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LSU Lively Orthosis

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In the decades since the end of World War II, medical science has made tremendous advances in its ability to prolong the lives of individuals who formerly would have died of conditions such as spinal cord injury and myelomeningocele. This ability has caused the medical field and society to place new emphasis on helping such individuals achieve the highest level of function possible.

Among these functional goals is independent ambulation. A complicating factor hindering, or even in some instances frustrating, this goal of ambulation has been the formation of soft tissue contractures of the ankle/foot complex and the knee. Before higher levels of function can be achieved, these contractures need to be prevented or corrected. While stretching exercises are undoubtedly efficacious in reducing contractures, the fact remains that they apply forces during a relatively brief period of the patient's total day. The efforts of the best planned surgery may be fruitless if no provision is made post-surgically to combat any deforming forces. The need exists for a device that can exert subliminal dynamic corrective forces over a long period of time, is adjustable, and readily fabricated. The Louisiana State University (LSU) Lively Orthosis is such a device.

The use of the word "lively" to describe an orthosis is undoubtedly unfamiliar to most American orthotists. However, it is common in the British literature and is usually used to characterize active or dynamic hand orthoses. The equivalent American phrase is dynamic flexion (or extension) assist.

In this particular situation, the name LSU Lively Orthosis (Figure 1) describes an AFO (or KAFO) with free motion at the ankle and subtalar joints with elastic straps to dorsiflex (or by modification to plantarflex) the ankle joint and selectively invert or evert the subtalar joint. In the KAFO configuration, there is a rigid portion extend-

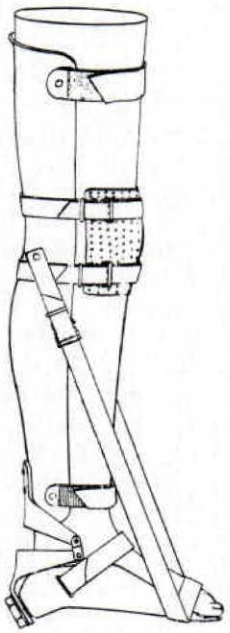


Figure 1. The LSU Lively Orthosis.

ing posteriorly to mid-thigh to block flexion and knee cap with elastic straps to extend the knee. The orthosis is intended to be used in a nonambulatory fashion to correct—and maintain correction of—various soft tissue contractures of the ankle and foot associated with such neuromuscular conditions as spina bifida. This article is written to trace the developmental history, theory, and fabrication techniques involved in its use.

HISTORY AND BACKGROUND

Work on what came to be recognized as the LSU Lively Orthosis began about 1975–76 by Roy Douglas, C.P., now Assistant Professor of Orthopedics, Louisiana State University, New Orleans. At that time, Mr. Douglas was participating in a muscular dystrophy clinic, and was confronted with a number of patients with severe equinovarus deformities. It was desired to reduce these feet to a plantargrade position so that the patients could be fitted with such devices as the LSU Reciprocating Gait Orthosis in an attempt to make them ambulatory. However, surgery for a number of reasons was not feasible. To fill the need, Roy Douglas designed the original Lively Orthosis.

It consisted of a molded plastic AFO with articulations at the ankle to permit plantar/dorsiflexion and inversion/eversion. The objective was for the patients to wear the orthoses full time and to use the elastic straps to exert low grade corrective forces over a protracted period of time to gradually render the feet plantargrade. Despite the relatively crude nature of the articulations, good results were obtained.

In September of 1977, Carlton Fillauer, C.P.O., visited New Orleans as part of a site visit to a number of centers. An exchange of views and a review of recent developments took place, and, as a consequence, a collaborative development effort was initiated. This effort is now bearing fruit, and numbers among its results the LSU Lively Orthosis and the LSU Reciprocating Gait Orthosis.

It was Mr. Fillauer's opinion that the lively Orthosis certainly merited further development, but that a major shortcoming was evident. The articulations consisted of a single pivot joint to permit inversion/eversion and a piano hinge immediately above it to permit plantar/dorsiflexion. Both were mounted on the posterior aspect of the orthosis and were not congruent with the anatomical tibial-talar and subtalar joints. As a consequence, considerable relative motion between the foot and orthosis resulted as correction was achieved. It was felt that the mechanical articulations should be aligned as closely as possible with the anatomical articulations as described by Inman, *et. al.*,[1] to minimize relative motion. It was also agreed that the mechanical components should be prefabricated for the orthotists' convenience. The present day design has evolved from these design criteria.

