The Role of Orthoses in the Treatment of Foot Problems

These 10 major conditions are encountered in daily practice.

BY RICHARD O. SCHUSTER, DPM

Editor's Note: *This previously unpublished manuscript was recently discovered by Joseph D'Amico, DPM. Despite being written in the late 1980s, it remains relevant today.*

The etiology of the vast majority of podiatric complaints is abnormal foot structure with resulting mechanical imbalance. The inequitable distribution of force adversely affects function as the foot develops increased concentrations of compression (pressure), tension (tearing), and shearing (rubbing) forces in various areas related to the structural fault. These forces are most frequently associated with excessive pronation.

Prescription foot orthoses represent perhaps the single most effective regimen in the podiatrist's armamentarium insofar as they address the source of the abnormal motions and forces, rather than the results. While palliative care may offer more immediate relief, its duration is frequently short-lived. Surgery certainly produces dramatic visible change in the appearance of the foot, but the situation will probably recur if the precipitating forces are not analyzed and measures taken to resolve them.

The role of foot orthoses is to establish and maintain a state of equilibrium throughout the foot as it functions in everyday living. They must be capable of redistributing and reducing the compressive, tensile, and shearing forces within the foot.

A statistical analysis of literally hundreds of thousands of orthosis cases reviewed over the past forty years reveals that the most commonly encountered foot pathologies that are effectively treated with prescription orthoses manifest one or several of these abnormal force concentrations. To a certain degree, orthosis prescriptions have followed trends in medical practice; the following represent the ten most common reasons for the prescription of foot orthoses over the past five years:

1) Plantar lesion accommodations
2) Heel spur syndrome
3) Plantar fasciitis
4) Metatarsal pain secondary to abnormal loading or arthritic degeneration
5) Intermetatarsal neuroma
6) Knee pain in athletes
7) Shin splints in athletes
8) Excessive pronation syndrome
9) Pediatric hypermobile foot
10) Postural symptomatology

The purpose of this article is to examine the cause of pain and its relationship to overall foot function, analyze the requirements of an effective foot orthosis, detail the necessary material properties, and discuss how the materials commonly employed in the construction of orthoses satisfy the demands of the foot pathology. It is generally accepted that the goal in biomechanical foot therapy is to prevent abnormal motions without interfering with normal motions.

Surgery certainly produces dramatic visible change in the appearance of the foot, but the situation will probably recur if the precipitating forces are not analyzed and measures taken to resolve them.

A properly designed foot orthosis must satisfy several important criteria. It must rectify the primary problem for which it was prescribed, i.e., it must effectively redistribute the abnormal force concentrations, yet do so in such a way as not to adversely affect the normal transfer of forces through the foot. Each of the foregoing ten foot disorders places specific demands upon the orthoses. One orthosis may be primarily supportive, increasing the functional efficiency of the foot's role in the kinetic chain of the interrelated body parts, while another may be primarily accommodative, relieving pressure concentrations. One may be designed to improve a runner's performance

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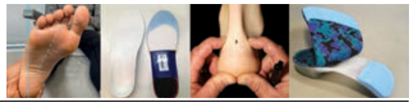

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while another may be designed to help someone cross the street before the light changes. A discussion of the ten most common reasons for successful foot orthoses follows:

1. Plantar Lesions

Most plantar lesions, i.e., calluses, intractable plantar keratoses, verrucae, ulcerations, and some irritations and scars occur under pressure areas; most pressure areas are under or anterior to the metatarso-phalangeal joints. Some even include the hallux and lesser toes. A highly important fact in protecting plantar lesions is that the location of the lesions on the foot or on the impression of the foot is seldom in the same location as it would be in the shoe, because of shear and rotary factors in stance and gait which vary with the individual.

The first priority of an orthosis designed to treat pressure lesions must be to relieve pain by redistributing pressure from the affected area to less sensitive parts of the foot. The second priority is to accomplish weight redistribution while augmenting the normal motion of the foot. The orthoses, therefore, must be capable of removing pressure from three or four sides of the painful area, and must provide effective foot support without impeding normal function.

