As the plaster sets, the elbow is fully flexed and the tube gauze is pulled down to form a horseshoe-shaped trim line 1" proximal to the olecranon.

8. Fully flex the elbow as the plaster sets.
9. As the plaster sets, gently pull downward on the inner layer of tube gauze in the area of the olecranon fossa to create a horseshoe shape trim line in that area (Fig. 7). Normally the posterior trim is about 1" proximal to the olecranon process or tip of the elbow. Care must be taken not to disturb the plaster wrap height above the humeral epicondyles.
10. Reinforce the cast if necessary before removal. Careful removal technique is important so as not to distort or disturb the shapes that have been created.
11. Before removal, some ranging is possible to check range of motion. While no criteria is set as to acceptable limits of range of motion, it is suggested that variations of the casting technique be attempted to determine suitability for each individual's needs. Generally almost full range of motion can be achieved.

POSITIVE MODEL MODIFICATION

The steps of model modification of the String Casting Technique wrap cast are essentially the same as for the German casting technique.

1. The negative impression is filled with plaster in the normal manner using tape or plaster to build-up an excess of plaster above the margins of the cast itself.
2. The Anterior Trim Line. The modification of the positive model will require that the anterior trim be reduced to about ⅛" radius as the residual limb flexes in order to create the proper effect about the elbow. The small radius will naturally fold into the crease of the cubital fold (Fig. 8).

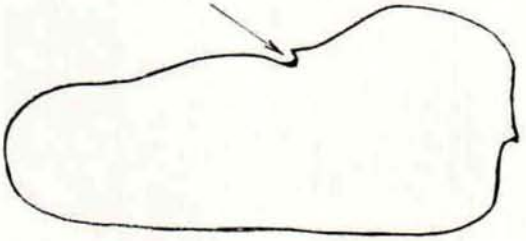

Fig. 8 – The anterior trim line is modified on the positive model to leave a 1/8" radius, which will naturally fit into the cubital fold.

Fig. 9—A snug fit is insured by removing 1/8" to 3/16" plaster from the positive model on the radial and ulnar aspects of the proximal trim line.

3. Small amounts of plaster are removed from the radial and ulnar sides of the proximal margin of the trim line. Normally ⅛" to 3/16" removal in this area is adequate to insure a snug fit (Fig. 9).
4. A build-up is applied to the anterior surface of the cast just distal to the anterior trim line. This will create a cavity for tissues to bulge into when the elbow is flexed. The build-up should be no more than ¼" and shaped as shown in Fig. 10.
5. Normally the posterior trim line is established during the cast taking. However, the trim line may be adjusted at the time of modification to create perfect radius shapes and to raise or lower the trim (Fig. 11).
6. For myoelectric applications, the electrode sites should be slightly flattened according to specifications established by the manufacturers of the components. A check socket is extremely useful in checking the range of motion of the modified model.

DONNING THE SOCKET

The socket is trimmed to fit and pulled on with a pullsock or is slipped into, using a small amount of skin lubricant. Excess anterior tissue is gently maneuvered into the cubital belly cavity of the socket. The elbow should be able to fully flex without impingement on the olecranon, the epicondyles, or the cubital fold (Fig. 12). In laminated sockets the epicondylar flares may be laminated using flexible resin to assist the patient in applying the socket and to provide a pliable and comfortable fit.

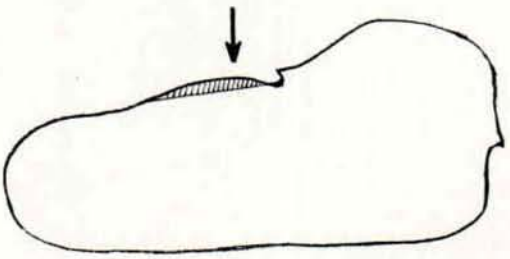

Fig. 10—A buildup of no more than 1/4" is added to the anterior surface to allow for the tissue to bulge when the elbow flexes.

Fig. 11—The posterior trim line is established during the casting procedure, but can be corrected or improved at this time.

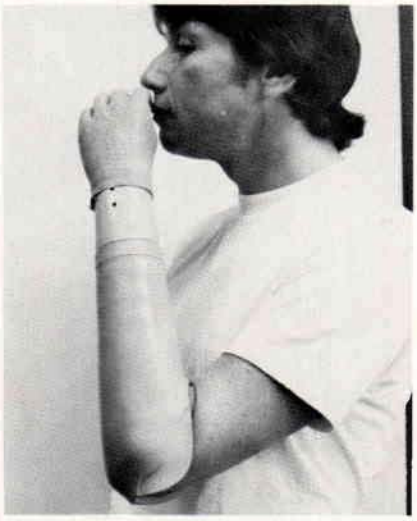

Fig. 12 – Full elbow flexion is possible in the prosthesis without impingement in the cubital fold.

Fig. 13 – Patient with dislocated total elbow prosthesis. An orthosis to stabilize the elbow was prescribed.

CONCLUSION

The advantages of the String Casting Technique are: 1) the ease in which a cast can be taken; 2) full range of motion and self suspension are provided by shapes and contours created in the cast and modification procedures, and 3) a high trim line distributes forces over the entire residual limb providing excellent lifting, suspension and surface

Fig. 14 – The string casting technique used for the impression for an elbow orthosis.

contact characteristics. The String Casting Technique has been used for below elbow arthroplasty orthoses. In figure 13 a patient at the U.C.L.A. Prosthetics-Orthotics laboratory exhibits gross elbow instability due to a dislocated total elbow replacement. Utilizing the String Casting Technique an orthosis (Fig. 14) was fabricated to hold the elbow in position and allow full range of motion. Further information is being gathered on orthotic designs and applications of the String Casting Technique.

Acknowledgments

Special thanks is extended to Mr. Larry Mott, Director of Education at the Otto Bock Company of Minneapolis, Minnesota, Mr. David Varnau, C.P.O. of the U.C.L.A. Prosthetic-Orthotic Laboratory and Barbara Brown for their assistance in the preparation of this paper.

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Timothy B. Staats, M.A., C.P., Technical Director United States Manufacturing Company. The Technique was taught at the United State Manufacturing Company Myoelectric Seminars and is a modification of the German casting technique as taught by Otto Bock Orthopedic Industry, Inc. in Minneapolis, Minnesota.

Wheelchair Based Upper Limb Orthotics

Peter H. Stern, M.D.
George Vitarius, C.O.
Janet Quint, O.T.R.

Modular designed assistive devices for patients with paralysis of the upper limbs have shown continual improvement. Although the prototype production of a seven degree of freedom, powered arm orthosis[1] resulted in failure, spring load, mechanical modules with a variety of attachment options are very effective in the management of patients with bilateral paralysis of arms and hands caused by lower motor unit dysfunction or mixed lesions of the spinal cord.

The Burke Rehabilitation Center (BRC) upper limb orthotic system consists of four modules.

Shoulder-Arm Modules

The shoulder-arm module consists of a spring loaded linkage with its proximal ball bearing housing attached to a standard, adjustable balanced forearm orthosis (BFO) bracket (Fig. 1). The distal ball bearing housing contains a sleeve receptacle for forearm modules. Spring tension can be adjusted for arm weight to achieve the desired lift. This module is commercially available.*

Forearm Modules

These generally consist of standard BFO's with the following refinements:

- An adjustable mechanism which allows for the determination of the optimal pivot point of the forearm swivel (Fig. 2).
- A multi-position elbow dial as an improved method to stabilize the arm (Fig. 3).

Wrist Modules

Wrist stabilizer splints attached to the forearm trough can be provided. These can be made for temporary use from low temperature thermoplastics and from acrylic nylon (Nyoplex) for permanent use.

Terminal Modules

These range from simple to complex. Attachments to the wrist support include a universal pocket, which serves as a receptacle for meal time and grooming devices, a cup terminal for joy stick wheel control and a number of other self-help devices.

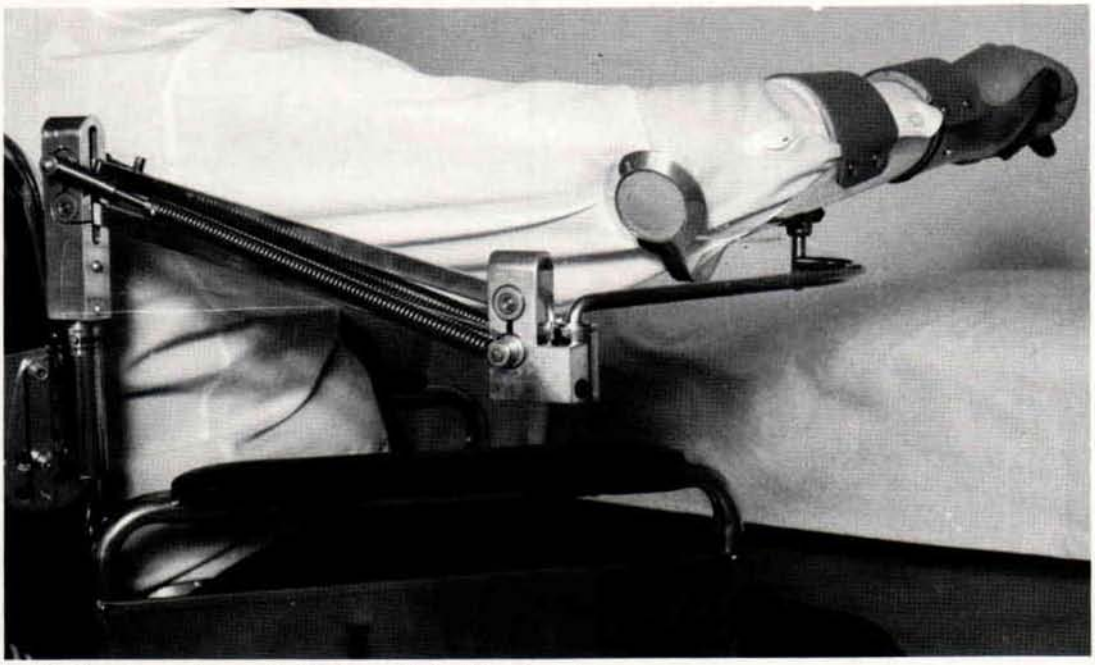

Fig. 1—Four bar spring loaded linkage attached to wheelchair.

The use of two or three jaw chuck prehension devices have been virtually abandoned in favor of key grip orthoses which come either wrist driven or externally powered with Bowden cable actuation[4] (Fig. 4).

PRESCRIPTION PRINCIPLES

As in other branches of medicine, a good prescription requires a thorough diagnostic evaluation. This includes a kinesiological and

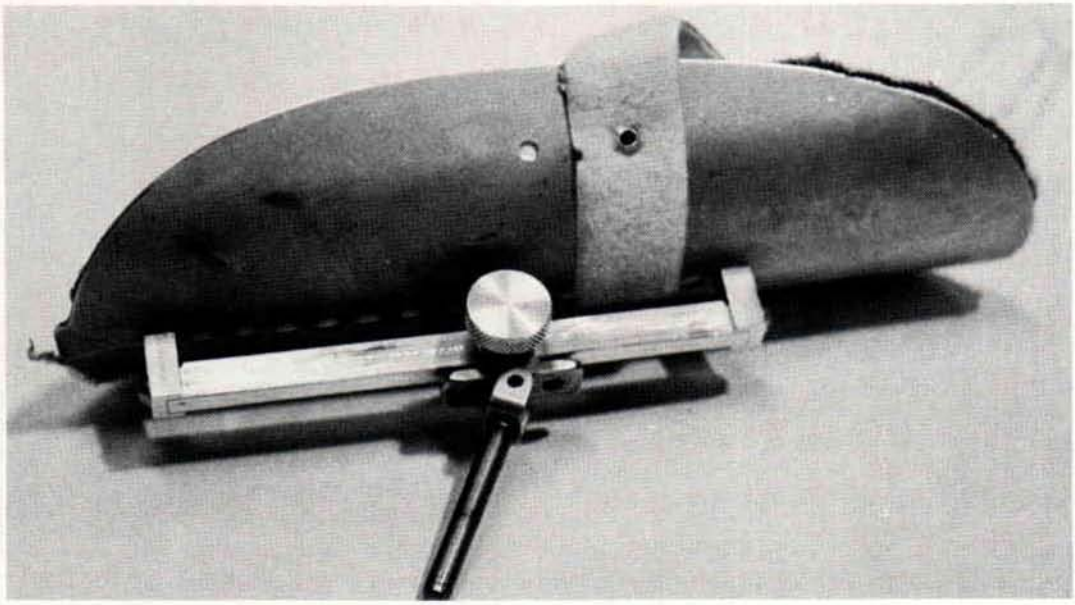

Fig. 2—Silver bar for the determination of optional pivot point.

functional assessment and sensory testing. At the BRC this is done by an occupational therapist (O.T.) in conjunction with a physical therapist (P.T.) and a nurse. The O.T. can "pull off the shelf" any or all of the modules described for an initial trial. The patient will then be brought up for a full team presentation for the physician to finalize the prescription.

Indications

The application of the BRC upper limb orthotic system (ULOS) should be considered not only for patients with bilateral upper extremity paralysis as a result of lower motor neuron disease such as Guillain Barre syndrome (GBS) and poliomyelitis, but also for mixed lesions such as spinal cord injury, multiple sclerosis and amyotrophic lateral sclerosis. Also, in rare instances, patients suffering from rheumatoid arthritis or primary muscle disease can benefit from this system. Mild to moderate spasticity is not a contraindication though severe spasticity cannot be accommodated. Patients must have wheelchair sitting tolerance with the wheelchair back rest adjusted to at least 45 degrees. Ataxia and incoordination can be a problem which can sometimes overcome by the application of a friction device (damper) at the elbow sleeve.

Specific Criteria

Proximal muscle groups in the shoulder and arms should grade at least poor for pectoralis major and poor minus for the deltoids. Elbow flexors and extensors can grade zero, simply because gravity can be used or the patient can use muscle substitution provided the various components are set with accuracy.

There is, of course, a great deal of variation in the selection of elbow and wrist modules and a "trial and error" approach is still needed. The same pertains to the hand where a good minus strength in wrist extension is required for the flexor hinge movement to actuate the BRC key-grip orthosis.