The mechanical components consist of five different sized assemblies that can be used either for the right or left leg. The free ankle joint proximally is linked to the rest of the assembly by a joint link and rigid pivot point. This rigid pivot point is to be forcibly adjusted as necessary to align the free linkage with the anatomical ankle joint

in the sagittal plane. Portions of the mechanical assembly are recontoured as necessary to improve alignment of both joints.

It is recognized that since the assembly is neuter, true alignment of the mechanical subtalar joint with the anatomical joint is difficult, if not impossible to achieve. In this instance a conscious decision to fabricate the components in a neuter configuration was made to control production and inventory expenses and, ultimately, the selling price. It should be noted, however, that to date no problems as a consequence of this decision have surfaced. Since 1975, over 500 assemblies have been distributed, giving some indication of the number that have been used on patients.

Over the years, the design of the orthosis has evolved. Originally, Mr. Douglas fit some of the orthoses in an AFO configuration, reserving the posterior extension proximal to the knee joint to instances of obvious knee flexion contracture. Today it is recognized as a result of experience gained that all orthoses should be fit high enough to control the knee. This is logical if the bi-articular nature of the gastrocnemious muscle is recognized. If the knee is left uncontrolled and if the posterior structures of the ankle are stretched, then flexion of the knee will ensue. Metal outriggers have been fit to various orthoses when severe deformity precluded developing proper corrective moments about the joints. The epoxy resin used originally to fabricate the subtalar pivot has recently been replaced with methylmethacrylate acrylic resin.[2] Not only is this new material* easier to work with, it is minimally heat sensitive, and thus the possibility of overheating the area about the pivot during fabrication, and thus destroying it, is eliminated.

*Rapidcure, A product of D.F.M.I.

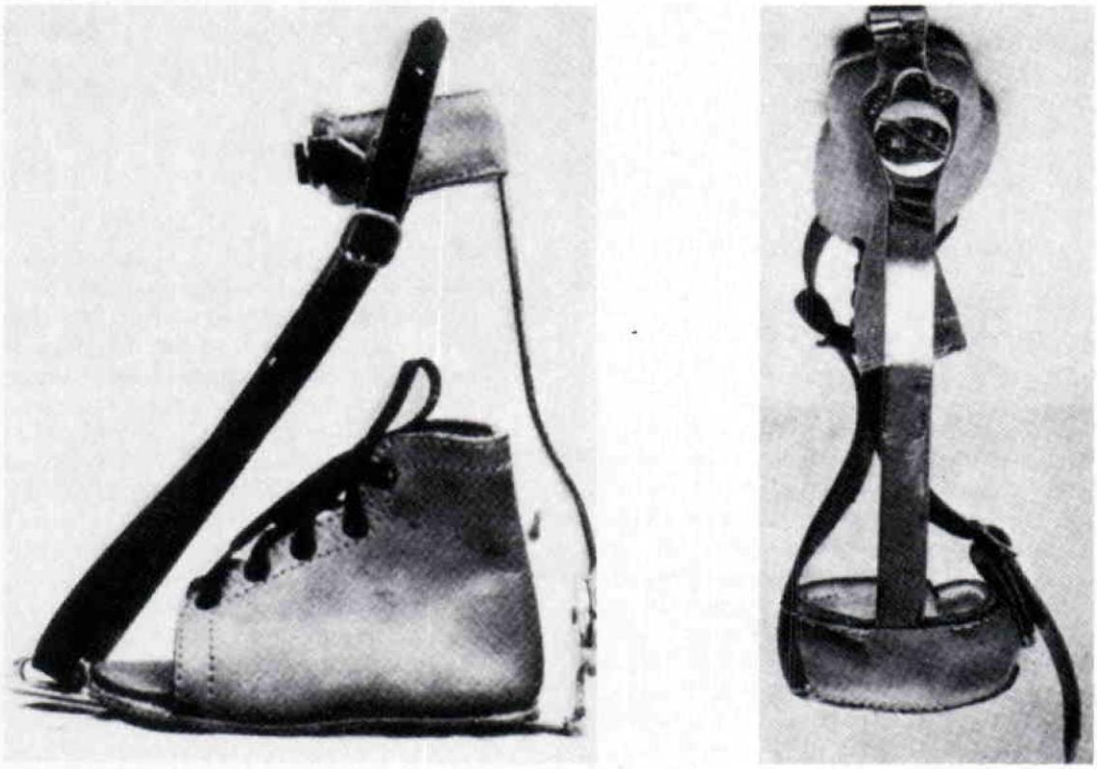


Figure 2. Night Splint described by George A. Pollock for treatment of talipes equinus, or equinovarus deformity in children with cerebral palsy. From *Prosthetics International* Vol. 2, No. 3, 1965, pp. 1273.

