Orthotics and Prosthetics, Vol. 28, No. 2, pp. 14-20, June 1974

LOWER-LIMB ORTHOTIC DESIGNS FOR THE SPASTIC HEMIPLEGIC PATIENT[1]

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Providing the spastic hemiplegic patient with a suitable orthotic device often presents a difficult problem. Since the ultimate goal is realignment of the foot-ankle complex and maintenance of this alignment during all phases of gait, it is evident that the realization of this goal cannot always be accomplished by conventional methods (1)(2).

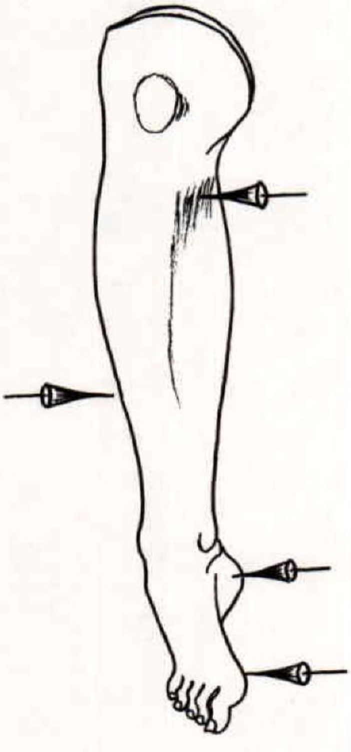

Fig. 1. Direction of forces in the frontal plane.

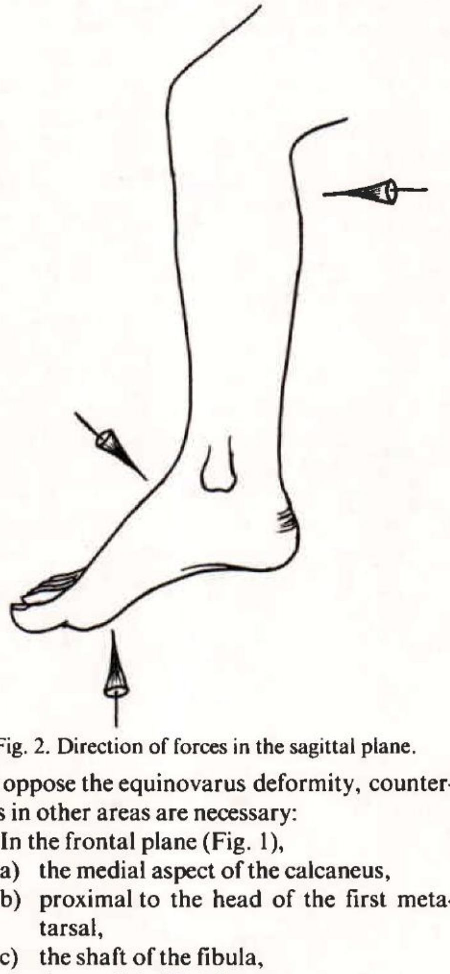

Fig. 2. Direction of forces in the sagittal plane.

To oppose the equinovarus deformity, counterforces in other areas are necessary:

1. In the frontal plane (Fig. 1),
   a) the medial aspect of the calcaneus,
   b) proximal to the head of the first metatarsal,
   c) the shaft of the fibula,
   d) the medial tibial flare.
2. In the sagittal plane (Fig. 2),
   a) proximal to the gastroc-soleus bulge,
   b) the metatarsal arch,
   c) the instep.

It becomes obvious that necessary counterforces cannot be provided effectively with a conventional below-knee orthosis with metal

[1] This study is supported in part by Grant Number 23 P-55029/2-03 from the Social and Rehabilitation Service, Department of Health, Education, and Welfare.

uprights; and that, at best, the conventional design can only be effective to a very limited extent. This is especially true because the man-machine interface is hardly intimate enough to oppose the deforming forces produced by spasticity. Therefore, the conventional ankle-foot orthosis, even if attached to a well-constructed shoe, does not lend itself very well to effective control of this type of deformity. Although sophisticated alignment principles are usually employed in the construction of a conventional ankle-foot orthosis, the complex multidirectional forces producing this deformity require more than a soft shoe-upper and a soft varus-correction-strap. In the conventional orthosis, plantar flexion is opposed by the sole of the shoe in combination with the plantar-flexion stop. However, even a well-designed shoe shank can only oppose mild to moderate spasticity effectively, and will hardly suffice for the severely spastic patient. Furthermore, inversion, that is, supination of the forefoot combined with varus deformity in the calcaneus, cannot be sufficiently opposed even with a shoe which has firm counters.