Functional Benefits

Patients with flail arms and hands are usually even more helpless in a wheelchair than

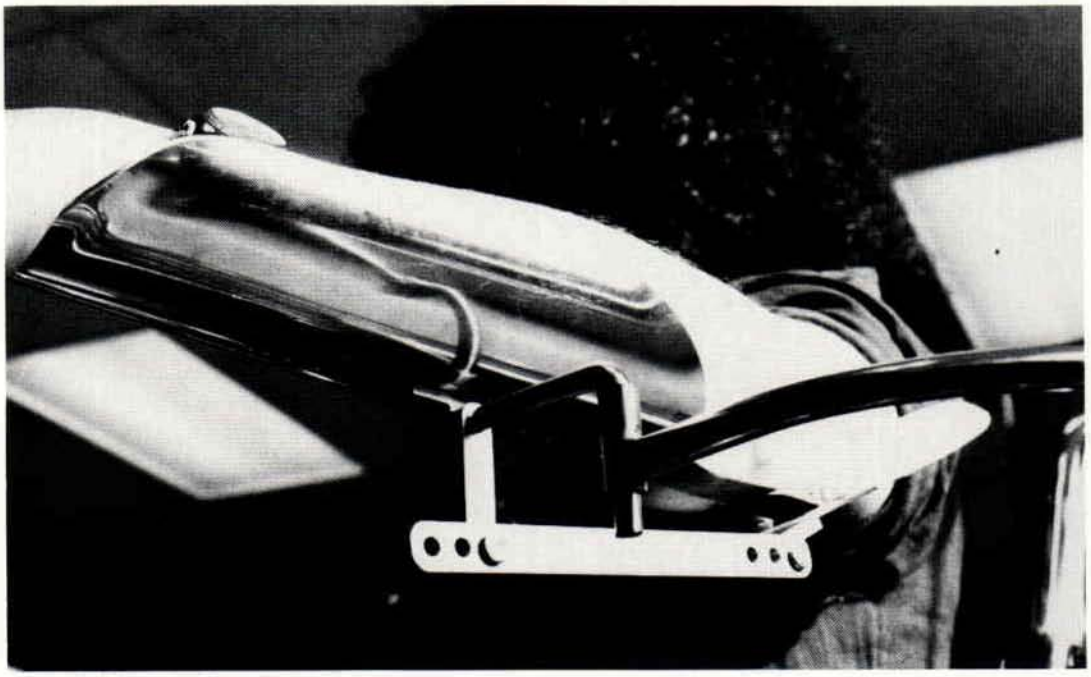

Fig. 3 – Multi-position elbow dial.

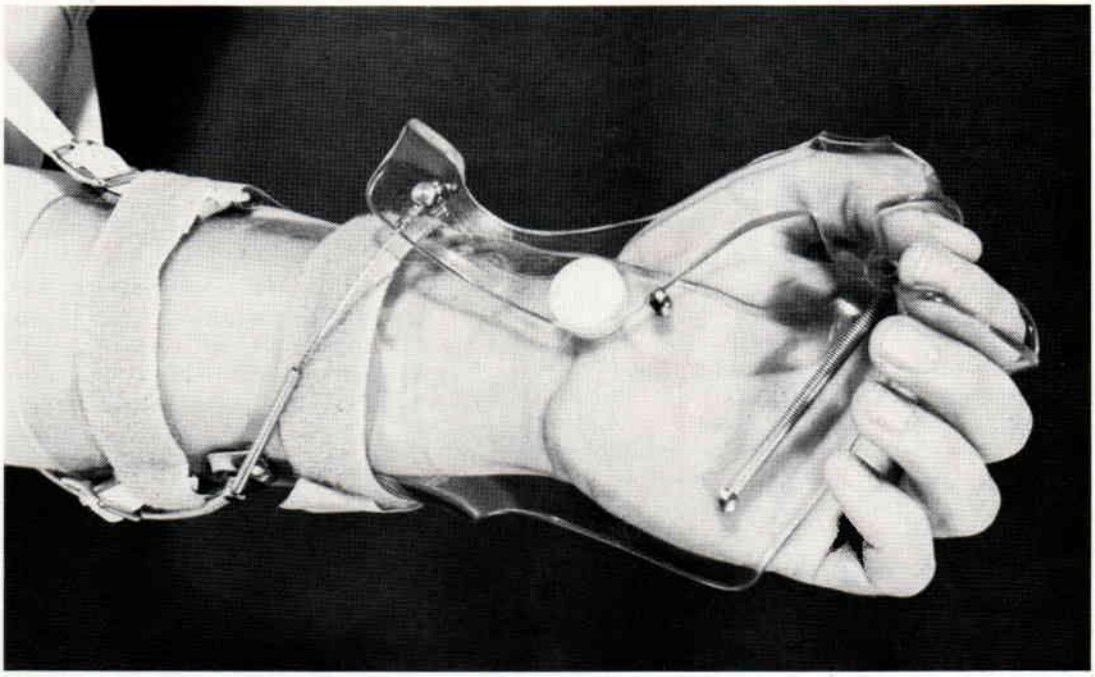

Fig. 4 – Externally powered, Bowden cable activated key-grip orthosis.

in bed where at least a bed-based environmental control system can be useful. Following application of ULOS, the following activities can usually be carried out after varying lengths of training and adjustments:

- Mobility. Joy stick controlled motorized wheelchair using a cup terminal.
- Mealtime activities. Using a universal cuff terminal patients can begin to eat by themselves given tray preparation. A lap board is to be provided.
- Grooming. Again with the help of the universal cuff a variety of self-help items such as shavers, toothbrushes and combs can be used.
- Writing/Communications. A variety of self-help devices can be adapted for use with a variety of terminal devices.

DISCUSSION

The Burke Rehabilitation Center developed an entirely externally powered seven degree of freedom exoskeletal arms/leg/hand assist which failed in clinical trials as did previous attempts by others.[5,6] Complexity of design, component breakdown and human factors in matters of control have made such ambitious projects unusable. The described ULOS has found widespread acceptance by patients and staff alike at this institution. However, there is a need for compulsive attention to details concerning the evaluation, application and "fine tuning" of all of the components. This alone is a labor intensive process.

While using ULOS, further refinements and additions are evolving. While these will be the subject of discussion at a later time, we believe that ULOS now is mature enough to be utilized by other rehabilitation institutions who serve patients in the disease categories mentioned. At the time of this writing, we have fabricated four dozen of these devices which are mostly used in-house but at times are also given to the patient at the time of discharge. We observed an additional benefit for patients who suffer from constrictive capsulitis or just general joint stiffness in the shoulder joints as a result of prolonged immobility in bed and under cervical traction. The ULOS system allows self-ranging to supplement physical therapeutic activities. The painful discomfort of stiff joints is markedly reduced over time.

SUMMARY AND CONCLUSIONS

A relatively simple, mechanical upper limb orthotic system (ULOS) is described which consists of four different modules supporting and assisting proximal and distal residual muscle power in patients with essentially flail arms and hands. The system is labor intensive in its initial application but should be cost effective particularly when commercially produced for widespread applications in patients who suffer from spinal cord injury, Guillain Barre syndrome, post polio paralysis, multiple sclerosis, amyotrophic lateral sclerosis or primary muscle diseases.

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*Available from Pro-Com, P.O. Box 325 Millington, NJ 07946

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A Lightweight Laminated Below the Knee Prosthesis

Jon P. Leimkuehler, C.P.O.

INTRODUCTION

Lightweight prosthetic designs become more important each year as people are surviving vascular disease and living longer lives. However, these people often are debilitated and lack the strength to handle a conventional prosthesis.

Previous work on "ultralight" below knee prostheses by Moss Rehabilitation Hospital and Rancho Los Amigos Hospital involved the use of thermoforming and other unconventional prosthetic materials and techniques. An "ultralight" below knee prosthesis came to be known as a design allowing the total prosthesis to weigh less than two and one half pounds. These designs did not gain wide use because of difficulty in fabrication and doubts regarding the durability and strength of the prosthesis. However, these designs did encourage prosthetists to become more conscious of the weight of prostheses, and to develop lightweight prostheses using more conventional materials and techniques.

Presented here is a design using wood and a laminated PTB prosthesis with a Pelite insert that weighs about 2⅛ pounds and has normal SACH foot function (Fig. 1). This design utilizes balsa wood and an external keel SACH foot.

FABRICATION

Fabricate a Pelite insert in the normal fashion. The socket lamination should be kept as thin as possible. Set the socket in a balsa wood block with polyurethane foam (Fig. 2).

Moisture in the moist wood attacks the foam and prevents it from proper curing. Whenever foam comes in contact with normal bass wood, it gets gummy; however, with balsa wood this is not a problem.

Bond a one inch thick piece of regular bass wood to the balsa wood block with resin for a stronger attachment of the alignment fixture. This wood plate will be removed when transferring the alignment. Attach the socket to an alignment fixture. A Symes foot* is used on the prosthesis. The foot is not bolted onto the shank. Instead, the external wood keel is glued and laminated into the prosthesis, eliminating the weight of the bolt and adapters.

The top of the foot is cut and sanded flat until the top is horizontal and level with the shoe on (Fig. 3).

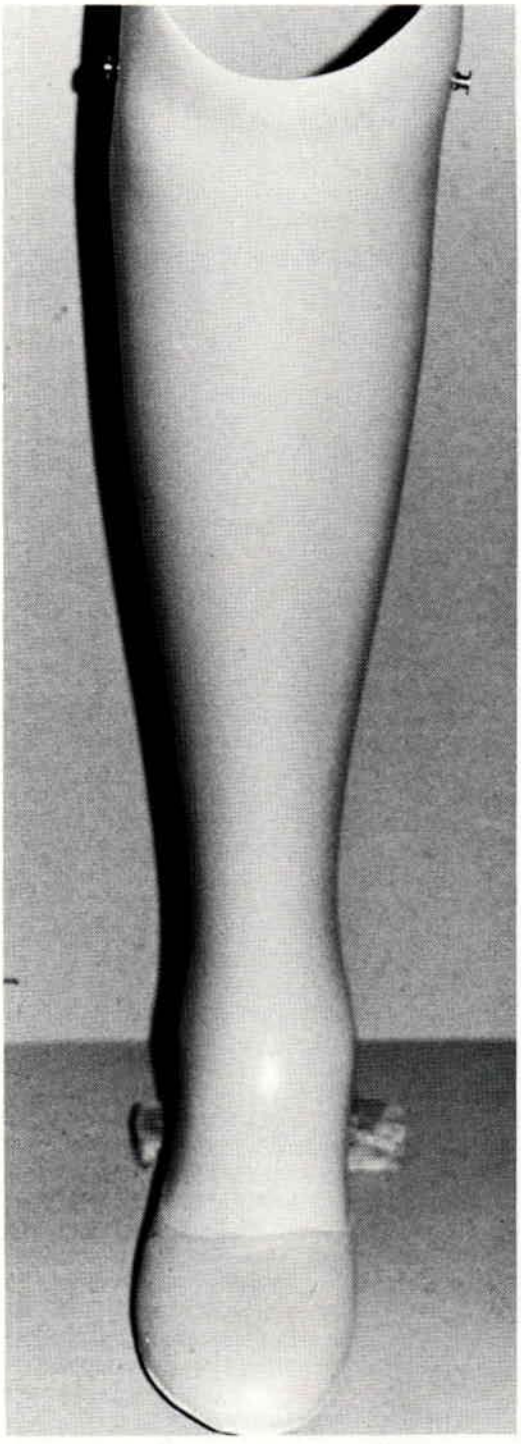

Fig. 1—Completed lightweight PTB prosthesis. The prosthesis weighs 2⅛ pounds when a balsa wood structure is used.

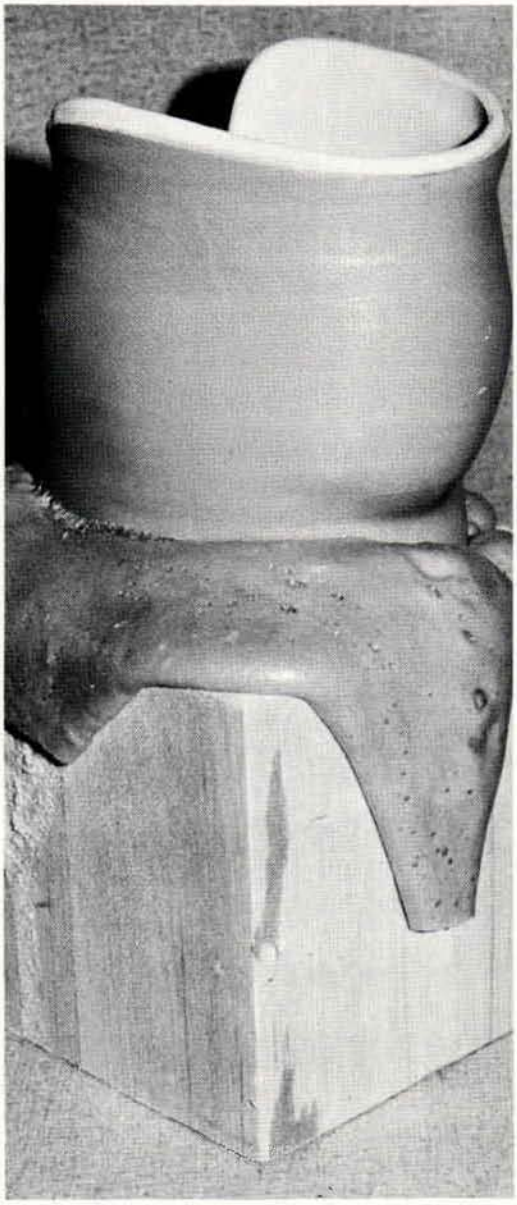

Fig. 2—The socket is set into a balsa wood block with polyurethane foam. The balsa does not have to be sealed with resin as polyurethane foam has excellent bonding properties with balsa wood.

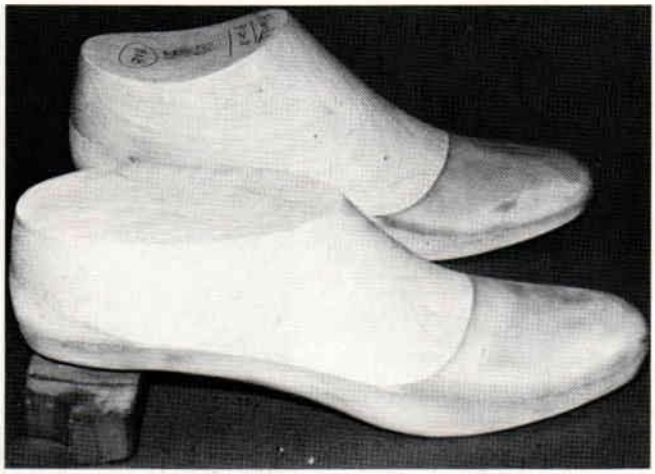

Fig. 3 – The Symes SACH foot (Otto Bock). Rear: Foot before it is leveled. Front: The top of the foot is leveled, allowing for the proper heel height.

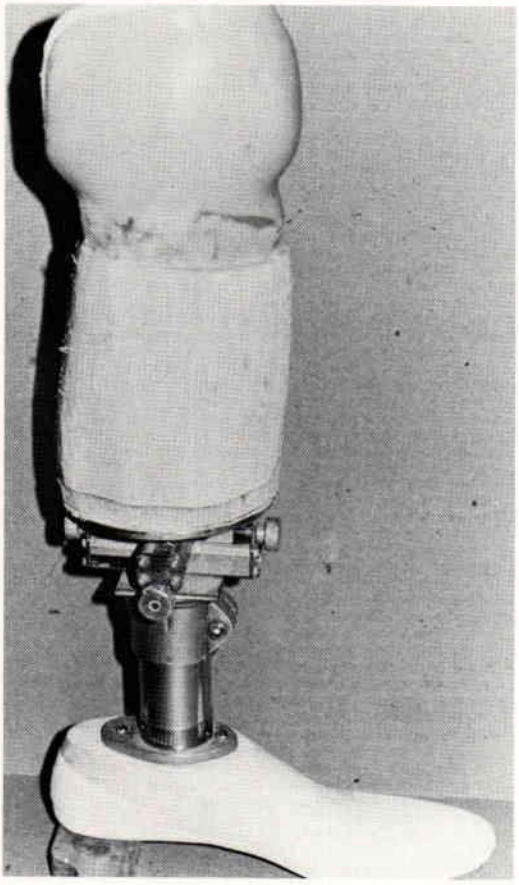

Fig. 4 – Static alignment. An end seal is bonded to the balsa for attachment of the alignment fixture.