The concept of using a low grade corrective force for a protracted period of time is, of course, not new. In his book *Orthopedic Appliances* (1939, reprinted 1963), Dr. Henry H. Jordan[3] credits F. Mommsen with introducing the concept in relation to the Quengel cast in 1922. In his discussion of the Quengel cast (an early example of what has since come to be recognized as fracture bracing, albeit not for fractures) Dr. Jordan states:

> "It was offered as a method of correcting a contracture over a long period of time, using subliminal forces which act uninterruptedly but which are not so pronounced as to cause pain and muscle spasm. The chief obstacle to the correction of contractures consists in reflex spasm to the muscles involved." (Page 21, 2nd Ed.)

In Denmark and other regions of Scandinavia, a device[4] similar in some respects to the LSU Lively Orthosis is used for correction of congenital clubfoot deformity. Designed at the Orthopedic Hospital of Copenhagen, it consists of a series of modular fitting elements that encompass the foot and knee. Adjustable linkages for alignment of the ankle and subtalar axes are provided, as well as rubber straps to exert corrective forces. In addition, the foot component is articulated and fit with an elastic strap for correction of forefoot adduction.

In contrast to the Lively Orthosis, the knee is held at 90° of flexion in the OHC design. In the treatment of an infant with congenital clubfoot and no neuromuscular disease, this is logical and desirable, for it permits a more secure grip of the infant's short chubby leg. In the older person with neuromuscular involvement and the concomitant risk of contracture, it seems much more logical to hold the knee as straight as possible.

In an article published in 1965,[5] George A. Pollock of Edinborough, Scotland, described an AFO for nightwear similar in some respects to the LSU Lively Orthosis. Examination of the photographs (Figure 2) reveals an orthosis of metal with a boot on a sole plate and a single posterior upright. The upright is articulated so as to permit free plantar-flexion/dorsiflexion and adjustment for inversion and eversion. Inelastic leather straps run from the toe of the sole plate to the calf band.

INDICATIONS AND CONTRAINDICATIONS

Objectives:

1. Prophylactically to prevent contractures of the foot and ankle
2. To correct contractures of the foot and ankle
3. Maintenance of correction gained from surgery
4. Secondarily, treatment of knee flexion contractures associated with the above.

Treatment of contractures associated with such neuromuscular conditions as:

1. Spina Bifida
2. Muscular Dystrophy
3. Spinal Cord Injury
4. Multiple Sclerosis
5. Poliomyelitis
6. Cerebral Palsy

Indications:

1. Soft tissue contractures of the foot and ankle (secondary involvement of the knee)
2. Absent or mild spasticity
3. Good prognosis for ambulation
4. Cooperative patient
5. Intelligent cooperation by well motivated family members or nursing staff

Contraindications:

1. Boney involvement
2. Severe spasticity
3. Poor prognosis for ambulation
4. Uncooperative patient
5. Parents or others caring for the patient who seem to be disinterested in his prognosis and unable to cope with his present daily needs.

As should be obvious by now, this orthosis works very gradually, even imperceptibly, over a long period of time. It thus demands frequent, careful, progressive adjustment, and periodic skin care by

whomever is caring for the patient. If such other conditions as severe mental retardation preclude any hope of ambulation or if sufficient commitment to the patient's future cannot be mustered, then the effort of fitting him with the orthoses might as well not be made.

The need for periodic progressive adjustments and hygiene make the need for intelligent, willing cooperation imperative on the parents' or nursing staff's part. Moreover, it should be borne in mind that the orthosis should never exert forces strong enough to cause pain and rejection of the orthosis. The parents, whatever their anxiety or compensation for feelings of guilt, should understand this and be specifically enjoined not to attempt to achieve too much correction too soon. In light of the subliminal forces exerted and even with reasonable care, anesthetic skin should also be considered a contraindication.

FABRICATION**

The patient's leg is cast in the usual fashion with plaster bandage to a point near the perineum and a length of rubber tubing is used along the anterior surface to facilitate removal of the cast. Before wrapping the leg, the leg and foot are examined for malalignment and the amount of correction that can be obtained is noted. The leg and foot are held in as near a normal position as possible until the plaster has hardened. The plaster cast is removed and filled in the usual manner. In addition to the normal relief for boney prominences, a flared edge is built on the posterior, medial, and lateral aspects of the thigh in the general vicinity of the proximal one-third. There should be approximately 1"–1½" clearance between the perineum and the proximal edge of the orthosis.

