Clinical Use and Fabrication of Molded Thermoplastic Foot Orthotic Devices: Suggestion from the Field
Gordon E Doxey

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The physical therapist may conclude that foot orthotic therapy is necessary for treating patients with foot and lower extremity dysfunction. The type and features of each orthosis should be determined by the patient’s anatomical structure, biomechanical alignment, diagnosis, age, and activity level. Correct prescription of a foot orthosis requires the clinician to 1) understand normal lower extremity biomechanics, 2) understand how biomechanical malalignment or pathological disease states alter lower extremity function, 3) perform an appropriate lower extremity examination, 4) identify disorders that respond to foot orthosis therapy (Appendix), and 5) choose the appropriate materials and the type of orthosis that provide therapeutic benefit. The purpose of this article is to review only the features, clinical use, and fabrication techniques for molded semirigid and rigid thermoplastic foot orthotic devices.

FOOT ORTHOSIS FEATURES

A molded semirigid or rigid foot orthosis is composed of a module or plantar shell and extrinsic “postings” on the plantar surface of the module. The module is fabricated from 3-mm or 4-mm sheet thermoplastic that extends from the heel to just proximal to the metatarsal heads. The thermoplastic is formed on a neutral position cast of the plantar surface of the foot. The cast of the foot provides an exact model of the plantar contours, especially the heel seat, the medial arch, and the calcaneal inclination. The cast usually is taken from the foot in a nonweight-bearing position: the subtalar joint in its neutral position between pronation and supination and the midtarsal joint pronated and locked to the hindfoot.

The subtalar joint neutral position allows the foot to be captured in an ideal position biomechanically. The relationship of the forefoot to the hindfoot is also captured in the cast and allows the clinician to adjust the size and the position of the postings on the plantar module and to correct for any abnormal compensation that results from malalignment.

The postings provide a method of adjusting the position of the neutral module so that the foot can be placed in and function from a more biomechanically correct position during weight-bearing activities. The postings are adjusted according to the measurements taken during the nonweight-bearing and weight-bearing biomechanical examination and by balancing the position of the plaster model of the foot with the module. The purpose of the postings is to provide plantar contact points with the foot against the module and with the floor in a manner that eliminates abnormal subtalar and midtarsal joint compensation. The module and posting system provide a more precise method of controlling foot function in comparison with the guesswork and repeated trials that are necessary for fabricating accommodative orthotics on the foot directly.

The flexibility or rigidity of the module is determined by the thickness of the thermoplastic and the characteristics of the plastic itself. Rigid thermoplastics maintain their structural form, even with weight bearing, and, thus, eliminate the bulk thickness that is required to support the foot with flexible or semiflexible materials. Semirigid thermoplastics deform slightly under weight-bearing forces but provide the “forgiveness” resiliency that many patients require to tolerate the module. The molded orthosis is slim, durable, and custom fitted. This type of orthosis is useful with a great variety of overuse syndromes, tendinitis, and pathological disease states in the foot (Appendix). Forefoot dysfunction should be managed first by establishing proper biomechanical function of the foot with the module and postings and then by adding a distal forefoot extension to balance and cushion the forefoot.

CLINICAL USE

The materials and method of fabrication can be varied to achieve any or a combination of the following biomechanical goals: 1) prevent abnormal compensatory motion at the subtalar and midtarsal joints, 2) rebalance the malaligned foot to a more neutral position, 3) assist or normalize the foot’s adaptive function to the ground at heel strike, 4) assist or normalize the foot’s propulsive function as a rigid lever at push-off, 5) maximize hallux function, 6) maximize toe function in propulsion, and 7) allow normal foot movements and muscle activity at the proper time.

The main purpose for using a foot orthosis is to treat foot dysfunction and symptomatology resulting from local disease or biomechanical foot imbalance. Foot orthotic therapy is more effective with disorders that are associated with intrinsic foot imbalance or dysfunction and are aggravated with weight-bearing stresses in comparison with conditions related to lower extremity malalignment extrinsic to the foot. A foot orthosis can be used as an effective treatment for symptomatology that results from excessive mechanical stress that accumulates because of abnormal biomechanical compensation. The painful anatomical structure and the possible biomechanical mechanism of injury should be determined during the clinical examination. The foot orthosis should then be fabricated so that the mechanical stress can be reduced while allowing normal foot function to occur. Normalizing the biomechanical function or changing the plantar contact points of the foot with the floor decreases the stress and the
mechanism of pain development. This normalization is accomplished by eliminating abnormal subtalar and midtarsal joint compensation, by eliminating contact on the painful plantar area, by redistributing weight-bearing stresses, or by achieving other goals suggested earlier in this article.

An appropriate module can be selected from a variety of thermoplastic materials. This system provides a method of adjusting the flexibility or rigidity of the module to the patient’s body weight, foot type, activity habits, and diagnosis. Rigid thermoplastics have a limited use with physiologically old patients or with any patient with rigid feet. Patients who have insensitive feet or vascular or diabetic ulcerations should not receive a foot orthotic made from rigid materials because of the disproportionate local pressure that may be created against the plantar foot and the module. Also, patients with neuromuscular dysfunction or severe arthritis may lack the necessary range of motion at the subtalar and midtarsal joints because of fixed deformities and will not tolerate rigid support. A variety of flexible and semiflexible materials can be used to fabricate an accommodative orthosis by following the guidelines of Glass et al., Hertzman, and Moncur and Shields.

Semirigid thermoplastics are useful with patients who have biomechanical dysfunction or local disease states of the foot and provide better tolerance for physiologically old or rigid feet. Three thermoplastics, low density polyethylene, high density polyethylene, and Coylene, are easily fabricated into the module and are inexpensive. Sheet Birko-cork is a nylon-impregnated, thermo-moldable cork that can be shaped and used to make the wedge-shaped plantar postings. Forefoot extensions can be fabricated from soft, sheet Birko-cork, Spenco, Plastazote, or PPT and extended to the metatarsal heads, toe sulcus, or end of toes, if desired.