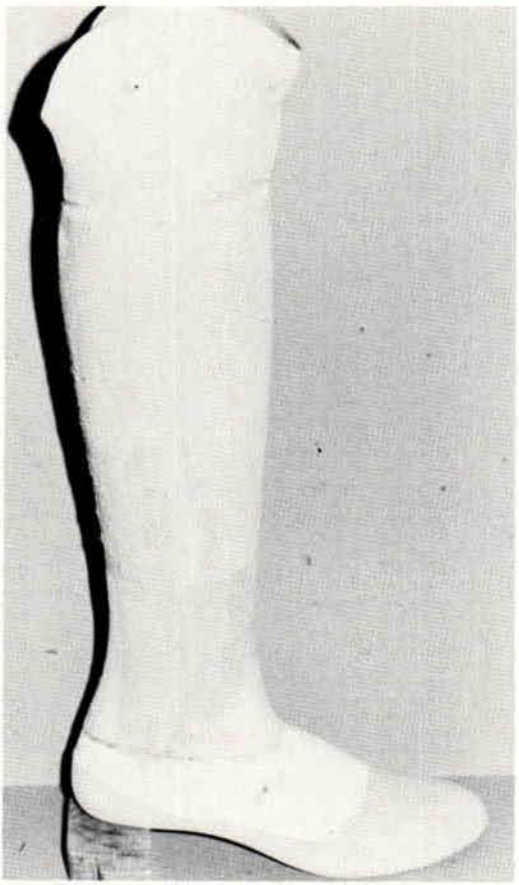

Fig. 5 – Following dynamic alignment, the alignment fixture is transferred for balsa wood.

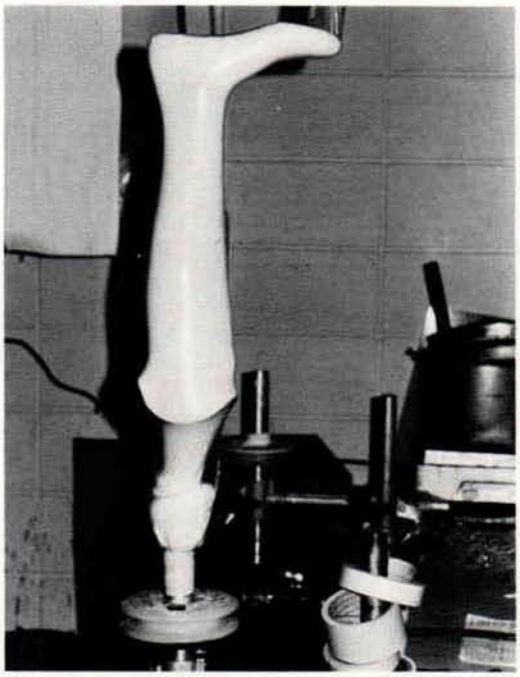

Fig. 6 – Final lamination. A layup of three layers of nylon stockinette is used.

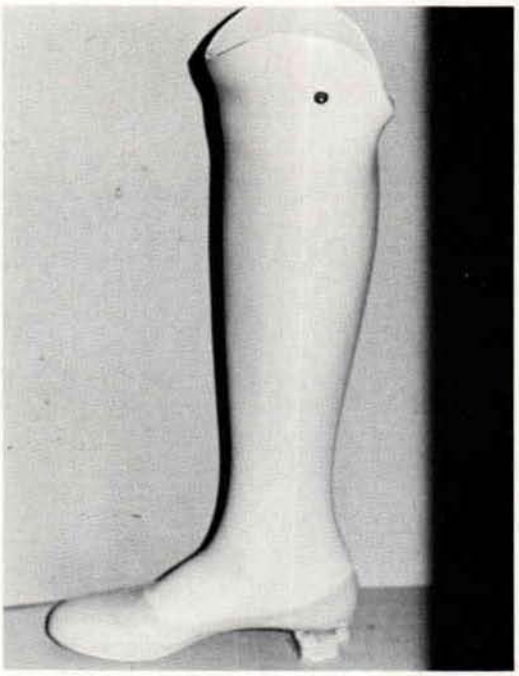

Fig. 7 – The lamination is beveled at the edges of the keel and leather is used to finish the foot.

The foot should be modified to provide better function. It was originally designed to be used for a Symes prosthesis and has a very small heel cushion. A larger, thicker and longer cushion should be installed. Heel wedges are commercially available that are the proper size needed for good heel compression.

A SACH foot plug is screwed securely to the foot and the alignment fixture is attached (Fig. 4). Dynamically align the prosthesis in the usual manner. Transfer the prosthesis in a vertical transfer device. After the alignment fixture is removed, a balsa wood block is glued to the top of the foot to make the ankle block. Then this is attached to the socket. Plastic resin should be used to glue the pieces together. Shaping is done in the normal fashion (Fig. 5).

Three thin nylon stockinettes are used to finish laminating the prosthesis. The lamination extends over the instep and malleoli covering all exposed wood (Fig. 6).

To finish the foot, the lamination is beveled by sanding around the edge of the sole, toe and heel wedge, and a leather cover and sole are used to cover the foot (Fig. 7).

DISCUSSION

This prosthesis is lightweight, cosmetic and uses conventional prosthetic fabrication techniques.

By carefully choosing the appropriate patient, you can make a very light, durable prosthesis. Balsa wood is recommended to be used for less active and lighter patients.

For the more active person, using standard bass wood with a Symes foot and a thicker, stronger lamination can result in a light, strong, cosmetic prosthesis. This usually will weigh about 2¾ pounds including a Pelite insert. When regular bass wood is used, the prosthesis should be hollowed out to a thickness appropriate for the weight of the patient, usually about ¼″ to 3/8″ thick.

Proper application of this technique will result in a weight reduction of 50–100 percent on many patients. Decreased prosthesis weight will ease suspension problems, and has the obvious potential of decreased energy expenditure during ambulation.

*Otto Bock 1P5 symes foot

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An Extension Orthosis for the Management of Elbow Flexion Contractures

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Audrey M. Yasukawa, M.O.T., O.T.R.

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

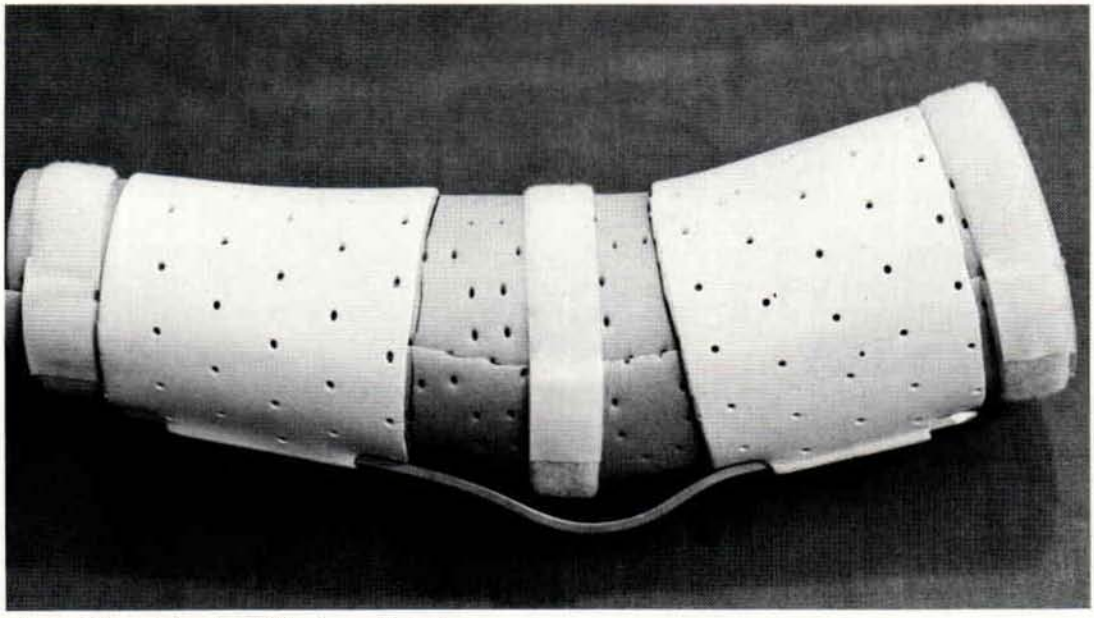

Fig. 1 – Elbow Extension Orthosis, medial view.

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,

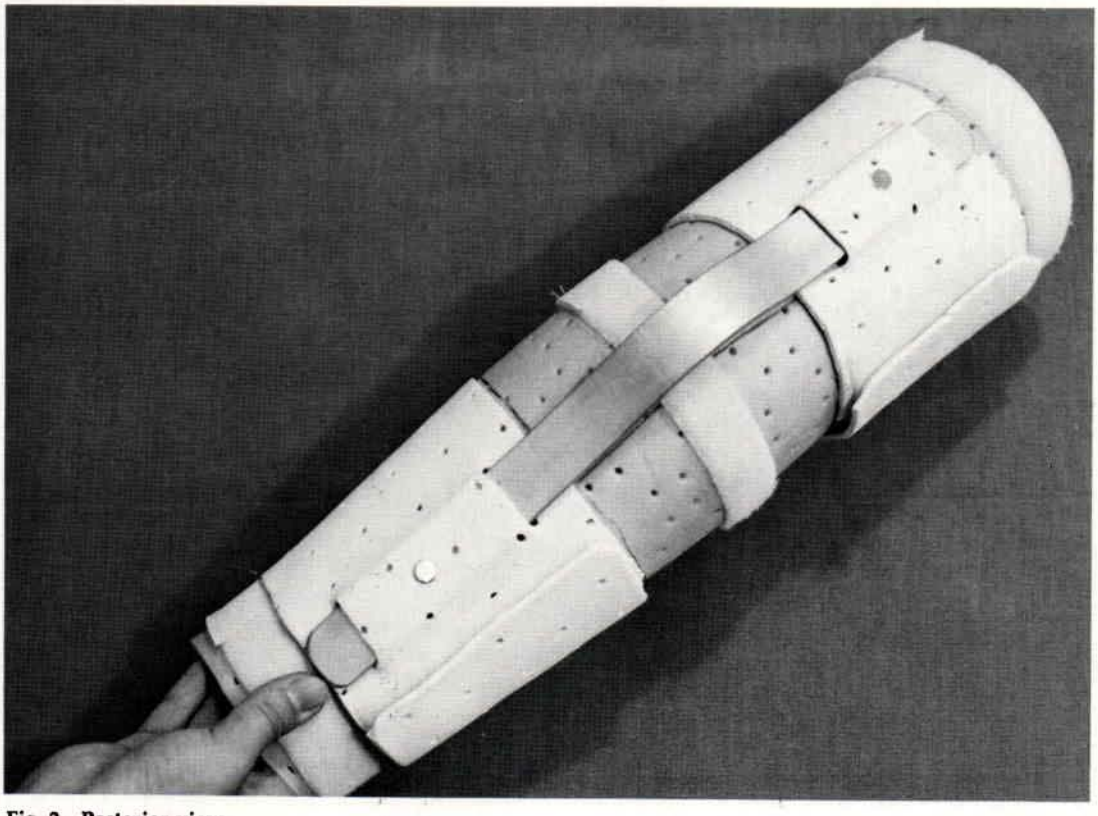

Fig. 2—Posterior view.

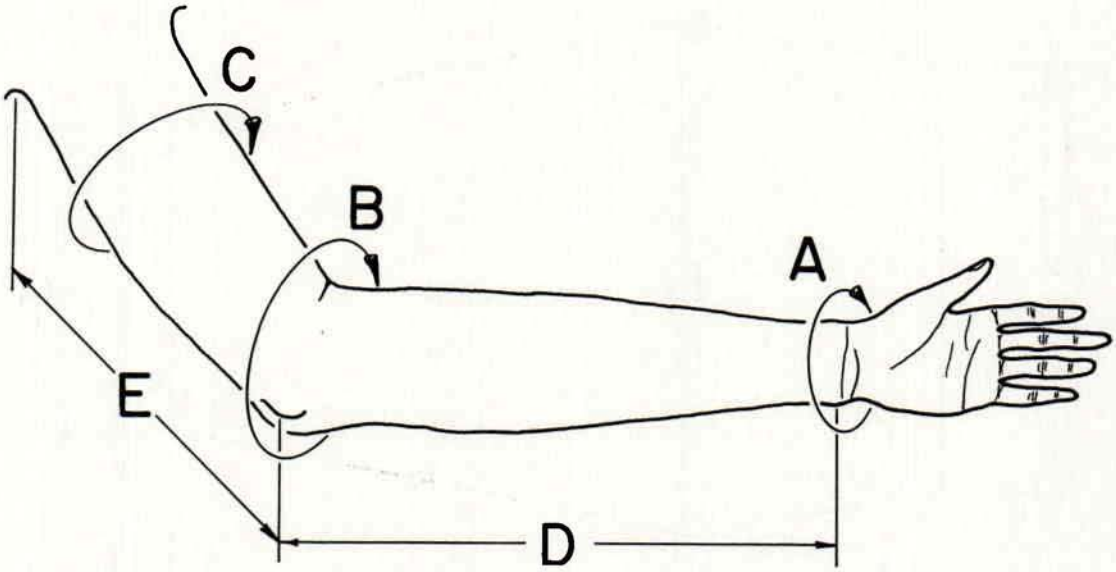

Fig. 3—Measuring diagram. Circumferences: A) Wrist, B) Elbow, C) Arm. Lengths: D) Ulnar Styloid to Olecranon, E) Olecranon to Axilla.

- 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

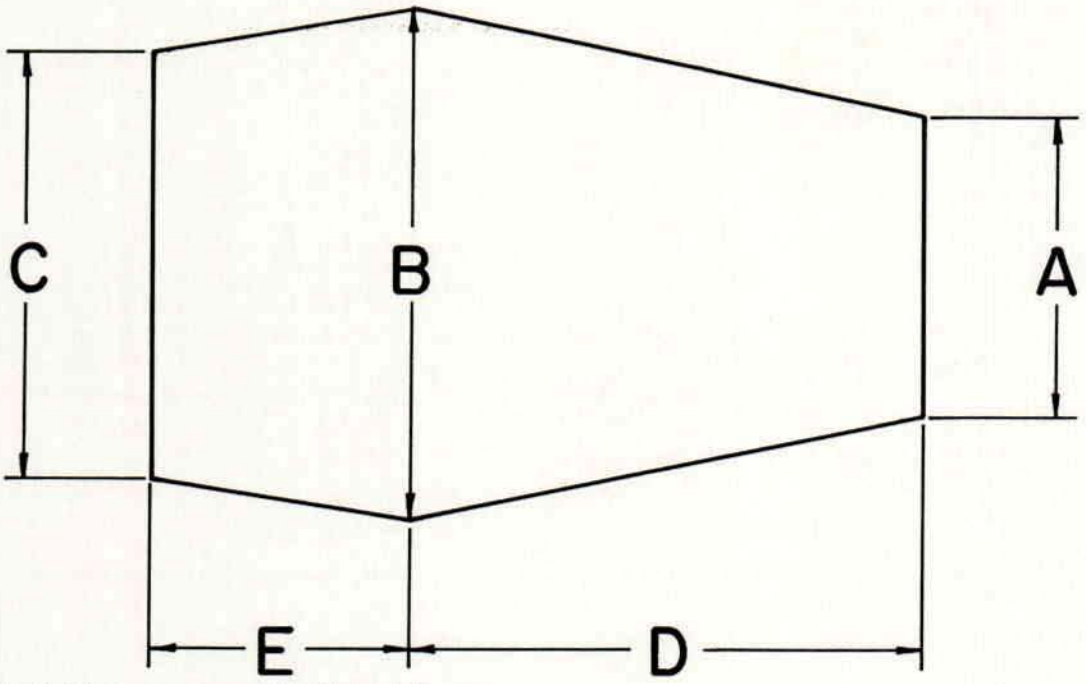

Fig. 4—Measurement layout for Plastazote liner.