This paper presents two devices which have been applied successfully at New York University Medical Center, Institute of Rehabilitation Medicine (IRM), for the past several years. The hemispiral ankle-foot orthosis, a variation of the IRM spiral ankle-foot orthosis, and the solid-ankle ankle-foot orthosis, which was first described by Jebsen, et al. (3), have been applied in cases where moderate and severe spasticity exist.

THE HEMISPIRAL ANKLE-FOOT ORTHOSIS

The hemispiral AFO (5) (see also article by Lehneis in this issue of *Orthotics and Prosthetics)*, is made from SADUR[2], a nylon-acrylic composite, and has been designed to provide the forces necessary for continuous foot-ankle alignment during gait (Fig. 3). The footplate extends from the proximal-plantar margin of the heel pad to a point 5 mm proximal to the metatarsal heads. On its medial border, flanges extend proximally to the head of the first metatarsal to prevent forefoot adduction and supination, and at the calcaneus, flanges extend proximally to prevent varus deviation.

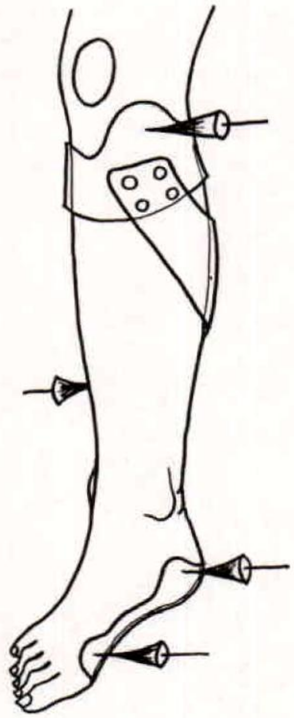

Fig. 3. The direction of the forces provided by the hemispiral AFO.

The spiral section of this orthosis originates on the lateral side of the footplate and extends almost vertically to the mid-level of the fibula at which point it turns posteriorly and attaches to the calf band at its medioposterior aspect.

The calf band, in its horizontal cross section, is triangular with a lateral opening approximately 5 mm smaller than the narrowest mediolateral dimension of the ankle. On the medial side, the calf-band flange extends proximally to cover the medial tibial flare area.

The triangular shape of the calf band and its minimal lateral opening provide a secure anchor for the spiral section and allow some degree of conformity to transverse rotation of the tibia. The pressure of the spiral section against the mid-shaft of the fibula and the pressure of the calf-band flange against the medial tibial flare provide the additional forces necessary to prevent deviation of the foot-ankle complex in the frontal

[2] Teufel Company, Stuttgart, Germany.

plane (Fig. 3). The forces which prevent equinus deviation are provided in the areas of the metatarsal arch, the flattened posterior section of the calf band, and at the dorsal aspect of the foot, by a firmly laced shoe.

The device is made from material 4 mm thick. Its appearance in the flat unmolded state is shown in Figure 4.

THE POSTERIOR SOLID-ANKLE ANKLE-FOOT ORTHOSIS

While the concept of the solid-ankle laminated device was not original at IRM, the present design (Fig. 5) is perhaps more directly related to the patient's functional disability. The force system is similar to that described for the hemispiral