The positive model (Figure 3) is covered with a layer of A-8 ventilated medium density Pelite, 3mm. thick, that will serve as a liner in the finished orthosis. The Pelite is heated for two to three minutes, molded to the cast and held in place with staples along the anterior centerline of the model. The size of the ankle joint assembly is selected on the basis of the width of the ankle (Figure 4). The minimum clearance over the malleoli with the Pelite liner in place is ⅜" on each side to allow for the thickness of the polyethylene in the finished orthosis and clearance for motion in two planes.

The subtalar joint of the assembly is aligned to coincide as closely as possible with the anatomical subtalar joint axis (Figure 5).

**This portion is derived from *The LSU Reciprocating Gait Orthosis*, a manual published by the Orthopedic Division of Durr-Fillauer Medical, Inc.

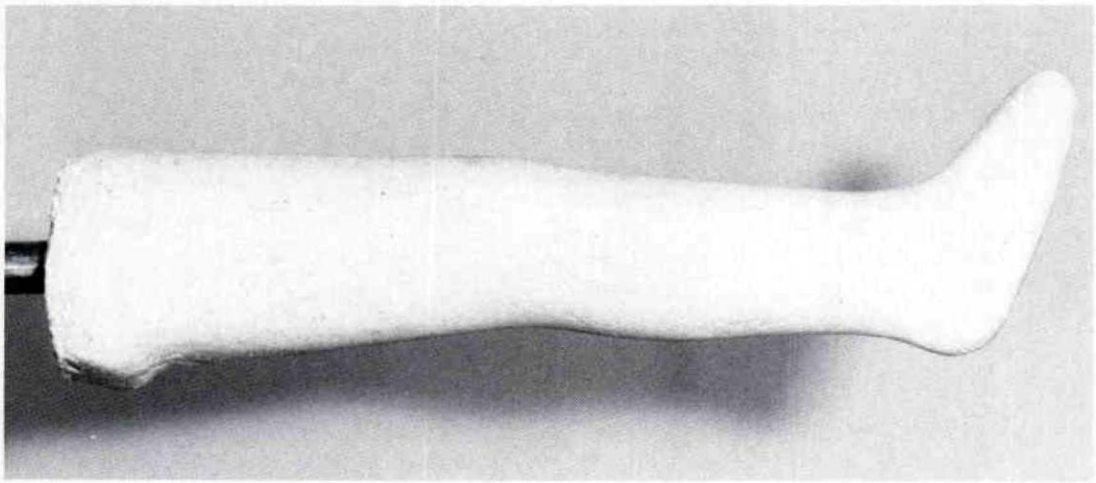
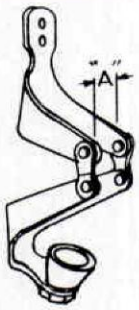


Figure 3. Positive model ready for fabrication of the orthosis.

Catalog No.	Size	For Ankle Diameter *	"A"
2340	XSM	Up to 2"	$2\frac{3}{8}$"
2342	SM	$2\frac{1}{16}$" to $2\frac{1}{4}$"	$2\frac{5}{8}$"
2344	MED	$2\frac{5}{16}$" to $2\frac{1}{2}$"	$2\frac{7}{8}$"
2346	LGE	$2\frac{9}{16}$" to $2\frac{3}{4}$"	$3\frac{1}{8}$"
2348	XLGE	$2\frac{13}{16}$" to $3\frac{1}{4}$"	$3\frac{5}{8}$"



* Minimum Clearance at Malleoli — $\frac{3}{8}$"