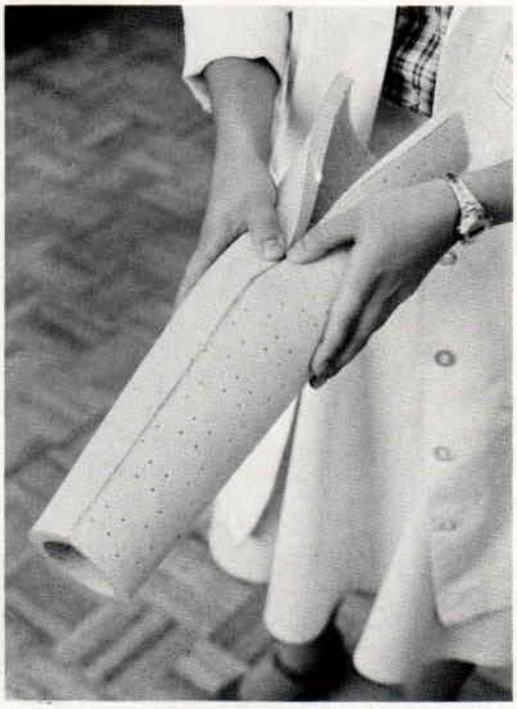

Fig. 5—Form Plastazote tube.

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).

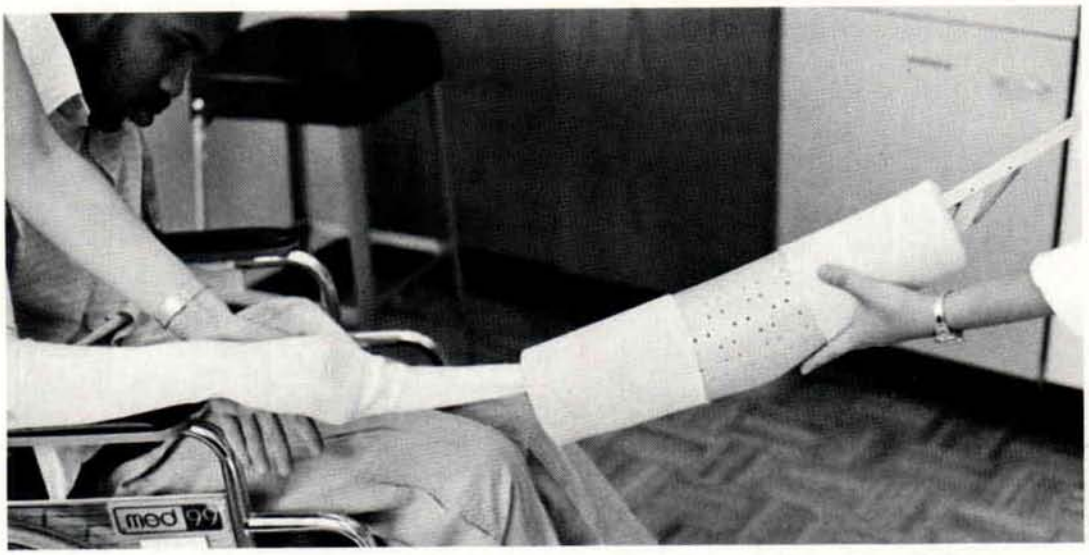

Fig. 7 – Direct stockinette through liner tube of Plastazote which has been heated in a 200 degree oven.

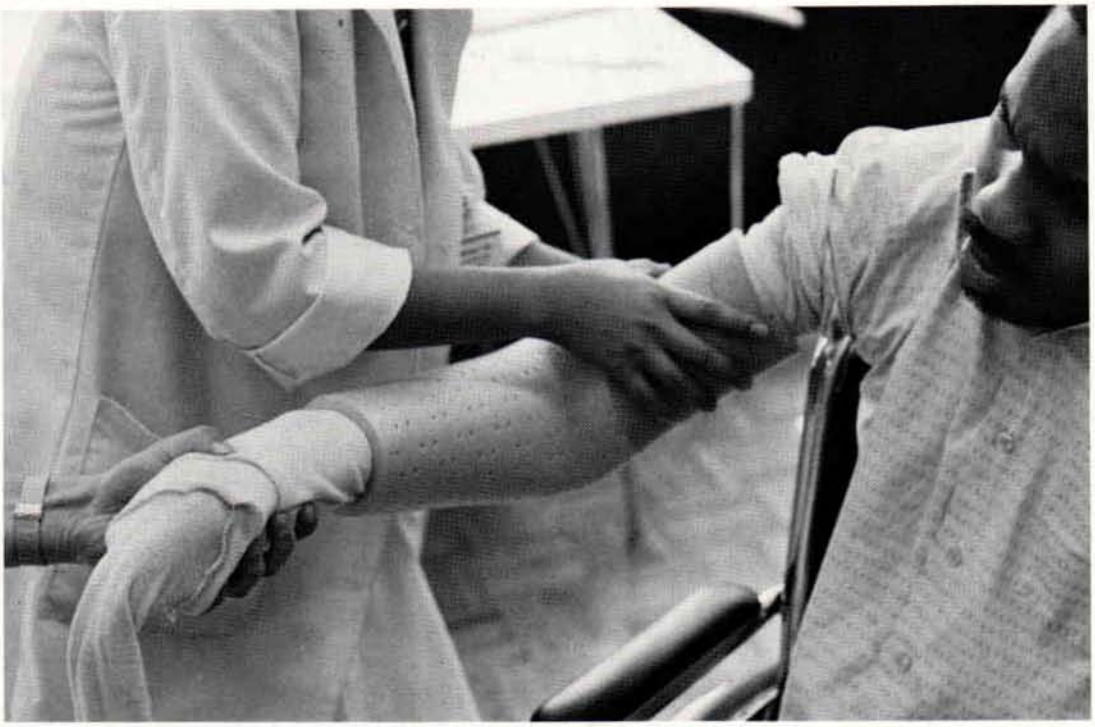

Fig. 8—Liner in position on arm. Set elbow to maximum extension at this point and wrap it with an elastic bandage.

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

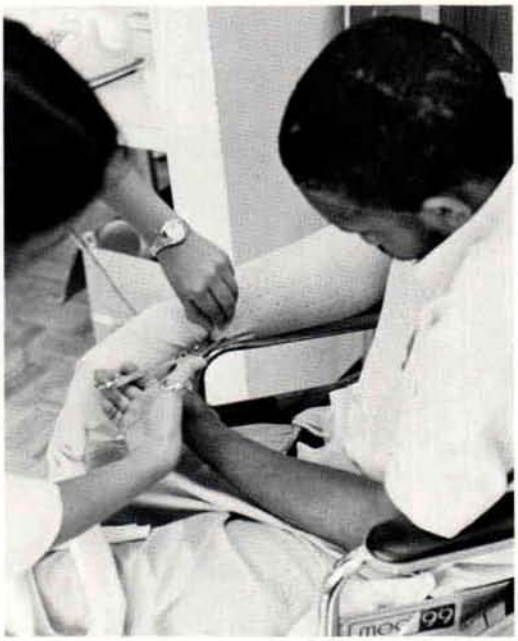

Fig. 9—Cut liner opening on medial side to ease donning.

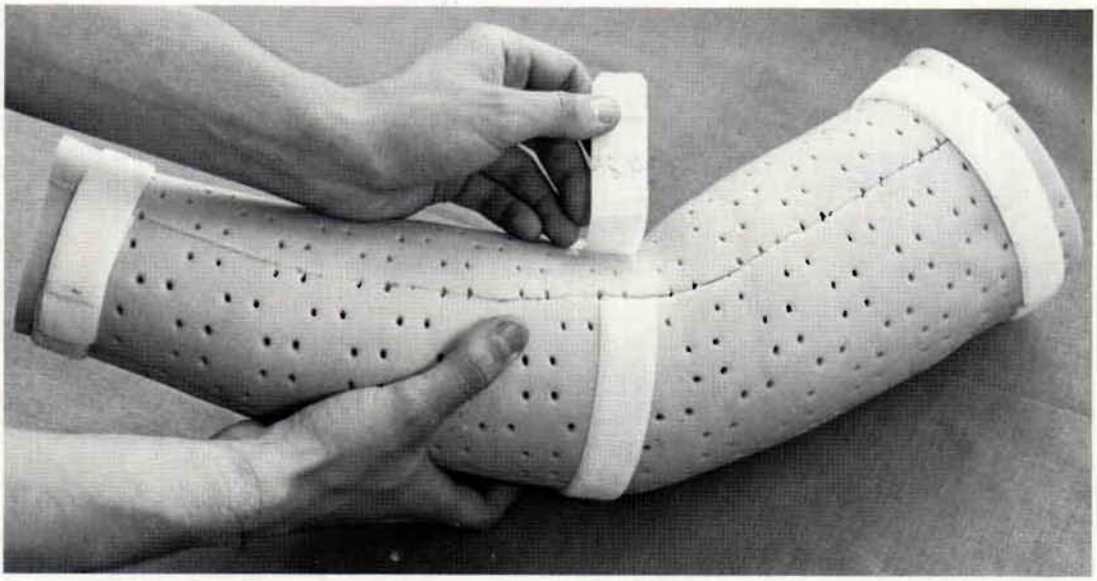

Fig. 10—Attach Velcro closures after the distal and proximal edges have been skived on a sander.

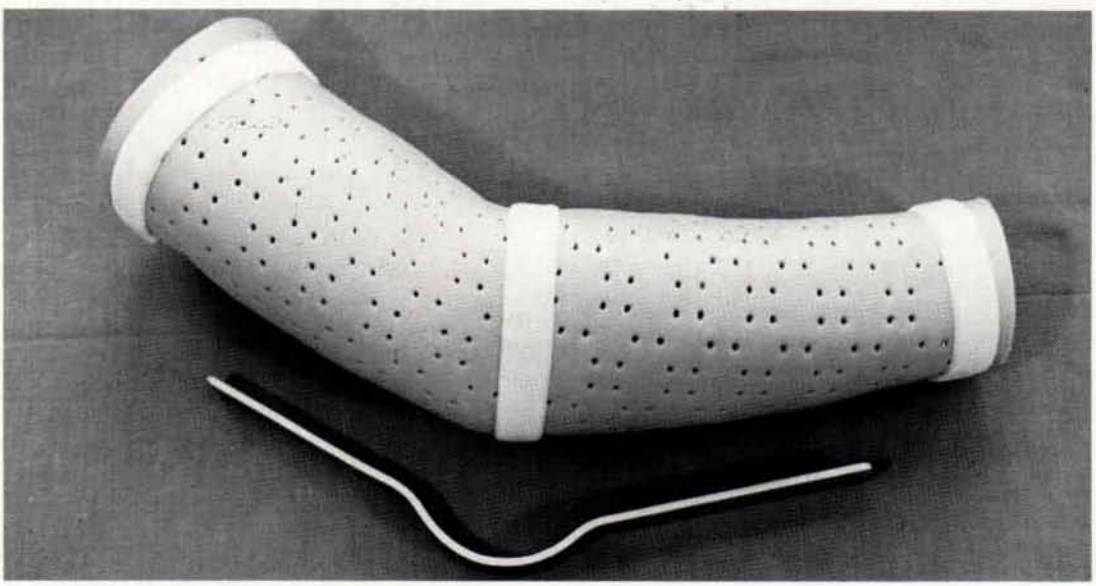

Fig. 11—Determine dorsal bar angle and contour a relief for the olecranon.

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).

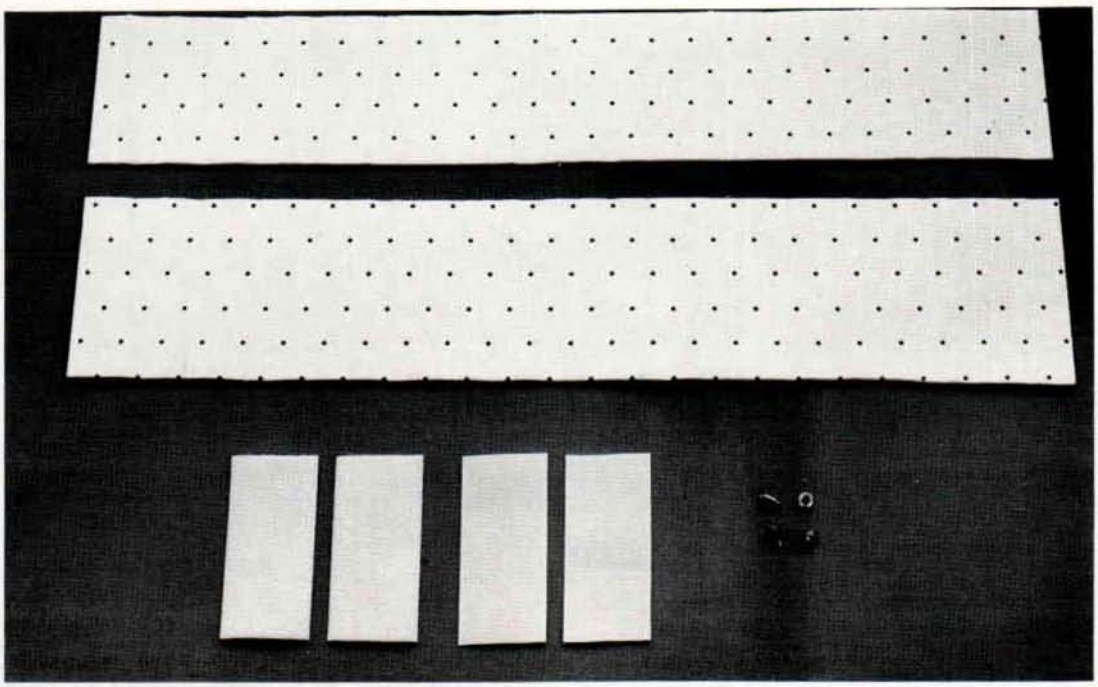

Fig. 12—Components of Orthoplast cuffs.