Figure 1: For most biomechanically-induced heel pains, a deepened heel seat essentially prevents the inferior soft tissue from being displaced medially and laterally and redirects the medial and lateral soft tissue plantarly to, in essence, cushion the heel with each step.

Since lesions are frequently under the metatarsal heads, the orthosis must extend past them, often beyond the toe tips, even to the vertical surfaces of the foot, should the need arise. While the orthosis must be moldable to accommodate the lesion, it must also be easily adjustable to ensure precise location. The exact location of a lesion is best determined by examining a worn shoe, or by noting its position on an orthosis that has been worn for a few days.

2. Biomechanical Heel Pain

Pain of mechanical origin at the heel is usually concentrated at the medial calcaneal tuberosity and may result from a structural fault, obesity, or both. The pain is attributable to excessive tension at the fascial origin accompanied by periosteal tearing. Treatment strategy dictates reducing fascial tension and alleviation of pain at the site of injury.

Biomechanical control of abnormal pronation is key to the reduction of force concentration at the fascial origin. The essential element of an orthosis designed to reduce pronatory forces is efficient posting. Centralized pressure at the painful site due to body weight and the impact of each step is effectively redistributed to the less sensitive tissues at the periphery of the heel by molding a deep heel cup into the orthosis (Figure 1). Treating pressure-sensitive areas not centralized plantarly (they may be anterior-medial, lateral, or posterior) often necessitates molding a depression in the orthosis at the site of maximum pain.

3. Plantar Fasciitis

Similar in origin to the foregoing heel pain, fascial pain is due to excessive tension. The location of the fault, however, differs. The fibrous tearing occurs within the fascia itself rather than at its attachment to the calcaneus. Localized tenderness exists as a result of the inflammatory component of tissue repair.

Orthosis therapy must simultaneously support the foot, reduce fascial tension, and remove pressure from the injured area. A unique problem encountered here is that the foot must be supported without placing direct pressure on a tender structure running directly throughout the area requiring support.

Specifically-shaped orthoses have a unique capability for relieving plantar fascia strain. The common treatment is to adapt to the imbalances utilizing efficient posting, support the arch, and sometimes elevate the heel. A frequent problem seldom addressed is that the plantar fascia often bulges under the arch through the forces of stance and gait. In these cases, the orthotic may aggravate the fascial problem. Orthosis design must anticipate the situation and avoid it by placing a deep groove along the area of the fascial tract (Figure 2).

Figure 2: In cases of "true" plantar fasciitis, cavus feet and anytime the fascia bulges under the stresses imposed on it during walking or running, placing a groove place in the shell of the device will often relieve or prevent associated symptomatology.

It is a good idea to use a groove as a precaution in cavus feet with fascial strain and those cases of anterior-medial heel pain where the problem can be both plantar fasciitis and heel spurs. In the event a protruding fascial band was not initially anticipated, it is desirable to be able to readily add this modification. An indication for this would be increased symptoms, redness along the fascial band, or a mild discoloration on the appliance from fascial band pressure.

4. Metatarsal Pains Secondary to Abnormal Loading or Arthritic Degeneration

Structural faults or degenerative changes in the metatarso-phalangeal area are major reasons why foot orthoses are prescribed. The abnormal loading of one or more metatarsal heads is most frequently structural in origin, but systemic arthritides also play a significant role. The goal is to re-establish a weight-bearing equilibrium in the forefoot, initially removing as much weight as possible from the painful metatarsal and its surrounding tissues. After the inflammation and tenderness have subsided, the orthosis may be modified to re-apply the proper proportion of the forefoot load to the original segment.

In these cases, orthoses are required which provide efficient balancing beyond the metatarsal heads, offering maximum protection of pain-

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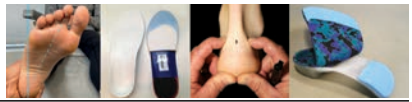

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ful areas and functional support of adjacent load bearing structures. A firm but flexible orthosis must limit selected motions beyond the metatarsal heads with the prudent use of bulk in the forefoot. The orthosis must be easy to adjust, as the symptoms related to degenerative forefoot situations can be constantly changing.

