A New Ankle Foot Orthosis With A Moldable Carbon Composite Insert

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SUMMARY

INTRODUCTION

THE ADVENT of thermoformed Ankle Foot Orthoses (AFOs) brought the demand to fit all patients with the latest mode; weight reduction, cosmesis, and greater control are the usual benefits derived, however, when ankle motion must be eliminated the outcome is not always completely satisfactory. Dorsiflexion cannot always be totally restricted by either altering the material, or by changing the trim lines. Any increase in bulk to add rigidity only adds to the problem.

Metallic reinforcing struts have been applied to the lateral and medial sides of the AFO (1) resulting in a dramatic improvement in resistance to dorsiflexion by a factor of four plus. Perhaps the inconvenience of forming a close-fitting metal insert has deterred the general use of this approach. Hopefully, the introduction of a new moldable high strength hybrid composite described here will open the way for wide spread application of the improved design concept.

COMPOSITE MATERIALS

Composite materials are a family of high performance materials consisting of a matrix reinforced with a fiber. The matrix can be a thermosetting resin such as an epoxy, polyester or polyimide, or a thermoplastic resin such as nylon or polysulfone. The reinforcement can be carbon fiberglass, Aramid, or boron fibers. The combination of a resin and a fiber results in properties of a quite different character than either constituent. These unusual properties are a result of the fiber being characterized by single crystal properties which are five to fifty times greater than those of the same material in polycrystalline form.

Composite materials are ideal for structural applications where high strength-to-weight and stiffness-to-weight ratios are required. The advantage of composites is that they usually exhibit the best qualities of their constituents and often some qualities that neither constituent possesses. The advantageous properties include:

- strength
- stiffness
- corrosion resistance
- weight
- fatigue life
- temperature-dependent behavior
- thermal insulation
- thermal conductivity
- acoustical insulation

Naturally, not all of these can be optimized at the same time.

APPLICATION TO ANKLE FOOT ORTHOSES

Generally the trim line of an AFO is near the lateral mid-line of the ankle but often it is moved further anterior in an attempt to achieve ankle stability. The frequent result is continued bulging from buckling of the sides at terminal stance and some loss of cosmesis from the increased bulk, especially when the copolymer plastic is used. When this is unacceptable we can resort to using a thicker *polypropylene*, with little benefit. It is obvious that if we are to block ankle motion we must introduce a stiffener in the area from proximal to the ankle to the arch area of the foot on both the medial and lateral sides.

The carbon composite insert has made a dramatic impact in solving all of the above problems. Without changing trim lines or increasing thickness, almost complete ankle rigidity can be achieved by including a pair of crescent shape composite inserts in the thermoform. A hybrid composite of glass and carbon fibers in a thermoplastic resin matrix was chosen as the ideal combination for the stiffness qualities and dimensional stability desired. A two ply 40% carbon fiber panel 3/32" thick is used for light duty requirements and a three ply 43% carbon fiber panel, 1/8" thick is used for the medium and large size patients.

When the ankle angle is in the normal range of about 5° to 10° of plantar flexion one