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

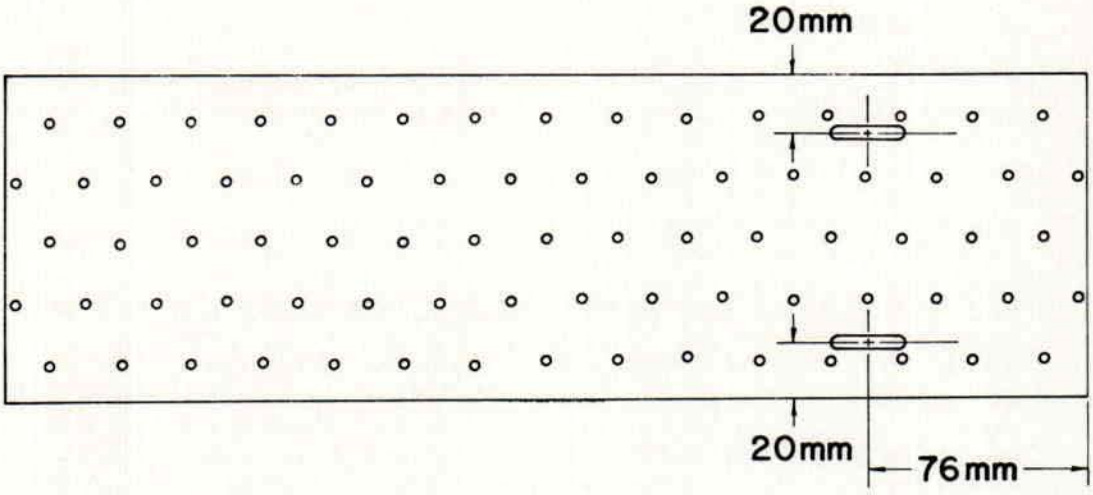

Fig. 13—Measurements for slots for the dorsal bar attachment.

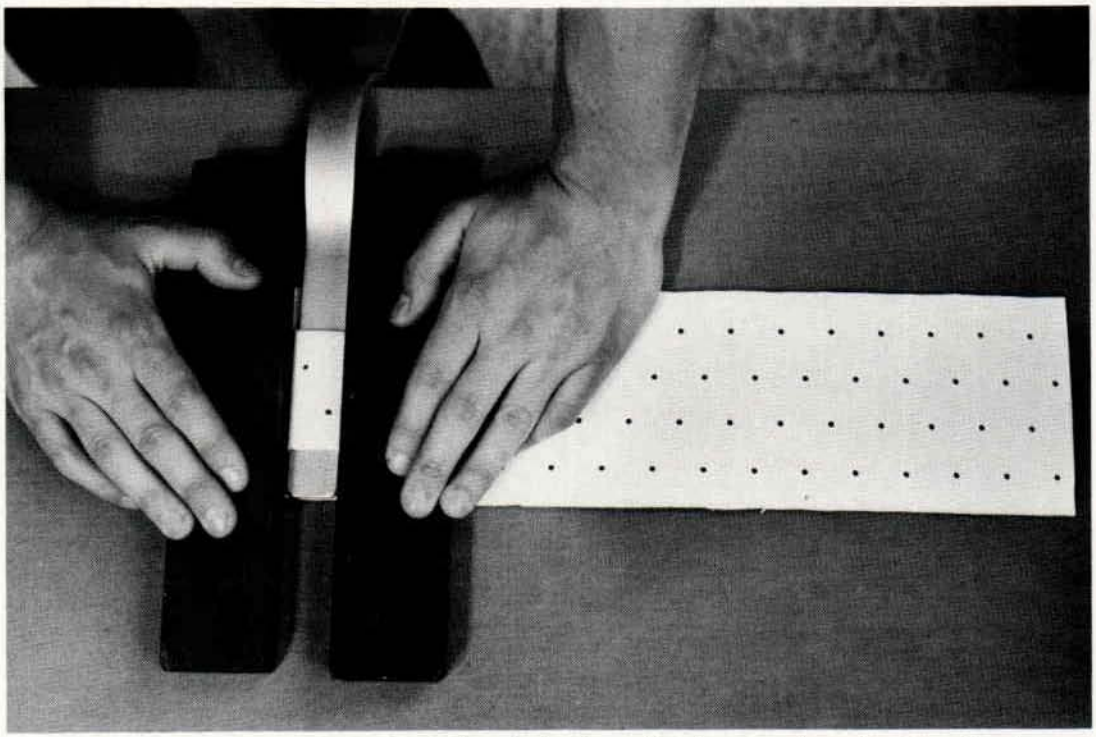

Fig. 14—Fit dorsal bar to cuffs by slipping it through the slots, which have been heated, and pressing down on both sides.

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.

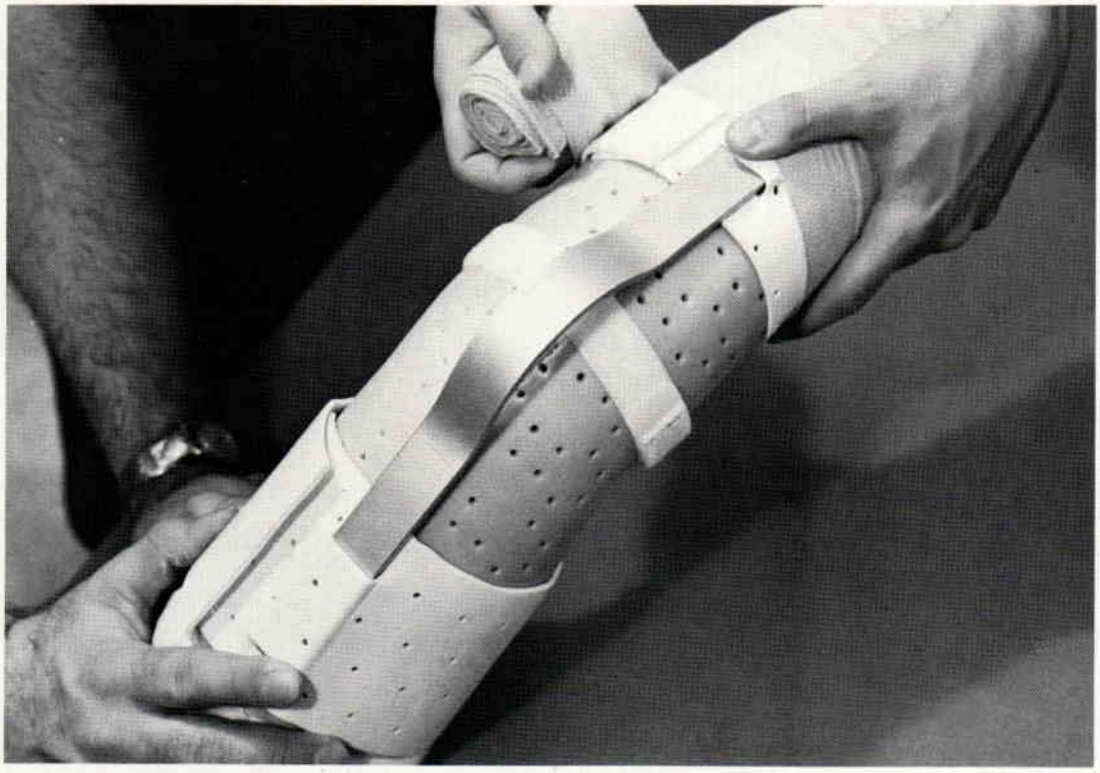

Fig. 15—Wrap Orthoplast cuffs over liner and hold in place with an elastic bandage until it cools.

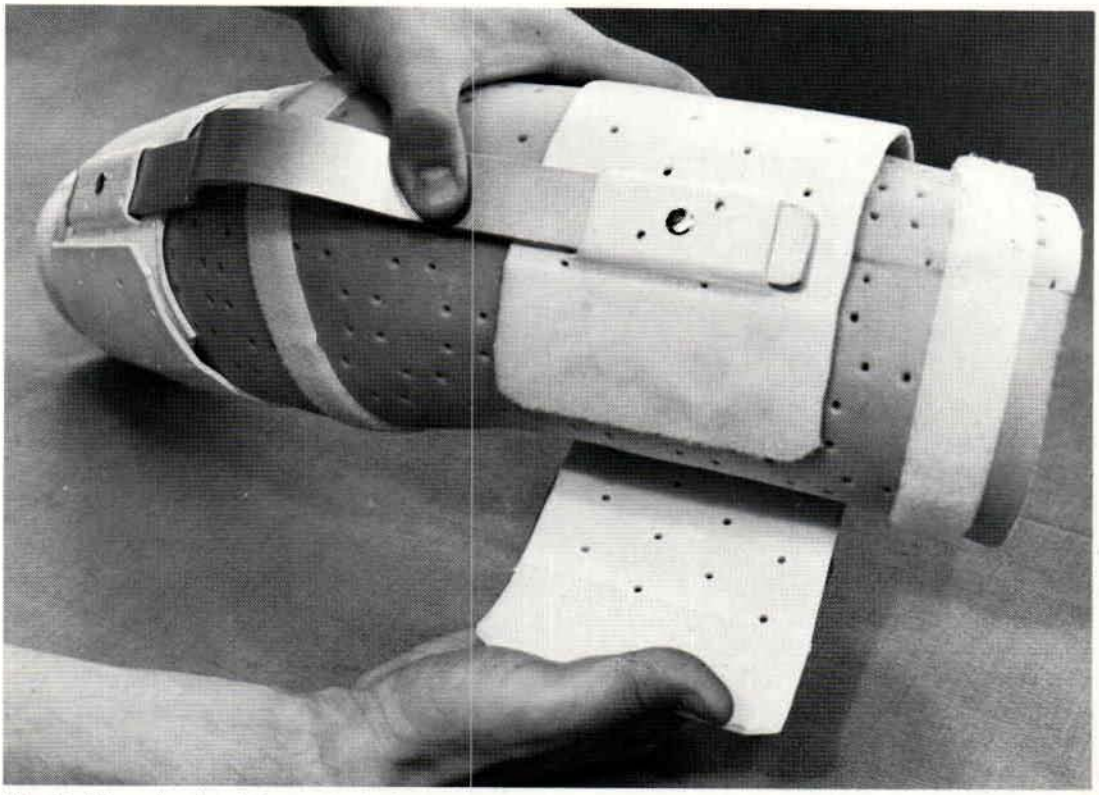

Fig. 16 – Rivet the dorsal bar to the Orthoplast cuffs and attach the Velcro closures.

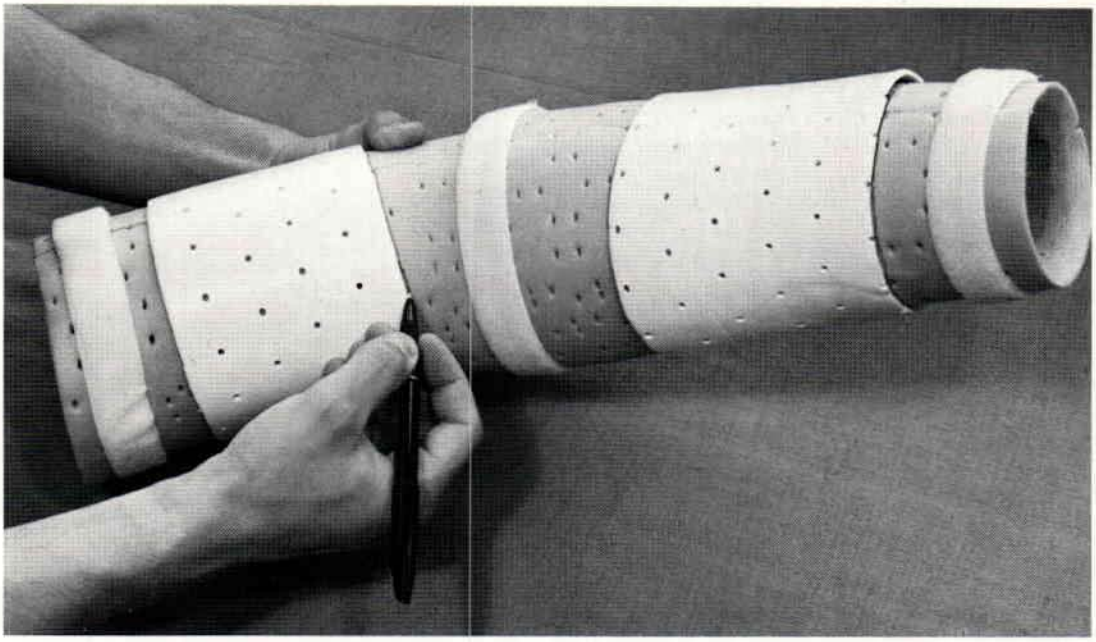

Fig. 17 – Trace position of cuffs onto liner.

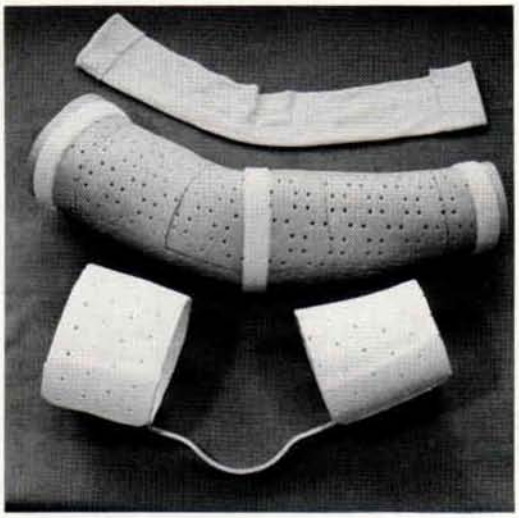

Fig. 18—Completed components of elbow extension orthosis.

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.

ACKNOWLEDGMENTS

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The Lerman Multi Ligamentus Knee Control Orthosis

Max Lerman, C.O.
Jack Schwartz, C.O.
Max Schwartz, C.O.

Developing an effective Ligamentus Knee control orthosis has been the goal of the orthotic profession for decades. Numerous innovative knee control orthoses are in common use today, all of which have their merits. The development of the Lerman multi ligamentus knee control orthosis was based on some of these existing designs with a few innovations. The Lerman orthosis was developed to overcome some of the drawbacks of previous knee orthoses, which include:

- Lack of *total* knee control.
- Difficulty of donning and doffing.
- Discomfort and pressure over the tibial crest.
- Complexity of fabrication.
- Distal migration.
- The need for very precise measuring techniques.
- The difficulty of changing contours of the uprights without disturbing the alignment of the knee joints.

The Lerman multi ligamentus knee orthosis took seven years to develop, and was modified and tested on over 250 patients. The results from the present design are excellent; no rejections and an insignificant number of adjustments or modifications have been seen.

The orthosis is designed to provide the following functions:

Medio-Lateral Stability

Medio-lateral stability is achieved by plastic posterior femoral and tibial bands which are attached to medial and lateral uprights with knee joints. These are long enough to provide adequate leverage. In addition, the unique floating medial and lateral condyle pads provide total contact through the complete range of motion to stabilize the knee. (Fig. 1)

Anterior-Posterior Stability

The anterior and posterior motion of the tibia in relationship to the femur is controlled by the floating condyle pads, by virtue of their universal hinging system attachment combined with total contact at the femoral and tibial condyles. (Fig. 2).

Derotation and Rotational Control

Derotational control is established by the encircling total contact gum rubber straps.