5. Intermetatarsal Neuralgia and Neuroma

With each step, the bones of the foot are in constant motion, changing their position relative to adjacent structures. Enlarged metatarsal heads, hypertrophy of the intermetatarsal nerves and their sheaths, or a combination of both may result in impingement of a metatarsal upon a nerve as a multitude of anatomy is constantly altering shape and position.

Orthosis therapy has essentially two goals: limit forefoot motion in the frontal and transverse plane to retard the rolling and shifting of the metatarsals and nerves; and separate the offending metatarsals heads so the nerve is no longer irritated. The former requires a properly posted rearfoot and forefoot orthosis, while the latter dictates a relatively high metatarsal correction, which must be precisely located to influence only one or two metatarsals.

6. Knee Pain

Excessive rotary motion of the tibia and femur, forcing contiguous structures, primarily the patella tendon and ilio-tibial band, through abnormal excursions is the result of foot imbalance and the main contributing factor in the majority of knee pains successfully treated with orthoses. The etiological factors, interestingly enough, are too much pronation and inadequate pronation.

Chondromalacia patella is commonly the result of an excessive Q-Angle as the tibia and femur rotate inward, and the patella experiences abnormal loading of its articular surface (Figure 3). Our studies have demonstrated a significant correlation between excessive forefoot varus and chondromalacia patella. The problem here is essentially one of forefoot control. Supporting the metatarsal heads in the neutral position varus attitude significantly reduces pronation and the accompanying internal tibial rotation as the talus adducts and plantarflexes.

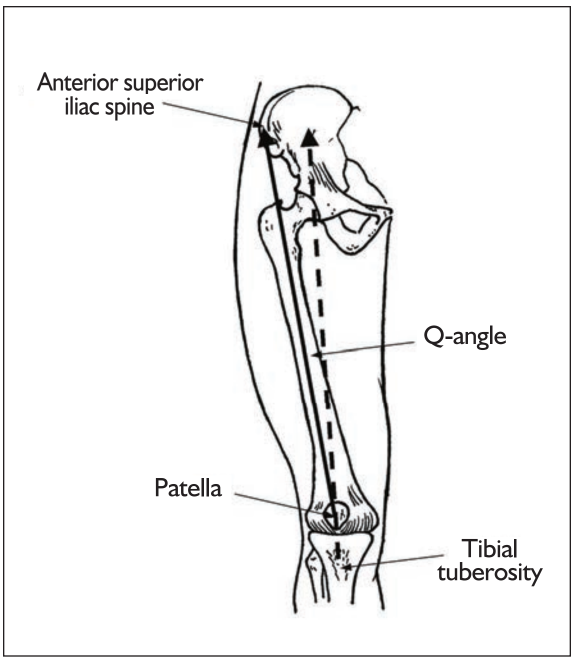

Figure 3: An increased Q angle has been linked to knee pain especially in individuals participating in athletic endeavors. Foot orthoses reduce the quadriceps angle and promote more normal motion patterns thereby reducing symptomatology.

Inadequate calcaneal eversion contributes significantly to ilio-tibial band syndrome. When the available range of calcaneal eversion is less than the cumulative varus components (tibial, subtalar, forefoot), the resultant situation of accentuated inversion places undue stress on the lateral anatomy of the knee. Pain arises from the friction of the ilio-tibial band grating against the femoral condyle. Treatment here is directed towards holding the calcaneus at its inverted neutral attitude as effectively as possible, contributing maximal everting range to the pronating complex. A lateral flange and efficient rearfoot post are the essential ingredients of successful orthosis design.