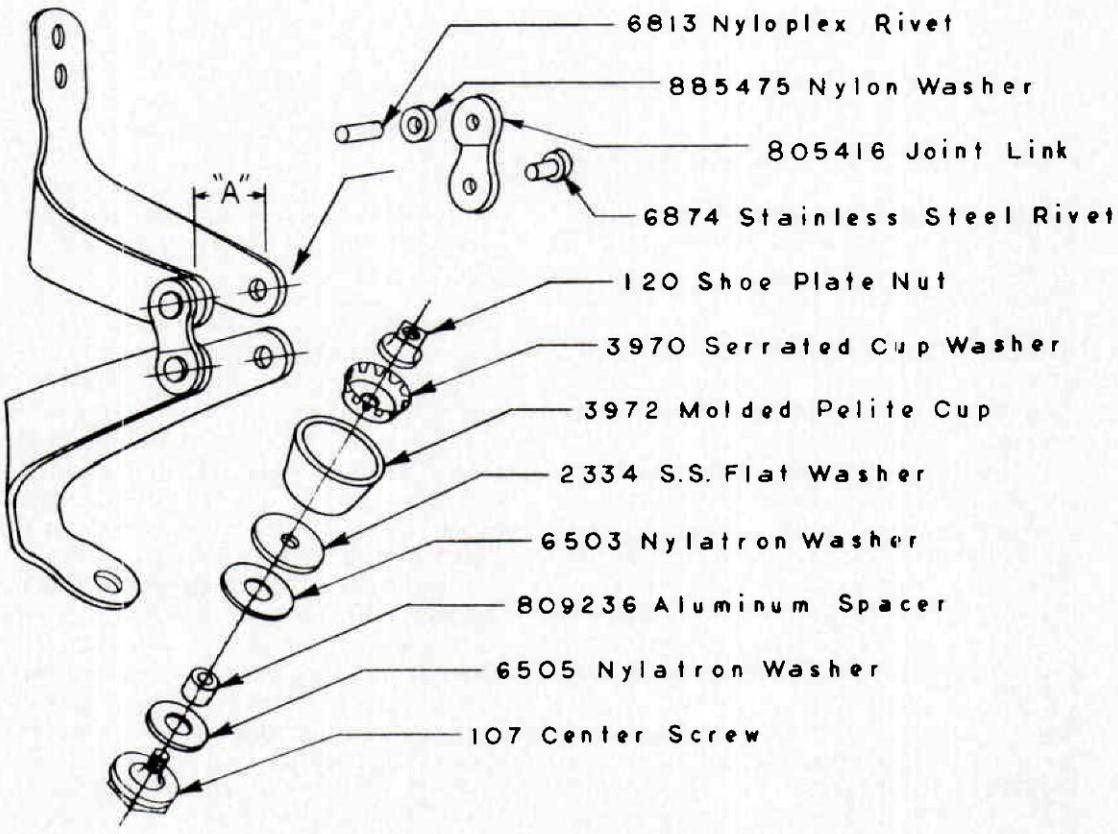


Figure 4. Selection of the Ankle Joint Assembly.

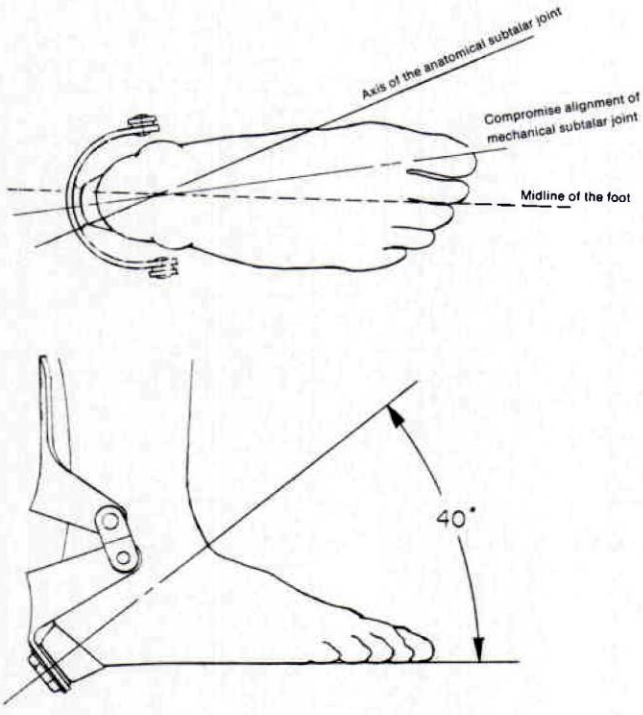


Figure 5. Alignment of the subtalar axis.

Sagittal: approximately 40" elevation from posterior to anterior relative to horizontal.

Transverse: approximately 25° internally rotated relative to the longitudinal axis of the foot (for reasons of economy and practicality, the ankle joint assembly is neuter. This means that alignment will undoubtedly prove to be a compromise).

As necessary, portions of the structure are contoured to achieve proper alignment. In aligning the ankle joint, the rigid linkage is forcibly adjusted, if needed, so that the loose linkage is aligned with the anatomical ankle axis (Figure 6).

Acrylic compound or epoxy is used to fill and anchor the molded Pelite cup that serves as a pivot point for control of the subtalar point. The matrix is mixed and poured into the Pelite cupe (Figure 7) with the pivot assembly intact; the cup is held in place on the heel with tape (Figure 8) until the resin hardens. The edges of the Pelite cup are then faired into the surrounding Pelite surfaces (Figure 9). If acrylic resin is used, this can be accomplished most efficiently by using a finger dipped in the catalyst to smooth the edges out before it sets completely.

Polyethylene, 3/16" thick, is heated to 375–400°F., and vacuum-formed over the model by the hand drape method. The area over the pivot point hole in the Pelite cup is heated and cut away (Figure 10) to provide access to the nut for the center screw. The area is then reheated (Figure 11) and the subtalar joint is assembled and tightened so that a seat is formed for the stainless steel flat washer (part #2334).