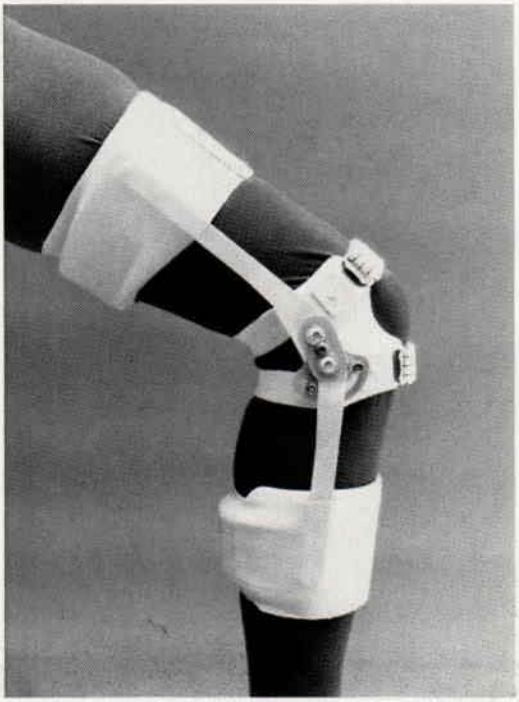

Fig. 1

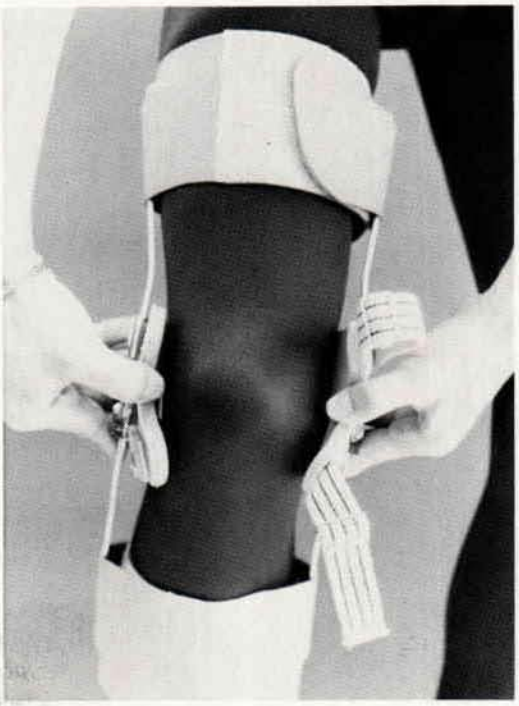

Fig. 2

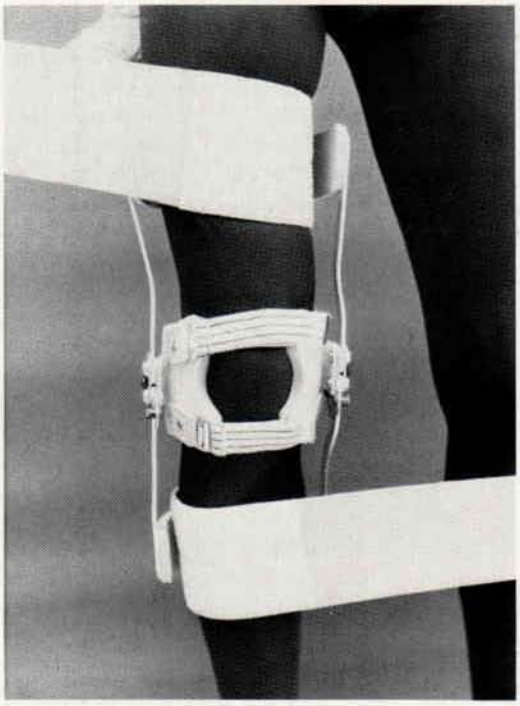

Fig. 3

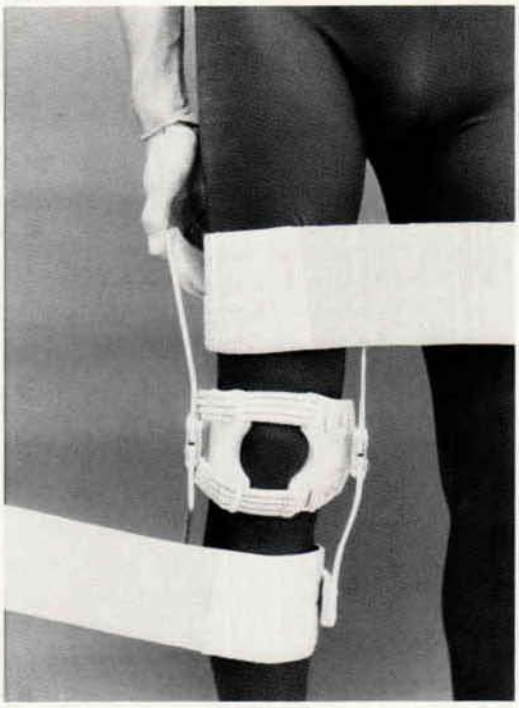

Fig. 4

These straps originate at the center-inside aspect of both the femoral and tibial bands (Fig. 3). The direction of the pull is opposite to one another, resulting in a torquing effect designed to derotate the knee joint. The direction of these straps may be changed as determined by the nature of the treatment (Fig. 4). For example, to protect the anterior cruciate ligament, external rotation of the tibia should be restricted; the direction of the tibial strap pull would be lateral to medial, and the pull of the femoral strap is in the opposite direction. The opposite strap arrangement is provided when internal rotation of the tibia is to be controlled. To derotate in both directions an extra derotation strap may be added, however the extra strap is not needed if both the femoral and tibial strap go in the same direction; the direction of the strap pull is determined by the comfort of the patient in this case.

Patellar Tracking and Distal Migration

Patellar tracking is provided by the floating condyle pads. These pads control the lateral and medial displacement of the patella through the full range of motion. The proximal and distal elastic patella straps prevent the distal migration of the orthosis and secure the condyle pads to the knee (Fig. 5).

Post-op Use

For post-operative ligament repair this orthosis comes with a standard polycentric hinge. When limited motion is desired (Fig. 6) the Lerman dial control knee hinge is used. This dial hinge provides extension and flexion control in any range (Fig. 1).

Measuring Techniques

A standard casting procedure is required for this custom made orthosis making sure that all landmarks are delineated and the center of the knee axis is established. A polycentric knee hinge is used because it comes closest to simulating the motion of the knee and provides more strength and torque stability than plastic hinges. The hinges also serve as an anchor for the floating condyle

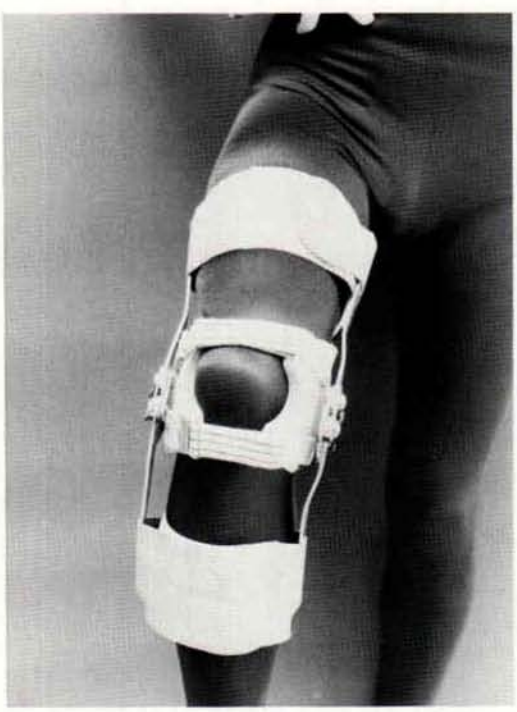

Fig. 5

Fig. 6

pad system (Fig. 3). The femoral and tibial bands are constructed out of polypropylene which affords some flexibility, thus slight malalignment of the knee hinge can be tolerated. Further adjustments to the uprights to provide better fit can be made with less trouble than a knee orthosis with metal connecting bands. The bands are purposely placed posterior to prevent pressure on the tibia. The floating condyle pads are made of high density polyethylene, which is malleable. The strapping material is standard gum rubber with Velcro and elastic orthopedic webbing. All parts which are in contact with the skin are padded with a closed cell vinyl foam. This orthosis is commercially available, but can also be custom fabricated.*

* Available from the U.S. Manufacturing Company, Pasadena, California.

Max Lerman, C.O., Jack Schwartz, C.O., and Max Schwartz, C.O. are of Lerman and Son, Inc., Beverly Hills, California.

Application of the Varus T-Strap Principle to the Polypropylene Ankle Foot Orthosis

Robert S. Lin, C.O.

INTRODUCTION

The ankle mortise with the severe yet flexible varus or valgus deformity presents a challenging case for orthotic management. The trend towards the use of thermoplastics in lower extremity orthotics can enhance this problem through the elimination of the varus or valgus correction strap (T strap). When a patient presents a dynamic ankle that has a profound tendency towards the varus or valgus attitude upon weight bearing, pressure on either malleolus is inevitable. For many patients, padding and relieving the medial or lateral aspect of the orthosis is sufficient in preventing pressure related problems. It is the active, well ambulating patient with the strong lateral displacement at the subtalar joint that often exhibits chronic pain at the malleolar site. A patient in this category was the motivation for the development of the concept of the internal varus correction door.

CASE REVIEW

E. G. is a 37 year old male with Friedrick's Ataxia and Charcot-Marie-Tooth disease. Numerous surgical procedures were performed bilaterally and the patient was presented to the orthotics department for post-operative provision of bilateral Ankle Foot Orthoses (AFO's). The patient's right leg was more severely involved than the left, exhibiting a more unstable and dynamic malalignment. This resulted in severe pressure on the lateral malleolus upon weight bearing. The first orthosis provided had been relieved and padded at and around the pressure area with only short term alleviation of pain. The critical factor was maintaining correct alignment at the ankle without causing breakdown or pain at the lateral malleolus. The patient refused the option of the conventional double upright metal AFO with varus correction strap due to the advantages that thermoplastics offered (i.e. shoe inter-

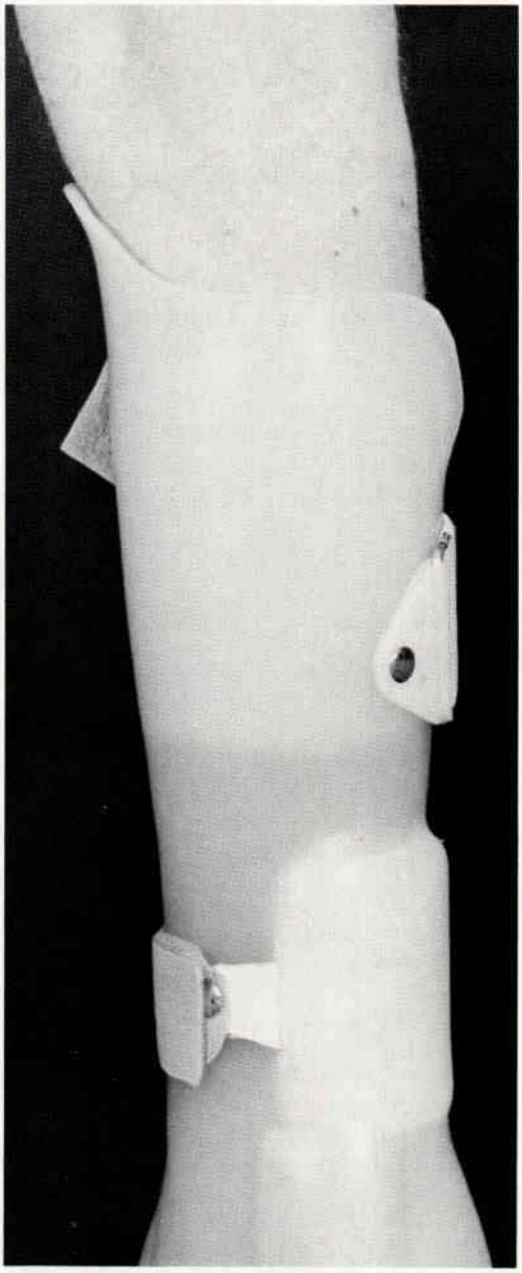

Fig. 1 – Posterior view of the Varus control pad. A slot is made in the posterior section of the orthosis to allow a strap attached to the Varus control pad to exit.

changeability, cosmesis, lightweight, etc.). Eventually a new right AFO was fabricated incorporating the internal varus correction door and conventional thermoplastic principles.

FABRICATION

Positive Model Modifications

The mold is taken high and incorporates a medial tibial flare. Care must be taken to accurately mark all bony prominences, especially the malleolus and the slope of the medial tibial flare. The positive model is then modified similar to those specifications for the NYU equinovarus solid ankle orthosis. One-eighth of an inch of plaster is removed from the positive model at the following areas: the medial/tibial flare, distal third of the shaft of the fibula, medial aspect of the os calcis distal to the medial malleolus. The amount of plaster removed can vary depending upon the presence or absence of subcutaneous fat at those above mentioned sites.

Varus Control Pad

Once all the plaster work is completed, a small padded, 3/16" polyethylene square is heated and conformed to the cast beginning two centimeters proximal to the proximal border of the malleolus and extending approximately ¼ of the way up the shaft of the fibula. The size and shape of the square determines the surface area with which the corrective force is applied. This can, very effectively, reduce the chance of skin breakdown. Padding of the square further decreases the pressure. The principal corrective force is directed to the distal third of the fibular shaft and is adjustable by way of two Velcro straps. The padded door is then temporarily glued to the positive model and the mold is prepared for vacuum molding the polypropylene AFO. After molding, the door is separated and hinged via a strap exiting through a small slot cut in the posterior aspect of the orthosis (see Fig. 1). A Velcro strap is attached to the anterior aspect of the door and padded to prevent strap pressure on the tibial crest.

Proximal trimlines extend over the medial tibial flare, thus providing the proximal-most force of the 3 point force system. The hinged door provides an adjustable second force with the medial aspect of the calcaneous acting as the third vector (Fig. 2). A single diagonal strap adequately stabilizes the orthosis on the leg with assistance from the shoe.

Two variations have been used with other patients with a similar clinical picture. In one case a ⅛″ polypropylene door was used in place of the 3/16″ one. This decision was based on the relative weight of the patient and the level of activity anticipated.

In the other case a thinner padding, (⅛″ instead of ¼″ Plastazote) was used at the site of the lateral malleolus with subsequent success. Such options are available to the orthotist depending on the characteristics that each individual case presents.

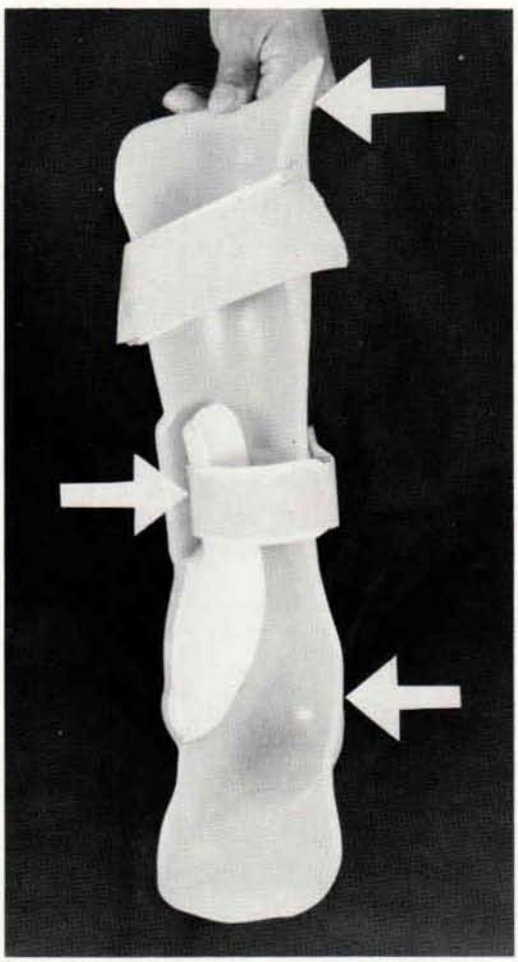

Fig. 2—The three point pressure system controls Varus forces. A high medial flair at the proximal trim line increases the level arm and decreases skin pressure. The Varus pad in the center acts as the fulcrum. The distal medial orthosis and the shoe provide the third force.