**FABRICATION**

A preliminary step to fabricating the orthosis is to take a neutral position cast of the plantar foot. Complete foot casting instructions have been outlined clearly in the brochure, “Neutral Impression Casting Technique,” from the Langer Group. After the cast is removed from the patient’s foot, the cast should be inspected to ensure that it captures the hindfoot to the forefoot relationship and reflects the shape of the arch and calcaneal inclination. Recast if necessary; a mistake in the cast will result in a mistake in the module.

Let the slipper cast dry for several hours. Then, spread baby powder on the inner surface of the cast, place the cast on foam rubber, and fill it with a mixture of plaster of Paris. The positive casting should also dry for several hours. The cast is then torn away from the positive casting, and the plantar surface of the casting is smoothed of irregularity and placed inside nylon hose.

The foot orthosis can now be fabricated by completing the following steps:

1. Cut a piece of thermoplastic, 0.50 to 1 larger than the projected size of the finished module, from the stock sheet.
2. Preheat the oven to 400° to 450°F. Coat the horizontal tray in the oven with a parting agent, so that the plastic can be removed without sticking. A silicone spray or vegetable cooking spray works well.
3. Place the plastic on the tray and heat it for approximately five minutes. The plastic should be heated only until it changes color and becomes clear and completely pliable. Overheating only makes the plastic more difficult to handle and increases the risk of altering its size and thickness. This is especially true for high density polyethylene.
4. Remove the plastic from the oven and drape it over the positive casting (Fig. 1). More uniform molding results are obtained if a vacuum press is used to mold the plastic over the casting, although good results can be obtained with manual molding. Mold the plastic quickly over the plantar casting in the following order: heel seat, calcaneal inclination, medial arch, and the medial and lateral sides of the module. The distal edge of the module, just proximal to the metatarsal heads, should be left flat. The module should be left in the vacuum press or held in place manually until the original color returns to the module. It can then be removed from the casting. The second module is molded in the same manner.
5. Remove the peripheral edges of the module and trim the module to the desired size. A standard module has a heel seat that is 0.25 to 0.50 in deep, the sides cut straight from the heel seat to the first and fifth metatarsal heads, and the distal edge cut just proximal to the metatarsal heads.
6. Smooth the sides of the module on an upright grinder and recheck the module’s size on the positive casting. The second orthosis is cut and ground so that it will have a similar size and contour as the first, but remember that asymmetrical differences between the two feet commonly
occur. The module is fit to each cast and foot individually.

7. Flare the dorsal edges of the module so that the peripheral edges will not be felt by the patient’s feet.

8. Cut out an appropriate amount of either soft or rigid Birko-cork (depending on the degree of posting hardness desired) and heat it at approximately 300° to 350°F until pliable, remove it from the oven, and place it flat on a piece of sheet plastic. The heel seat portion with the positive casting is centered over the sheet Birko-cork and pressed into the table. Push the edges of the Birko-cork under the convex contour of the heel seat until the space is filled in; then adjust the module and positive casting into the desired position. These steps ensure that the amount of posting material and the module’s position are adjusted so that the orthosis will balance the alignment between the foot and the ground and the amount of grinding is reduced. Smooth the peripheral edges of the posting with a flat steel edge. After the module and posting material have cooled, they are easily separated from the sheet plastic. Figure 2 illustrates the appearance of the foot orthosis at this stage of completion.

9. Leave the heel posting level or adjusted for the hindfoot varus or valgus, if present. One-inch square forefoot posts can be added to the distal medial or lateral edges of the module for forefoot varus or valgus, if present.

10. Grind the postings to the desired biomechanical level and shape. Outline their position on the module with a pen, and peel them from the module. Spread a layer of barge cement on the dorsal surface of the postings and on the appropriate parts of the plantar surface of the module, and dry with a heat gun. Then place the postings back on the module.

11. Check the orthosis under the positive casting for fit, shape, and appearance, and make adjustments if necessary. Figure 3 illustrates the appearance of the finished module and posting.

FITTING

When the patient returns to the clinic, examine the foot orthosis for fit and comfort on the patient’s nonweight-bearing and weight-bearing feet. The alignment of the patient’s lower extremity is checked while he is standing on the orthotic devices, without shoes, on a small platform. Any adjustments for fit, comfort, or biomechanical alignment are then made.

A trial ambulation is then performed. The patient may need to start orthotic therapy with two hours of wearing time the first day and increase an hour a day thereafter, although many patients tolerate a more accelerated break-in schedule. The patient should return to the clinic to continue other physical therapy, to have the therapeutic benefit of the orthotic devices assessed, to have orthotic adjustments made, and to receive a reexamination of the original complaint. The amount of follow-up is determined by the nature of each case. The patient should continue to wear the orthotic devices during any activity that is associated with excessive mechanical stresses, continually for preventing symptoms related to chronic conditions, until full activity can be resumed after an acute injury, or indefinitely with conditions resulting in malalignment from local disease states.

SUMMARY

The semirigid or rigid molded thermoplastic foot orthosis can be used as treatment for a variety of foot and lower extremity disorders. The foot orthosis functions to decrease biomechanical dysfunction or to change plantar contact points on the foot. Clinicians providing foot orthotic device therapy can best meet the therapeutic needs of their patients by fabricating orthotic devices from a variety of materials according to the nature of each case.
REFERENCES


APPENDIX

Diagnosis Where Foot Orthotic Device Therapy May Be Indicated

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<td>Cuboid syndrome</td>
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PHYSICAL THERAPY
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