Caution should be taken not to overheat the area, which may cause softening of the matrix and inadvertent loosening of the shoe plate nut (part #120). This caution is not necessary if acrylic resin is used, as heat does not degrade it in the same fashion as it does epoxy.

While the assembly is in place, the proximal attachment holes are drilled (Figure 12). Trimlines are then established. A gap of ¾" between the foot and leg sections is necessary so as to permit free motion without pinching the patient. The plantar

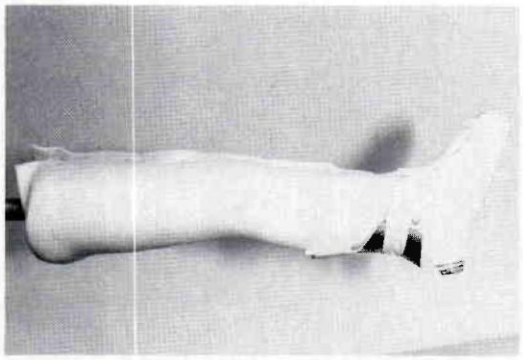


Figure 6. Metal assembly in place ready for filling the Pelite cup with matrix. Note presence of Pelite pad beneath proximal portion of the assembly to serve as a spacer to allow for the thickness of the polyethylene.

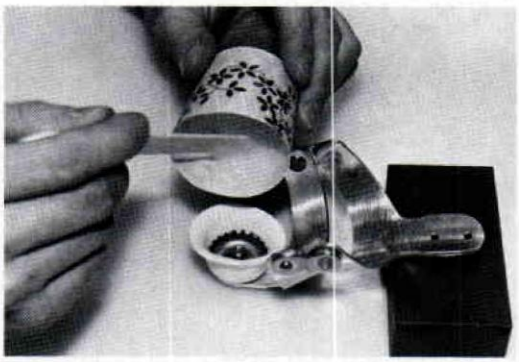


Figure 7. Filling the Pelite cup with matrix.

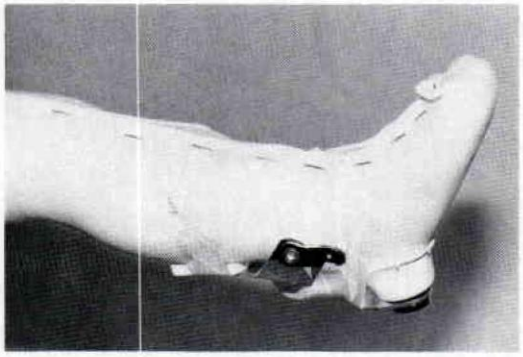


Figure 8. Assembly held in place with tape.

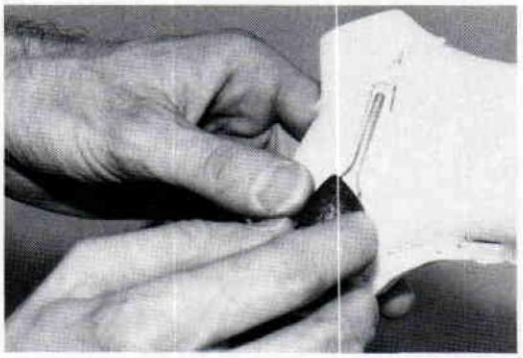


Figure 9. Fairing the edges of the cup into the overall contours of the model.

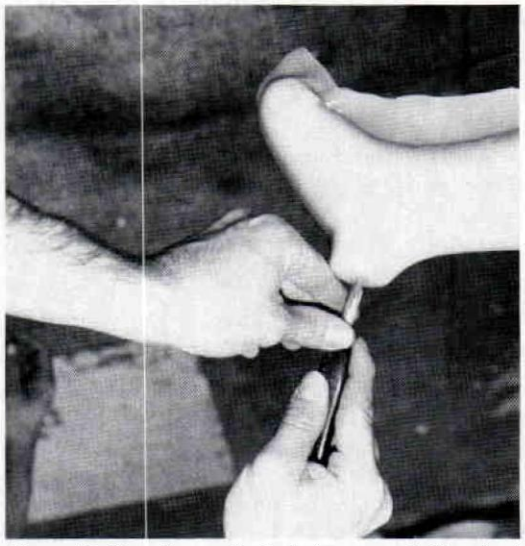


Figure 10. Opening up the hole for access to the pivot point of the subtalar axis.