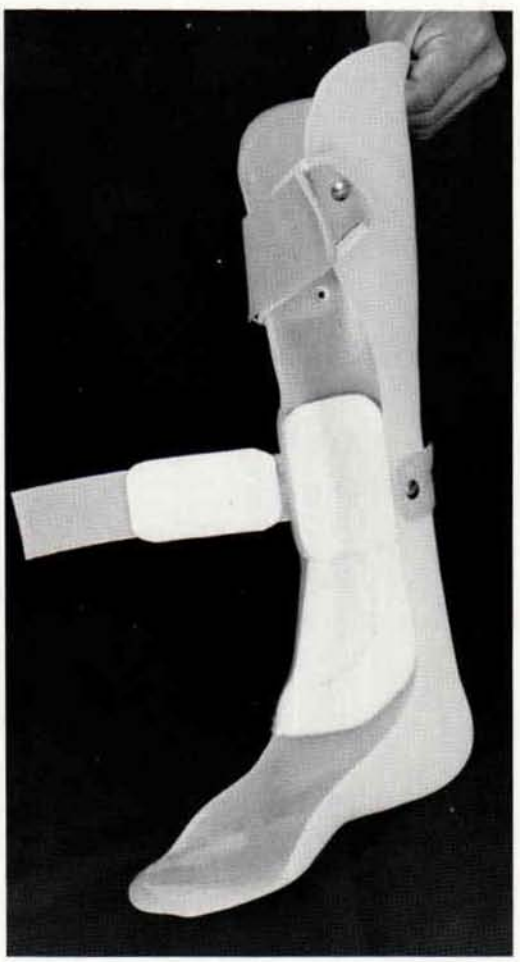

Fig. 3—The strap extending from the Varus control pad is padded where it crosses the tibia.

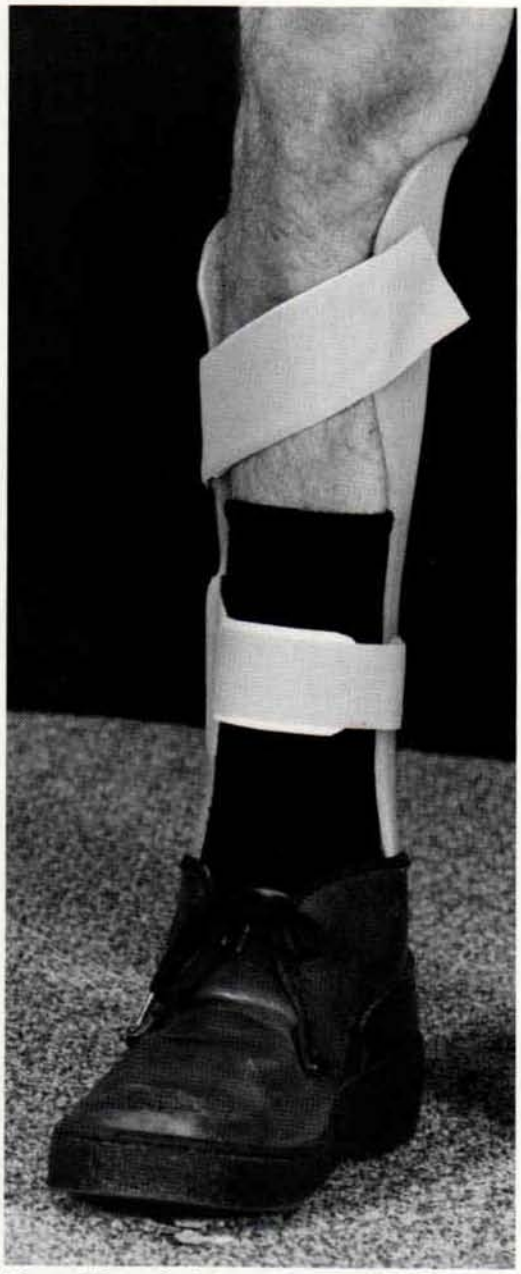

Fig. 4—The orthosis is worn with normal bluchor style shoes.

SUMMARY

Application of the internal varus correction door in this case study has proven successful to date. The underlying principles are precedented and widely applied in the conventional T-strap arrangement used with double upright AFO's. This new concept allows stable alignment of the ankle mortise with the aforementioned advantages of thermoplastic bracing and the virtual elimination of undue malleolar pressure.

Robert S. Lin, C.O. is of Newington's Children's Hospital, Newington, Connecticut.

HYBRID CARBON COMPOSITE

•INSERTS •SHEETS

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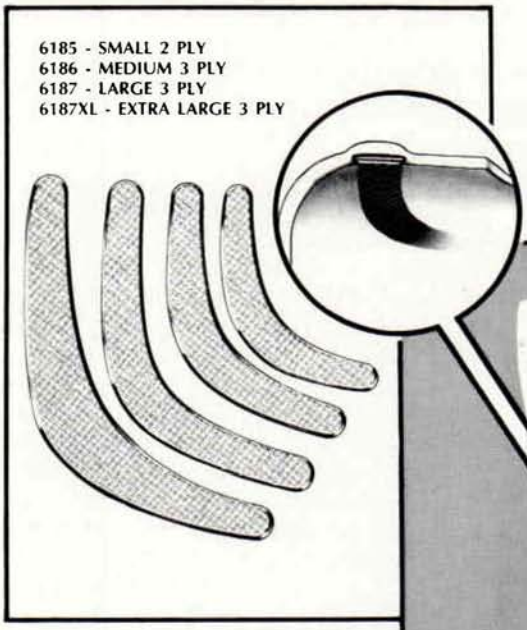

The recent introduction of exotic fibres for the production of thin, light weight and high strength laminated forms suggested the development of a moldable sheet material from which special designed inserts could be used in reinforcing plastic orthotic items. Now orthotists and prosthetists have a cost and labor effective alternate to the tedious task of hand making metal reinforcements.

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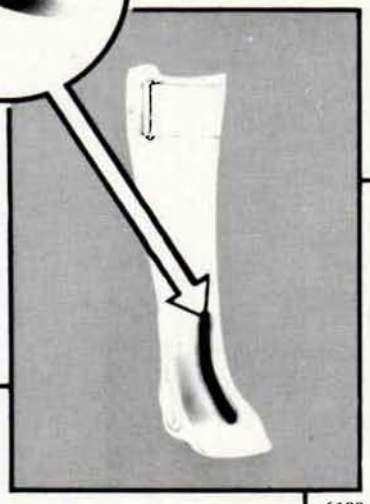
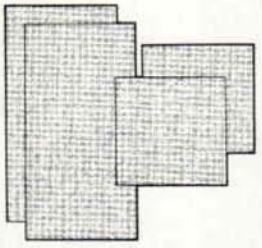


AFO with Composite Inserts

When the inserts are located on the lateral mid-line and are well encapsulated in the plastic wall the AFO will have maximum rigidity and thus prevent undesirable motion in the ankle.



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New Publications

Orthopedic Shoe Technology for the Orthopedic Shoe Technician

Clyde A. Edwards, Precision Printing Co., Muncie, Indiana 47305, 246 pages. 1981.

Available from: National Registry for Orthopedic Shoe Technology, P.O. Box 870, Muncie, Indiana. $62.50.

This book is intended to be used as a text by orthopedic shoe technicians in the course of meeting the needs of patients with foot problems. As such, it covers evaluation of the patient's shoes and feet as well as techniques for the modification of shoes and the fabrication of foot orthoses and shoes. This last point is of particular interest as there is very little in the way of published information describing the fabrication of shoes.

While there are a number of editorial oversights of a minor nature, the book in general is well thought out and the material is well presented and illustrated with clear line drawings. It should be pointed out that the philosophy espoused is essentially that of pedorthotics and podiatry; some trained in the slightly different philosophy of orthopedics may have reservations. It also should be borne in mind that the book presupposes the availability of shoe working equipment and the knowledge of how to use it; such knowledge and equipment is no where near as common in the world of orthotics as it might be. Nonetheless, this book should prove to be an interesting and useful addition to the professional library of those concerned with the treatment of foot problems.

Charles H. Pritham, C.P.O.

Moire Fringe Topography And Spinal Deformity,

edited by M. S. Moreland et. al. Pergamon Press, Inc. Maxwell House, Fairview Park. Elmsford, New York, 10523, 1981, 305 pages, index. $45.00.

Moire Fringe Topography is a technique that can be used to reveal the contour lines of a three-dimensional body in a two-dimensional photograph. The result is much the same as a large scale ordnance map. Furthermore, it is possible to convert the information on the photograph to a digital form that can be assimilated and manipulated by a computer. In the immediate context of this book, the goal is to use the technique in large scale screening of school children for idiopathic scoliosis and further to use it as a follow up tool to assess efficacy of treatment. In a broader sense, considerable interest has been generated during the past decade in the use of Moire Fringe Topography and similar techniques in the production of cosmetic restorations, sockets, orthoses, and shoe lasts; while avoiding what are perceived by some as the inadequacies of such traditional techniques as casting, tracing, and measuring.

This book is the product of an international symposium and consists of 34 scientific papers presented by authors from Japan, Europe, and North America. As such, it provides an excellent review of the state of

the art and documents the potential of the technique. It also illustrates the difficulty in converting what is at its simplest a rather intriguing parlor trick to a meaningful measurement tool. The goal is to establish a standardized technique that gives reliable and reproducible results that can then be accepted unequivocably by others. Such indeed was the topic of the symposium and considerable discussion is devoted to it in the papers and in the transcripts of the panel discussions.

This book will undoubtedly not appeal to all in the profession of prosthetics and orthotics but will be of interest to that smaller group concerned with scoliosis and the application of advanced technology to age old problems. In general, the quality of the illustrations, writing, and editing is quite good and the book should be readily understood by most readers.

Charles H. Pritham, C.P.O.

Course Announcement

"The Second Annual *ADVANCED*
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LECTURES

What Below Knee Suspension For What Patient?
Nonquadrilateral Above Knee Sockets
The Adult Problem Stump—Revise or Fit?
The Conservative Treatment of Osseous Overgrowth
Special Problems of Amputation During the Growing Period
Are Prostheses and Training of the Hip Disarticulation Patient Adequate?
Above Knee Gait Deviations and their Correction
Sensory Implications of Lower Extremity Amputation
Femoral Defects (PFFD)—Total Rehabilitation
American Methods for Treating the Child Lower Limb Amputee
Amputation in Art Before Columbus
The Patient's Decision to Accept or Reject the Limb
Is Cosmesis Important for the Lower Extremity Amputee?
A Woman's Reactions to Prosthetic Design
Tibial Defects and their Rehabilitation
Fibular Defects and their Rehabilitation
Bone and Joint Problems
Skin, Muscle & Nerve Problems
Geriatric Legs
Legs for Heavy Work
Newer Feet and Ankles (S.A.F.E., Mauch, Haberman, etc.)
Sport Prosthese
Sexual Implications of Leg Amputation
Mourning by Amputees
The Multiple Amputee—Total Rehabilitation—"The Adult"
The Multiple Amputee—Total Rehabilitation—"The Child"

SPEAKERS

Victor Cummings, M.D., Prof. of Rehab. Med., Albert Einstein College
James T. Demopoulos, M.D., Dir., Dept. of Rehabilitation, Hospital for Joint Diseases-Orthopedic Institute, Prof. of Rehabilitation Medicine, Mt. Sinai School of Medicine
Malcolm Dixon, R.P.T.
Mary Dorsch, CPO
Donald H. Eisenberg, Executive Director, Nassau County Medical Center
John Eschen, CPO
Lawrence W. Friedmann, M.D., Chairman, Dept. of Physical Med. & Rehab., NCMC also Professor of Rehabilitation Medicine, SUNY at Stony Brook, Health Sciences
Liesl Friedmann, OTR, Institute of Rehabilitation Medicine, NY University
Selene Jaramillo, M.D., Institute of Rehabilitation Medicine, NY University
Elizabeth Kolin, Ph.D., Clinical Psychologist, Nassau County Medical Center
H. Richard Lehneis, CPO, Ph.D., Dir., Prosthetics & Orthotics, Institute of Rehabilitation Medicine, New York University School of Medicine
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The theme of the seminar is New Innovations in Prosthetics and Orthotics. The faculty is composed of heavy hitters in the field of medicine, orthotics, prosthetics and physical therapy.

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In addition to a super scientific program, arrangements have been made to provide social opportunities for those attending. Friday evening there will be a "no host" cocktail party providing plenty of opportunity to renew old acquaintances and to make new ones. Plans have been made for the ladies to visit the Pendleton Mills on Friday. The ladies will also find great pleasure in browsing among the 110 shops located in close-by Jantzen Beach Center. Then, too, the new mall in downtown Portland is only minutes away.

While not yet firm, an attempt is being made to organize a fishing trip either as a "pre" or "post" seminar activity. Finally, plans have been made for an elegant "no host" Buffet Luncheon at noon on Saturday.