Speed and sudden frequent change of direction are features of athletic competition that place great demands on foot orthoses. The loads in the foot are considerably greater, as well as the rate and extent of variation of the foot's shape while running or changing direction. Compensatory mechanisms, such as that occurring at the base of the first metatarsal, must be anticipated in orthosis design or blisters may well occur. As equally important as effective posting is an orthosis which does not produce an edge irritation. Athletic orthoses that irritate the foot will be relegated to the closet.

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7. Shin Splints

Shin splints in athletes are usually stress fracture symptoms or anterior or posterior compartment syndromes. Posterior shin splints result from a sudden, extreme pull on the posterior tibial (PT) muscle and its related structures. Rapid forceful motion at the insertion of the PT tendon results when the medial border of the foot develops an extreme vertical component of motion, or heel contact involves considerable impact shock. The injury may manifest itself as myofascial and/or periosteal tearing evident at the lower 1/3 of the medial tibia, or tendonitis as the PT tendon courses behind and below the medial malleolus.

Varus imbalances in the foot and leg are most commonly at fault; the problem is aggravated when the sub-

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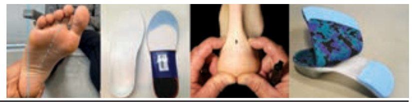

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talar joint cannot evert the calcaneus beyond the vertical. Orthosis control is directed at inverting the heel, so as to provide available shock attenuating eversion, while posting the forefoot to neutral. Efficient posting is the key to success.

8. Pronation Syndrome

Excessive pronation as a compensating mechanism for a varus or valgus deformity often forces a joint beyond its designed excursion limits; the resulting overload and repetitive bottoming of the joint against its ‘stops’ is a frequent precipitant of osteoarthritic degeneration.

Structural foot deformities alter the line action of muscles and tendons relative to the bones and joints they influence to a position of greater or lesser mechanical advantage. Agonists overpower antagonists and the bones and joints react to the chronic imbalance by deviating further from the ideal position, resulting in joint deformity, exostoses, etc.

Orthosis requirements include support of the arch, highly efficient rearfoot and forefoot posting, and conformability to local anatomical asperities. “Both the cavus and planus foot present their own unique problems. The former requires special heel contouring and consideration for plantar fascial protuberances, while the latter must be supported as it assumes a variety of shapes from its non-weight-bearing to fully loaded position with possible plantar bulging of the navicular and talar head. The orthoses must also be capable of preventing medial and lateral shoe irritation due to enlargement of the 1st MPJ, the navicular (with or without an os tibiale externum), as well as the base and head of the fifth metatarsal. This must be accomplished with no edge effect or irritation where the border of the orthosis contacts the foot.

9. Pediatric Hypermobile Foot

The dramatic response of calcaneal apophysitis to effective orthosis therapy is well known. Virtually any foot imbalance producing an adverse effect upon the child’s gait will benefit from orthosis treatment. Abnormal in toe or out toe, tiredness, growing pains, excessive shoe wear, tripping, etc. must be evaluated so the source is understood. At this stage of development, a significant percentage of the foot skeleton has yet to ossify.

Orthoses are required that provide maximum support without restricting normal motions. Efficiently posted conformable plantar supports must spread the load, effectively re-distributing localized areas of increased pressure and stress. Elimination of edge effects is particularly important in the treatment of children’s feet. The orthosis must accommodate, rather than restrict, the normal anatomical variants as the foot cycles through the stance phase. This is exceptionally important in the pediatric environment since a new factor has been introduced. Not only the dynamic aspects of the walking and running foot must be addressed, but consideration and provision for the foot as it grows through one or two shoe sizes must be incorporated into the orthosis design.

10. Postural Symptomatology

Experience with running athletes has confirmed that the symptoms from over-use (postural symptoms that start after a period of use) in the knees, hips, back, and even the shoulders can result from imbalance in the lower extremities and feet. Over-use symptoms usually develop more insidiously in the less active patient population. Limb length discrepancies and varus or valgus foot imbalances induce a state of non-equilibrium in the entire weight-bearing structure. Repetitive compensatory motion of the foot and leg related to long hours of standing, especially in a small area, as well as walking and running, are frequently the etiologic factors in knee and hip pain. It has been stated that 50% of back pain, the leading cause of work-related disability, is attributable to foot imbalance.