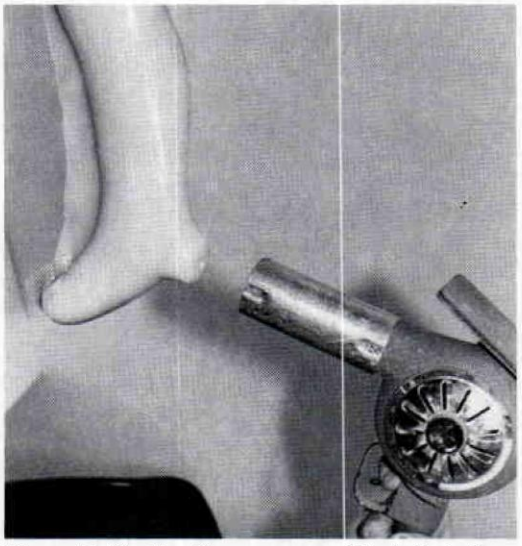


Figure 11. Heating the area around the hole to form the flat seat.

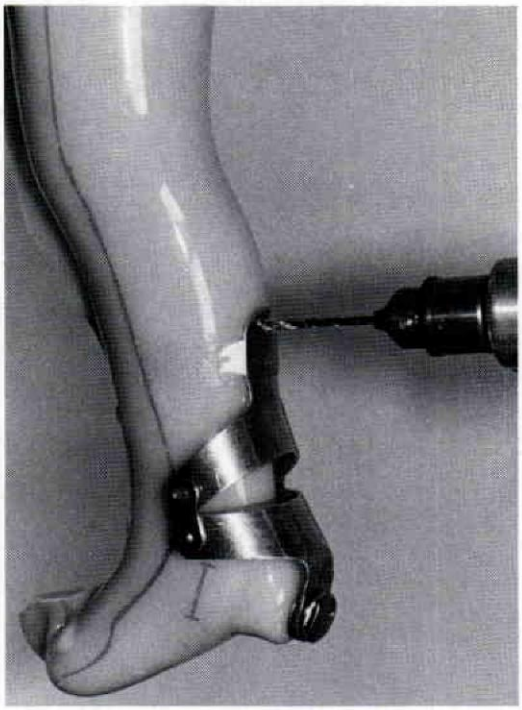


Figure 12. Assembly in place and holes for proximal attachment being drilled.

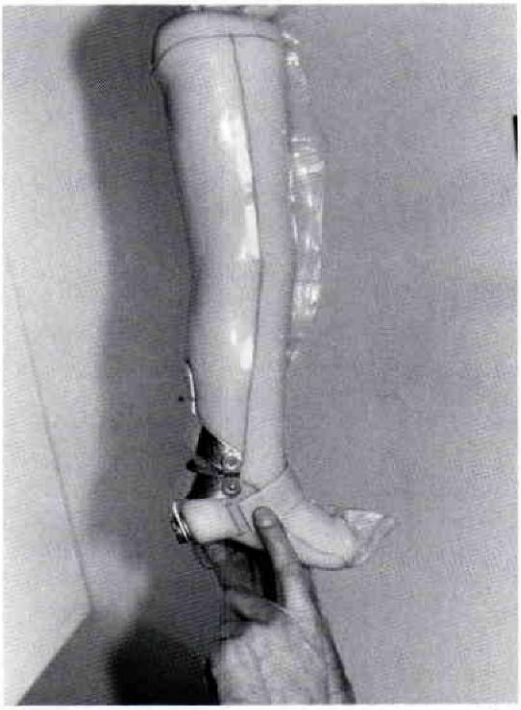


Figure 13. Trim lines drawn on model. Use of a one inch strap facilitates proper orientation of slots cut in the footplate.

surface of the footplate should extend beyond the toes for comfort and to prevent impingement of the edge. One inch long slots (Figure 13) are cut in the foot section for the Velcro® strap that pulls the foot and leg posteriorly into the orthosis. The strap should be located in the smallest part of the instep and the slots should be perpendicular with the strap. Location of the strap and orientation of the slots is best established with the aid of a strap or piece of tape. The orthosis is then cut out along the established trimlines and the edges are smoothed and finished. The ankle joint assembly is then riveted to the leg shell.

A piece of extra-firm A-30 perforated Pelite is molded over the patellar area of the positive model to provide a knee extension pad (Figure 14) for distributing the pressure over the knee when the orthosis is in place. Two 1" wide elastic straps are installed horizontally on the knee pad to apply an extension force. Velcro® straps, 1" wide, are used at the ankle and proximal thigh areas to hold the orthosis in place.