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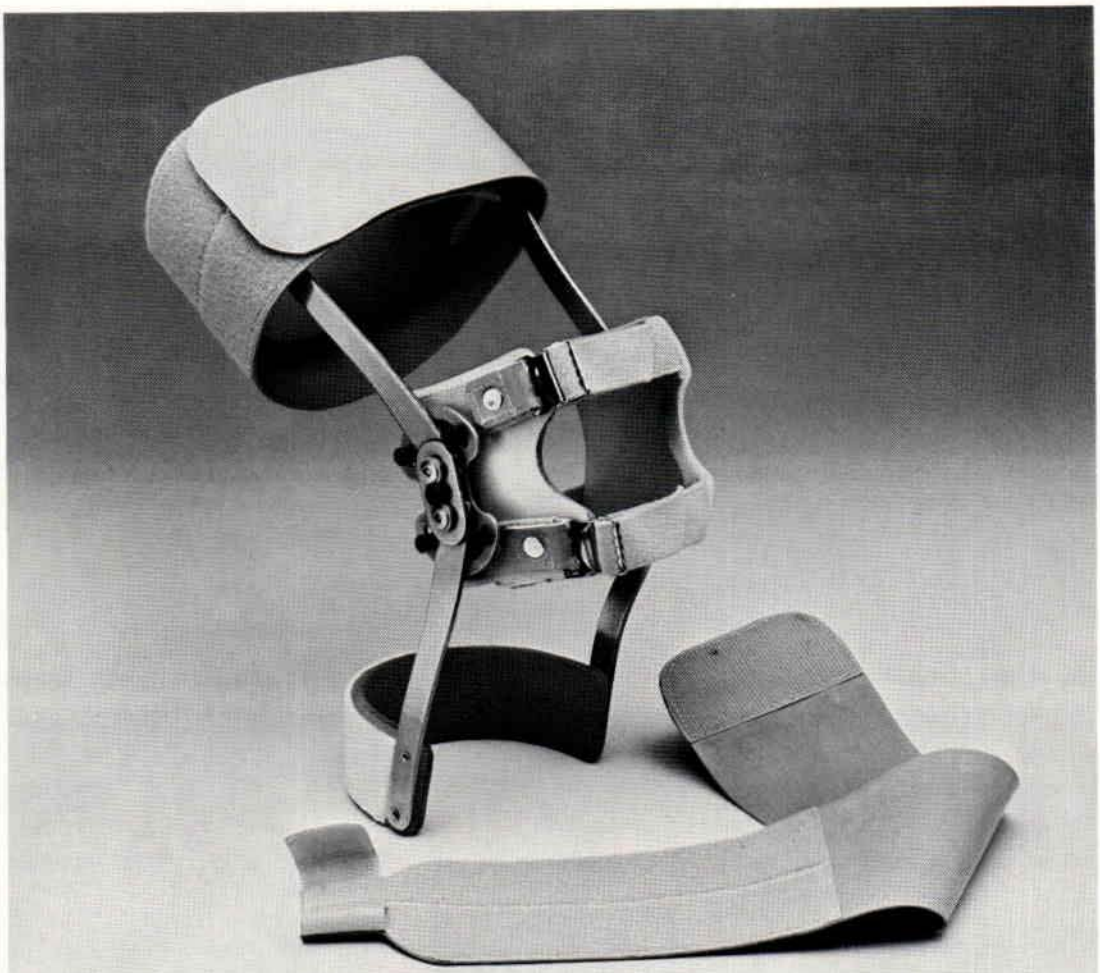

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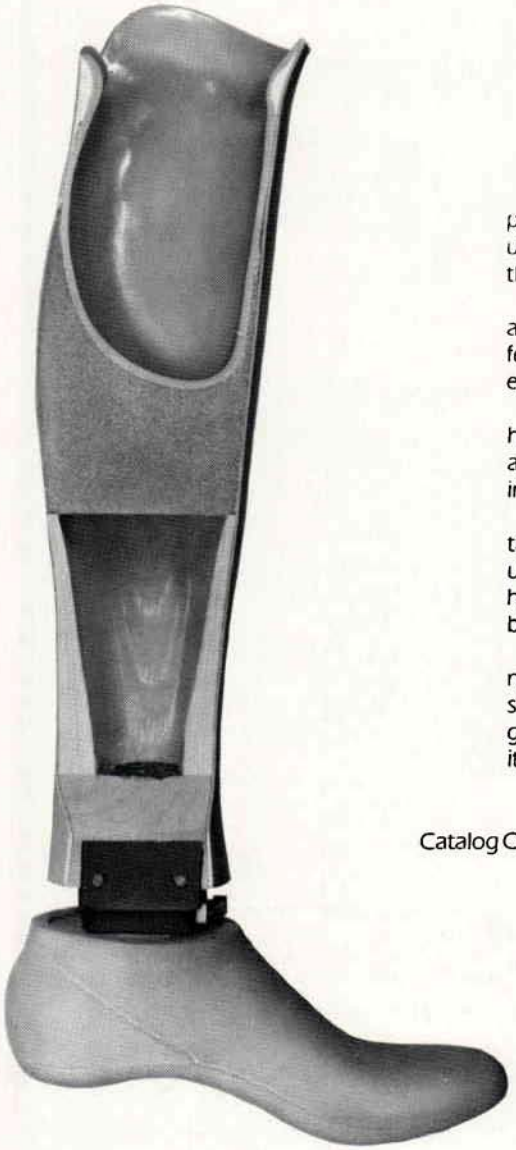

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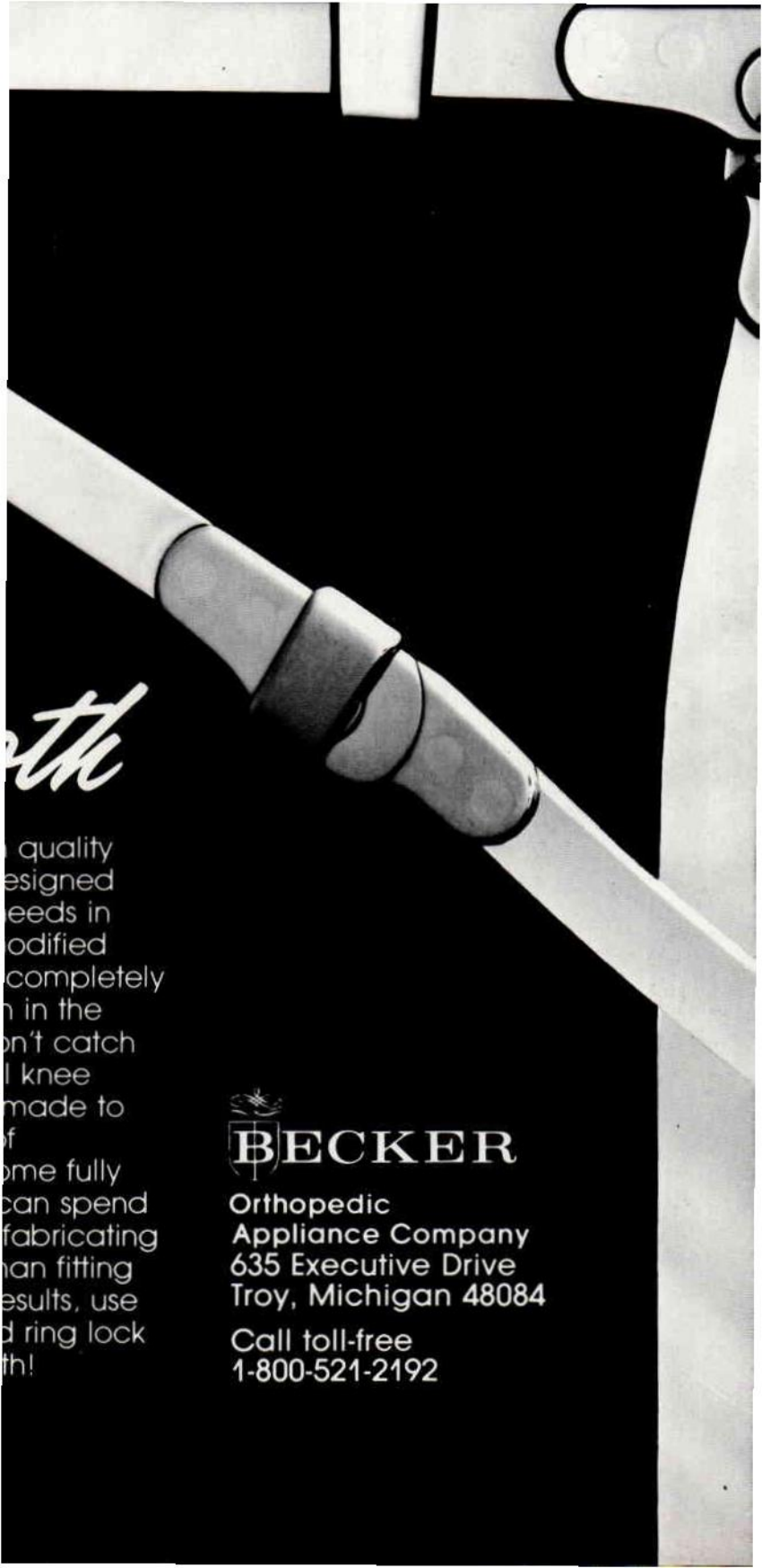
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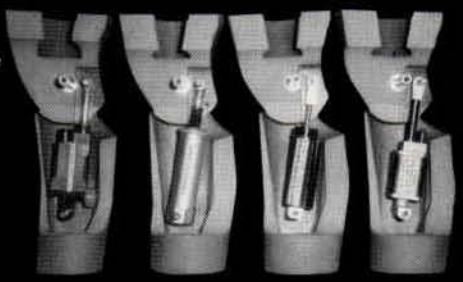

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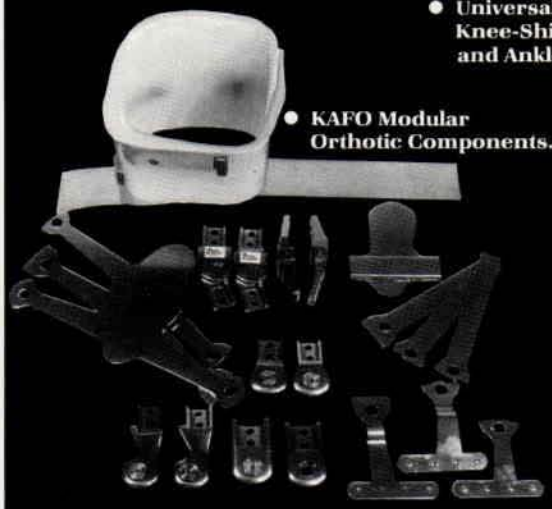

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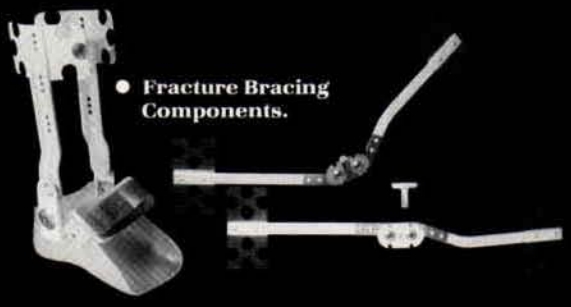

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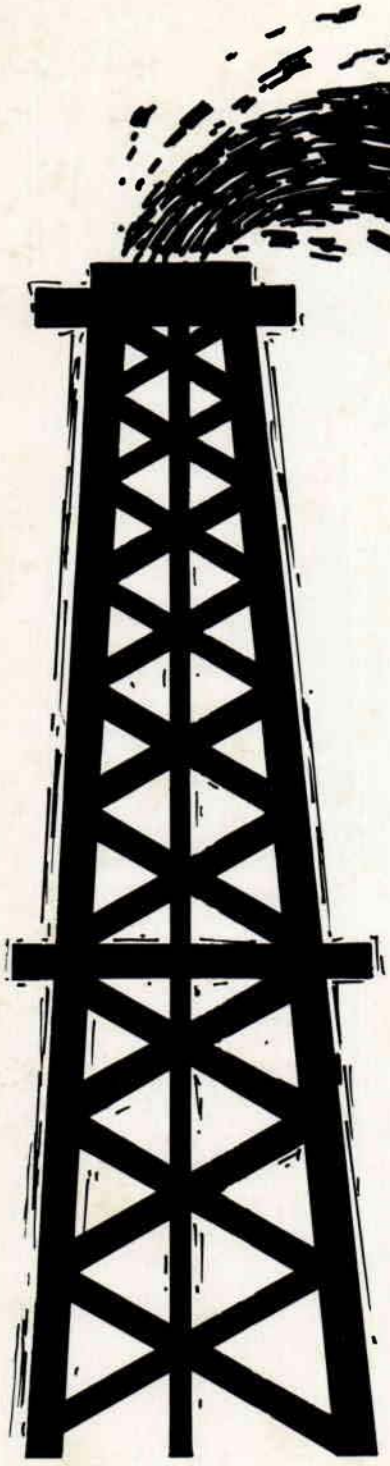

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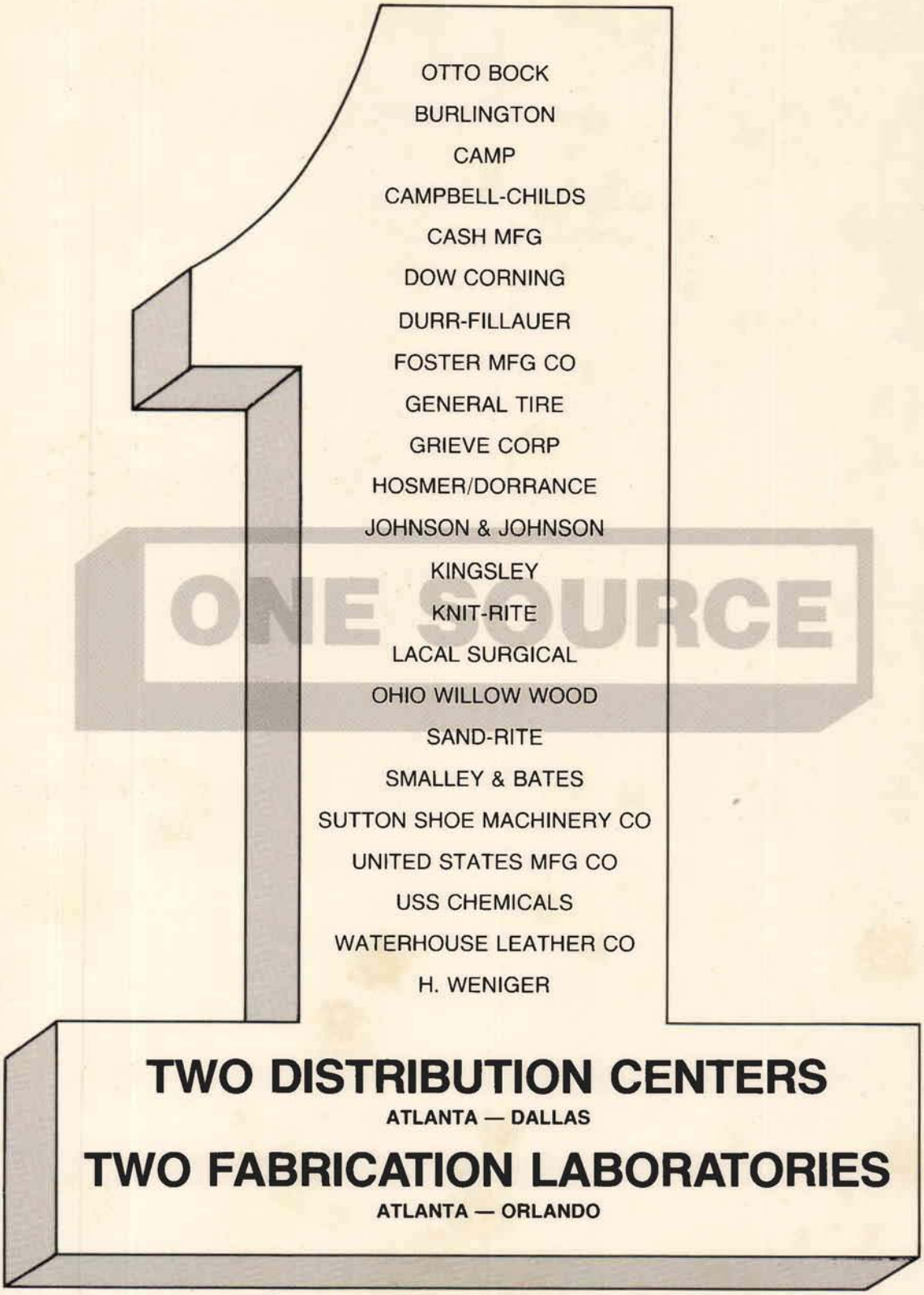

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