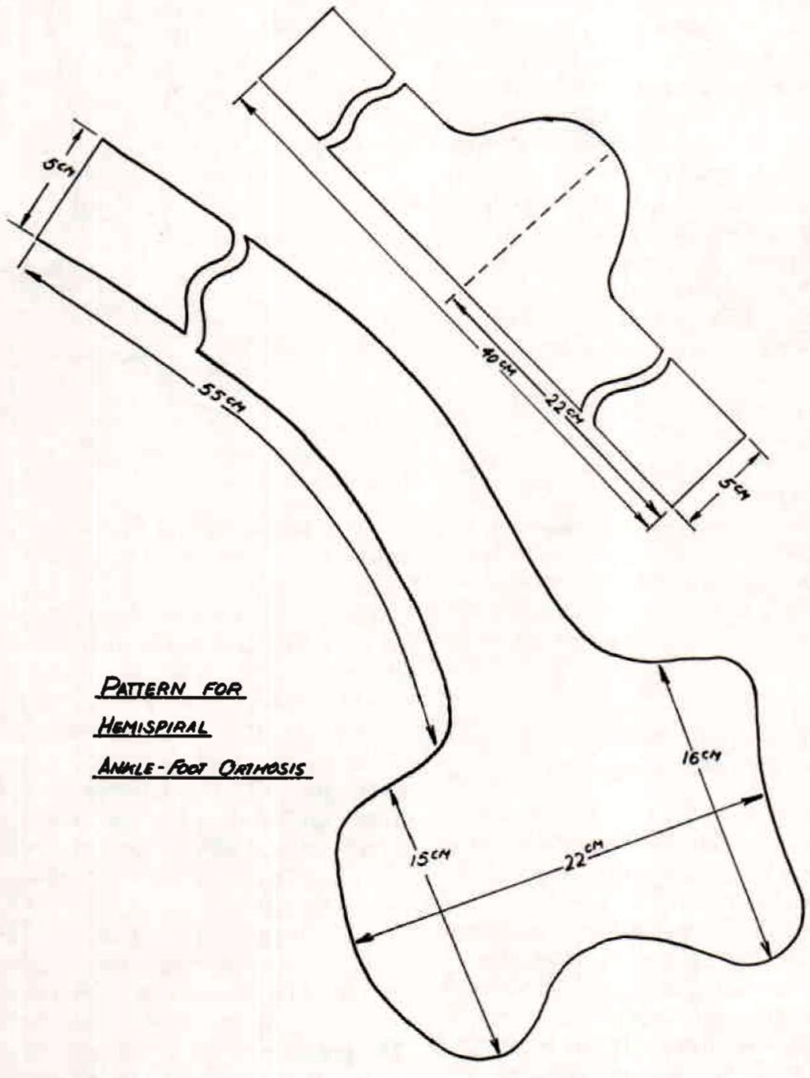

Fig. 4. The pattern for the hemispiral AFO. SADUR 4 mm thick is used. Precut kits are manufactured by Teufel Co., Stuttgart, Germany, and are also available through distributors.

AFO. Thus, to control the varus component of the equinovarus deformity, the laminate is extended proximally to fit intimately over the medial tibial flare, and support is provided behind the head of the first metatarsal and over the medial aspect of the calcaneus. In addition, a counteracting force is provided at the mid-fibula level.

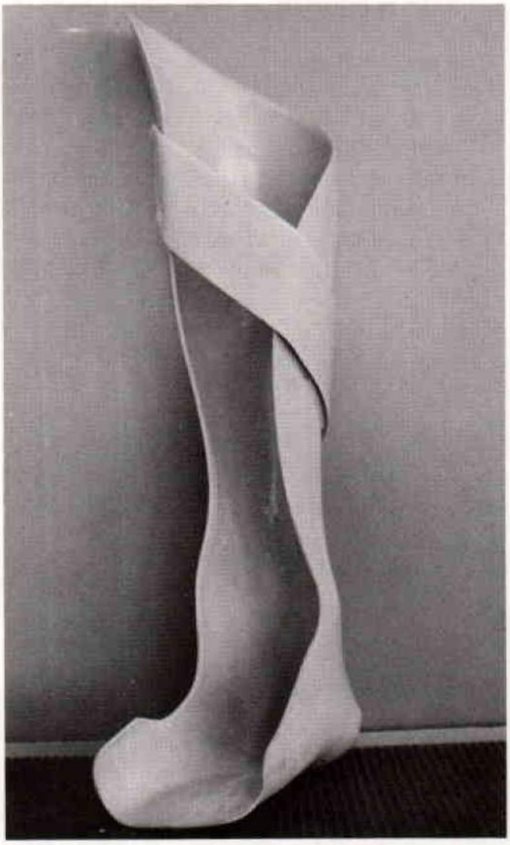

Fig. 5. Anterior view of a solid-ankle AFO for the left leg.