The medial and lateral 1" wide elastic straps that control the foot and ankle are installed (Figure 15). If necessary, an outrigger or outriggers can be used to establish a proper line of pull and torque in severely plantarflexed limbs. Two-pronged buckles are used to secure the elastic straps.These buckles are mounted on 1" wide dacron straps with loops in the straps for the distal strap of the knee-cap. This is to maintain the knee-cap in its proper location. The 1" dacron straps are riveted to the posterior shell so as to insure proper alignment of the knee-cap.

FITTING

The orthosis is applied, checked for excess pressure, and modified appropriately. The elastic corrective straps should be adjusted to exert light-to-moderate pressure. The parents should be cautioned to always have the patient wear a stocking inside the orthosis and not to attempt to gain too much correction at once. Wearing tolerance

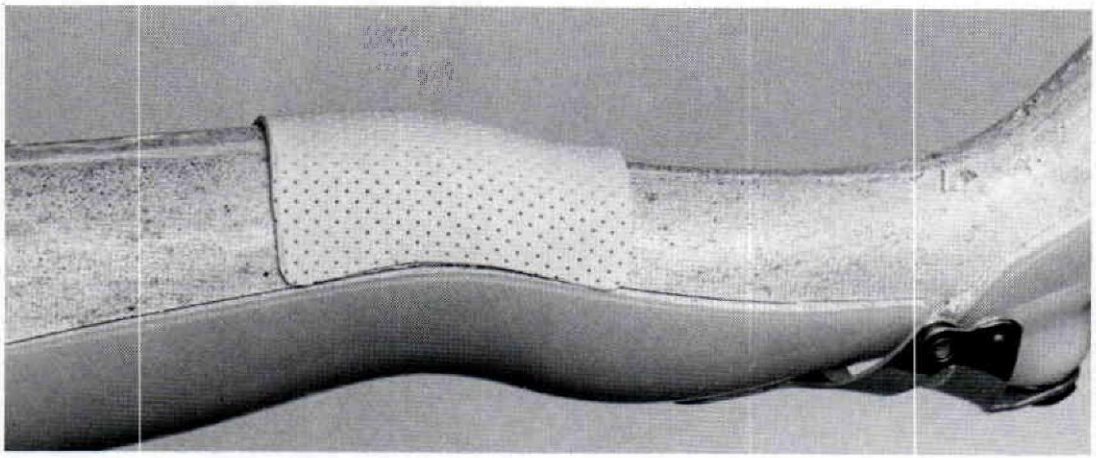


Figure 14. Molded Knee-cap of extra-firm A-30 Pelite.

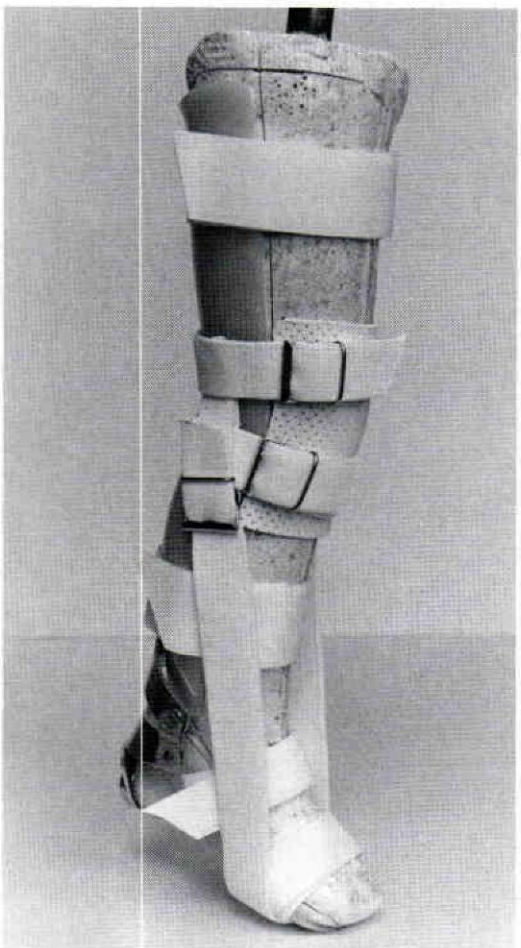


Figure 15. Finished orthosis with elastic and Velcro® straps in place.

should be built up slowly, starting initially with a period of an hour or so and culminating several weeks later with all night wear. The elastic straps should be tightened gradually.

CONCLUSION

Today more than ever, the advances in medicine prolong the life expectancy of severely involved patients. Society expects, and ethics demand that, whenever possible, these individuals be afforded a lifestyle with maximum dignity and independence. The prevention and correction of contractures play a definite role in the achievement of these goals. The LSU Lively Orthosis is one device to aid the medical team in meeting this goal.

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