Orthoses must be designed to eliminate or attenuate the abnormal or excessive foot motion. As in most situations, effective posting is essential. Often, mobility must be augmented by incorporation of features providing for lost motion at an arthritic or traumatized joint, or facilitating such motion. In almost all cases, an orthosis extending under the metatarso-phalangeal joints, and often one extending under the entire foot, can most effectively provide this control.

Essential to patient comfort and acceptance is the elimination of irritations of the foot by the orthosis, commonly referred to as edge effects.

Orthosis Design and Material Requirements

Analysis of the ten most commonly treated problems in daily practice revealed that each requires an orthosis that effectively supports the foot without interfering with normal motion. All require efficient posting, many require the ability to redistribute pressure. Essential to patient comfort and acceptance is the elimination of irritations of the foot by the orthosis, commonly referred to as edge effects.

Support

At first glance, it appears that the material requirements for supporting the foot are quite straightforward. To be supportive, a material must be non-compressible. The greater the surface area of the foot that is supported, the more efficiently the load is distributed.

Normal Motion

Essential to material selection is an understanding of normal motion. Quite simply, it is the motion of the foot as it supports the body during each step. Ideally, the foot transfers body weight from heel to toe in a smooth fluid manner. Key to this process is the hinge-like motion of the

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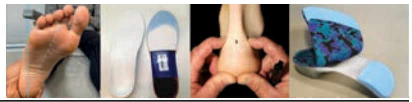

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metatarso-phalangeal joint. Inman has illustrated that the heel is on the supporting surface approximately 65% of the stance phase of gait, whereas both the heel and the forefoot support the body 100% of the time.(1) Current studies within the profession support this finding.

Extending the orthosis in an effective seamless manner to provide support beneath and distal to the metatarsal heads yields a 53% increase in efficiency over an orthosis that stops behind the metatarsal heads. If an orthosis is to extend beyond the metatarsal heads and provide optimal support, it must be capable of bending as the metatarso-phalangeal joints bend and be simultaneously supportive. It must be flexible as well as non-compressible.

Effective Posting

The posting is the interface between the orthosis material contacting the foot and the shoe, and is often the determinant of orthosis success or failure. Posting efficiency depends upon the proper size, angle, and placement of the post, as well as the manner in which the post and orthosis material influence the foot.

The smaller the area of the post, the greater the likelihood it will sink into the shoe innersole and be ineffective. Designing forefoot and rearfoot posts with extended surface areas provides a "snowshoe effect", preserving posting efficiency, since the post will distribute weight over the entire insole, rather than sinking into it (Figure 4).

Figure 4: Extending the forefoot posting to the sulcus with a flexible material provides a "snowshoe effect", increasing post efficiency and plantarflexing effect of the metatarsals, especially during the "on forefoot" demands imposed on the foot during sports participation.

Rearfoot Posting

Rearfoot posting is designed to support the heel in an inverted attitude. It functions as an inclined plane under the heel. The stiffness of the orthosis material must not serve to isolate the post from the heel. A flexible material enables the post to press through and influence the heel, whereas a rigid heel cup will merely be rotated through an arc—sort of like putting a wedge under a golf ball—all it does is roll off.

Forefoot Posting

Forefoot posting, to be effective, must directly influence all the metatarsal heads. When beneath, rather than behind, the metatarsal heads, the post supports the weight-bearing area of the varus or valgus imbalances, rather than the soft tissue behind it. A protractor placed on the dorsum of the metatarsal heads before and after differently-posted orthoses are placed under the foot will dramatize the effectiveness of various posting techniques. When the metatarsal heads are supported by placing posting directly beneath them, the protractor will show a significant correlation to the degree slant of the post; when the post stops proximal to the metatarsal heads, it will show a minimal influence of the post.