In the sagittal plane, the trim line extends anteriorly to the lateral midline to provide effective support (Fig. 6). The proximal medial termination also extends anteriorly to the medial midline, while all other areas recede posteriorly to the midline. As viewed in the frontal plane, the posteroproximal trim line progresses diagonally across the gastroc-soleus bulge. This posteroproximal trim line, however, will only be adequate if the dominant deforming force of the equinus deformity is relatively less severe. When, however, the equinus deforming component is dominant, the posteroproximal trim line needs to extend horizontally across the gastroc-soleus bulge at a level 20 mm below the neck of the fibula.

The solid-ankle AFO is made of a plastic laminate with fiberglass matting as the reinforcement material. Both polyester and acrylic resins have been used. Patient follow-ups have proved, however, that the acrylic lamination not only produced a lighter device but also a more durable one.

Because a smooth and natural-like transition from heel strike to toe-off is virtually impossible with the solid ankle (6), a SACH heel and rocker bottom are added to the patient's shoe to provide simulated plantar flexion at heel strike and a nearly normal transition from foot-flat to toe-off.

The importance of the shoe in these devices is frequently underestimated. Although the devices in and by themselves provide sufficient

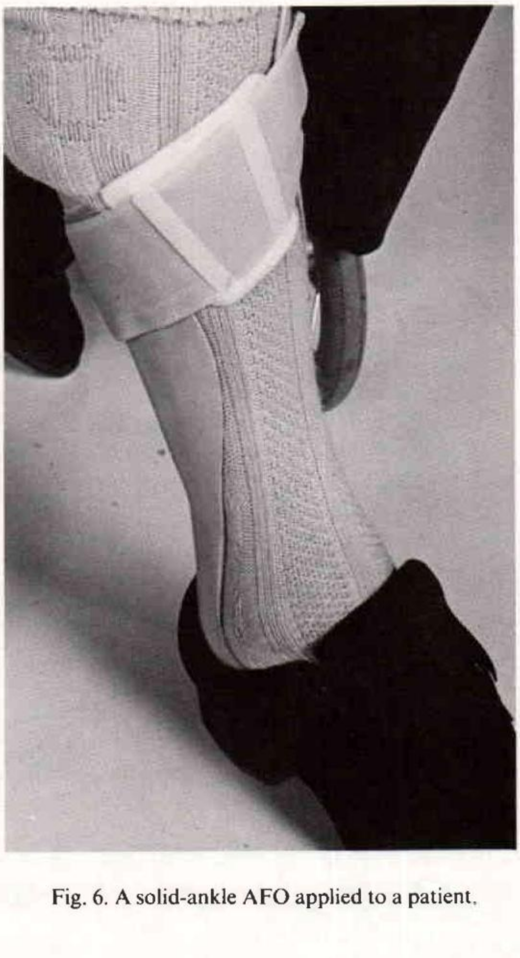

Fig. 6. A solid-ankle AFO applied to a patient.

static support for the foot-ankle complex during gait, additional support is needed. A good shoe, firmly fitted, is required to assure constant contact of the foot with the footplate.

THE CASTING TECHNIQUE

The need for a plaster cast for the construction of an orthosis made from either thermosetting or thermoplastic materials is obvious. However, the casting technique requires some elaboration, since simultaneous stabilization in three planes during casting cannot be satisfactorily achieved by an orthotist working unaided. Either a second pair of hands, or an auxiliary device, is needed. Because both AFOs are similar inasmuch as they have been designed to provide the same corrective force system, the same casting technique is applicable to both. In our experience, casting in two stages (4) (5) assures a negative cast which most closely reflects the desired alignment.

The two stages are:

1. The foot-ankle complex is wrapped to approximately the mid-shank level. While the plaster bandage hardens, the forefoot-hindfoot relationship, as well as their relation to the shank, is established and maintained. The medial aspect of the calcaneus and the area immediately proximal to the head of the first metatarsal should be compressed and contoured.
2. The proximal section is wrapped to the tibial plateau, overlapping the distal section by approximately 50 mm. While the plaster bandage hardens, the posteroproximal section, the medial tibial flare area, and mid-shaft of the fibula are compressed.