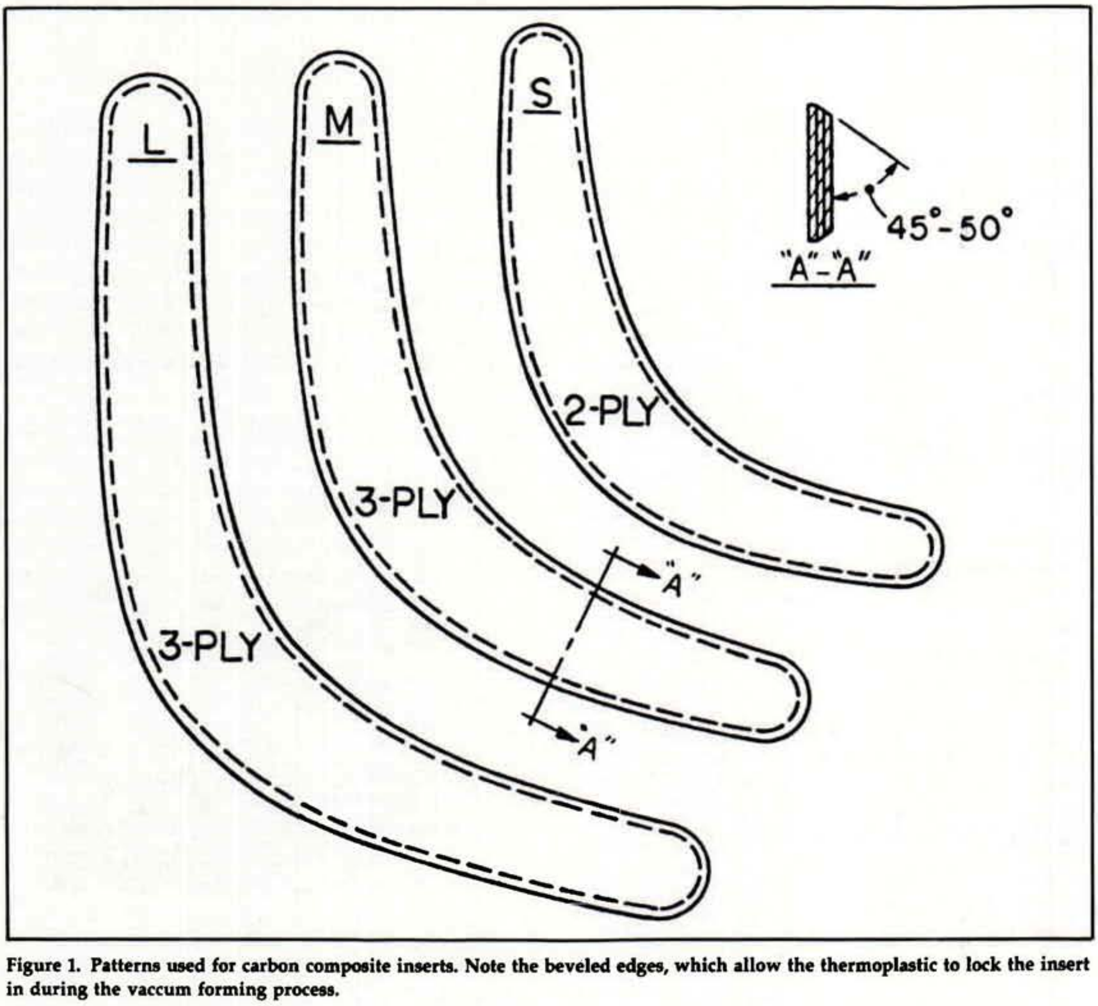

Figure 1. Patterns used for carbon composite inserts. Note the beveled edges, which allow the thermoplastic to lock the insert in during the vaccum forming process.

of three sizes of precut inserts are selected (Fig. 1). The patterns are designed to fit just posterior to the usual trim line, beginning about three to four inches proximal to the malleoli, passing posterior to the ankle prominence and extending into the foot area, terminating near the junction of the plantar surface with the medial and lateral walls. This minimizes flexing in the foot insert and bulk in the shoe.

Custom shapes (Fig. 2) are required occasionally for other angles and these can be cut on a metal band saw and the edges smoothed on a sand cone. It is important that the inner edge be undercut on a 45° angle to insure interlocking with the polypropylene wall.

There is no problem if a liner is used; the insert is simply pasted to the liner or the plaster model prior to the thermoforming procedure.

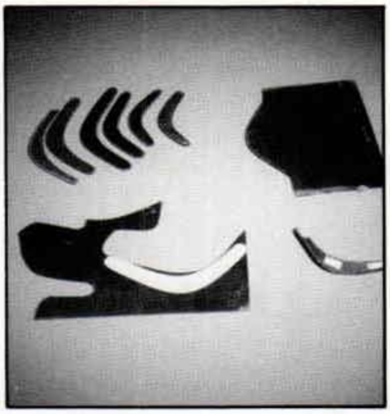

Figure 2. Custom carbon composite inserts can be cut on a metal band saw and smoothed and beveled with a sander.

FABRICATION

To form the carbon composite insert to the model it should be heated with a heat gun or in an oven until it is pliable (approximately 300°F.) and then pressed in place with insulated gloves (Fig. 3). Attach the molded insert to the liner or to the plaster cast with Scotch Mounts 1/32" thick (Fig. 4). Scotch Mounts are urethane foam pads with an adhesive coating on both sides. Place three pieces on the insert, one on each end and one in the center, to provide extra spacing away from the liner which, along with the under-cut edge, assist in the encapsulation of the inserts. Use a ventilated foam liner or a nylon hose over the cast to assure complete vacuum forming.

Figure 3. The carbon composite insert is heated to 300° by using an oven or a heat gun; it is then pliable and is held in place on the mold until it cools.

The drape forming procedure is preferred since it assures maximum and uniform material thickness throughout the orthosis. Optimally, the polypropylene shows good forming and definition around the inserts (Fig. 5). If the inserts are not properly embedded in the walls of the plastic a poor result can be expected as they will separate at terminal stance; when this occurs the composite pieces can be salvaged and reused.

Figure 4. The insert is held in place on the mold with 1/32 inch thick Scotch mounts; three small pieces above the insert and provide some space under the insert.

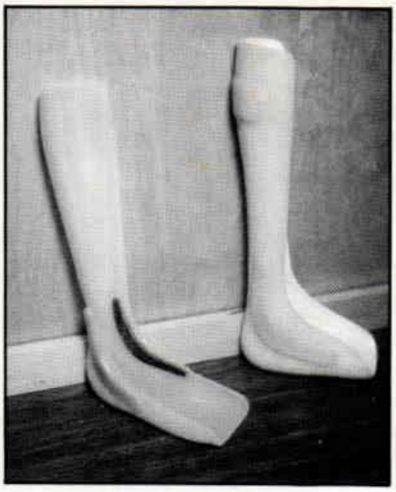

Figure 5. Completed Ankle Foot Orthoses with carbon composite inserts in place.

SUMMARY

Presented here is a simple process added to an accepted conventional laboratory fabrication procedure. It demands no new equipment, skill or time consuming labor yet it adds a new dimension to the function of the AFOs. It consists of three steps:

1. Select precut or custom made inserts.
2. Thermoform inserts to model.
3. Adhere inserts to model.

Several dozen floor reaction type orthoses have been in use for over a year with excellent results and no reported failures. When the inserts of adequate thickness are properly placed and secured in the polypropylene walls, minimum deflection and gapping will occur. We expect this conformable insert concept will find widespread use in many areas of plastic orthoses where increased rigidity is required.

References

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Footnote

[1] Darrell R. Clark, Thomas R. Lunsford, "Reinforced Lower-Limb Orthosis-Design Principles", Orthotics and Prosthetics, June, 1978.