In both devices the angular relationship of foot and shank must reflect the heel height of the shoe to be worn. To assist in achieving this requirement, a casting board with a vertical alignment rod is used. This device reflects the heel height as well as the apex of the longitudinal arch (see preceding article). To preshape the metatarsal arch, a metatarsal pad is inserted between the layers of plaster wrap, while the core of the plaster bandage or any other roll of the appropriate diameter is placed under the digits to accentuate the contours of the metatarsal joints. During this procedure, one of the orthotist's hands stabilizes the hindfoot and forces the calcaneus into valgus while the other aligns the forefoot and forces it into pronation and abduction (Fig. 7). Keeping in mind that the negative cast produced should reflect proper alignment as well as tissue compression in the areas necessary for force application, the following points must be observed in casting for the solid-ankle AFO:

1. Preshaping of the cast is done with emphasis on the plane in which the dominant deforming force is present. That is, if the inversion component is the stronger, the areas of the medial tibial flare, the mid-fibula level, the medial aspect of the calcaneus and the area directly proximal to the head of the fifth metatarsal, are compressed.
2. If the equinus component is the stronger, a flat compression proximal to the gastrocsoleus bulge, parallel to the knee axis, is produced in combination with a well-defined metatarsal arch.

Fig. 7. Casting the distal portion of the leg for either a hemispiral AFO or a solid-ankle AFO.

3. When stabilization in both frontal and sagittal planes is required, the cast should reflect a combination of both preshaping techniques.

CAST MODIFICATION

Despite the emphasis on negative cast preshaping, further modifications of the positive cast are required to assure optimal effectiveness of the corrective and supportive forces. The precompressed areas usually need further plaster removal, the amount being in the range of 4 to 8 mm. Plaster buildups of 6 to 8 mm in the areas of the lateral malleolus and the base of the fifth metatarsal are required for both the hemispiral and the solid-ankle AFOs.

For the solid-ankle AFO, an additional buildup at the anterolateral, mid-fibula area is desirable to prevent trim-line pressure.

MOLDING AND LAMINATION PROCEDURES

MOLDING THE HEMISPIRAL

Before the hemispiral pattern is molded over the prepared cast, the edges of the precut plastic must be highly polished to remove scratches, and thus ensure the durability of the device. For the molding procedure, a domestic oven is satisfactory, but a commercial oven equipped with blower and thermostat is better.

Before the actual molding process is undertaken, the dry cast should also be heated to molding temperature to increase working time and reduce the possibility of stresses occurring when the plastic is molded over a cold cast. The calf band is molded over the cast first and cut to length while still in the flexible state. This, as well as the footplate-spiral section, is held on to the cast by elastic bandages until it has cooled sufficiently to maintain its shape. The footplate, which in its original form is oversized, the proximal termination of the spiral section, and the lateral opening of the calf band are trimmed and polished to appropriate proportions.

LAMINATION AND LAY-UP OF THE SOLID-ANKLE AFO

Plastic lamination is done in the conventional manner. If acrylic resin is used instead of polyester resin a lighter yet more durable device is produced. When, in combination with the acrylic resin, nylon-tricot with fiberglass matting is used instead of the more widely applied nylon stockinette, improved durability and reduced overall weight will result. Depending on the weight and height of the patient, the layers of nylon-tricot and fiberglass matting varies from 8+6 to 10+8.

RESULTS AND CONCLUSIONS

Both devices described have been used successfully at the Institute of Rehabilitation Medicine, New York University Medical Center. Since 1969, sixty-two patients have been fitted with these devices, of which nineteen were of the solid-ankle design. Most patients required the addition of a SACH heel and a rocker bar.

As with all plastic orthoses, a cast that is well precontoured and accurate is mandatory. In addition, a preconceived design contour should be firmly in the mind of the orthotist during the casting procedure so that appropriate forces and counterforces can be applied over the proper areas while the plaster hardens.

Although the areas proximal to the head of the first metatarsal and the medial aspect of the calcaneus are subject to high pressures, the medially directed force at the mid-level of the fibula frequently caused greater fitting problems in both of the designs. However, if the lateral pressure area is maintained at the mid-fibula level, is distributed as far as possible along the shaft of the fibula, and the anteroposterior dimension trim line is sufficiently wide, pressure can be avoided completely. Precontouring of the cast negative as well as appropriate modification of the positive model will help in avoiding potential problems. In the hemispiral orthosis, care must be taken that the lateral origin of the spiral section is extended proximally far enough and is contoured appropriately to avoid excessive pressure at the proximal edge, a condition that occurs frequently. The cast for the solid-ankle AFO should be modified in the lateral anterior aspect to assure sufficient spread of load in the anteroposterior dimension.

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