Forefoot posting beyond the metatarso-phalangeal joints on an orthotic maximizes the plantarflexing and propelling effect of the forefoot. At the same time, there is no inhibitory effect since the forefoot post is flexible. The mechanical result is that the plantarflexing effect of the forefoot occurs sooner and through greater range.

Effective posting, therefore, must be spread over a large area, extend beneath the metatarsal heads, and be able to influence the rearfoot through a flexible material in contact with the foot.

Forefoot posting beyond the metatarso-phalangeal joints on an orthotic maximizes the plantarflexing and propelling effect of the forefoot.

Pressure Redistribution

To remove pressure from an area, a material must lend itself to the molding of depressions at the painful sites. Weight dispersion around three or four sides of the painful area, bearing the load on healthy non-sensitive tissues, is certainly the most effective form of redistribution. The location of the depression is most important, and often difficult to predict insofar as the foot frequently moves with the shoe. Lesion contact is most often distal and lateral to the area evident at rest. The orthosis material, therefore, must be moldable and easily adjusted in the event a depression must be moved slightly for precise location.

Edge Irritation

The orthosis goal is to be in as intimate contact with the foot for as much of the gait cycle as possible. The complex and varied motions of the foot cannot all be predicted. Inevitably, at one point or another, the foot will press against the edge of the appliance. If the edge presses back, there will be an irritation. Consequently, the orthosis material must be capable of being feathered out at the edge without the fear of breaking or splintering. The thinner and more flexible the edge, the more innocuous it is likely to be.

Material Selection

A material must now be selected which is non-compressible, flexible, able to incorporate broad posting,

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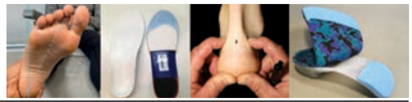

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be readily molded, and provide ease of adjustment. Some of the materials commonly employed have one or more of these above characteristics, yet are simultaneously lacking in others.

Rigid materials, such as steel and various thermoplastics, are certainly non-compressible. While they provide adequate support, they are non-flexible and, of necessity, must end behind the metatarsal heads. The resulting loss in duration of support (65% vs. 100% for a flexible material) and posting efficiency (rearfoot isolation and inability to support metatarsal heads) represent a significant drawback.

In general, they are not amenable to easy correction. Heating a plastic appliance in one area commonly affects the orthosis in other areas as well, permanently altering the shape in an unwanted fashion. Their unyielding qualities contribute to the arch irritation and blistering cited in a July '85 *JAPMA* article which found that 40% of athletes fitted with rigid orthoses developed pain attributable to the orthoses[2]

Leather, due to its unique histological composition, similar to that of human skin, is a moldable yet non-compressible material.

Soft materials such as polyethylene foams are at the other end of the spectrum. Their flexible, resilient nature renders them readily acceptable from a comfort standpoint, but they provide little or no support, and they lack sufficient durability.

Ironically, what seems to be the best choice for supporting the foot is a skin itself. Leather, due to its unique histological composition, similar to that of human skin, is a moldable yet non-compressible material. Furthermore, it is flexible, enabling it to be extended beneath and beyond the metatarsal heads in seamless support of the major weight-bearing segments of the foot. The orthosis now functions as the foot functions, in intimate contact. Leather's flexibility further serves to maximize the efficiency of the posting, enabling it directly to influence the rearfoot and extend beneath the metatarsophalangeal joints, directly influencing the forefoot.

The uniqueness of its composition enables leather to span the spectrum of requirements from soft to rigid while maintaining its flexibility and non-compressibility. The non-compressible quality of leather can be further enhanced by laminating several layers together. A technique employed in the construction of exotic aircraft, when two molded materials are glued together, the resulting structure is significantly stronger and more durable than if it were cut from one solid piece.

When desirable, leather's non-compressibility can be attenuated. Due to its ability to "feather out" to a fine resilient edge, or an area of reduced thickness, it can be made softer. Foams and similar materials can be integrated into the orthosis as dictated by the needs of the patient.

While leather is non-compressible, it is not "hard". The skin cells provide for a small measure of conformability as they respond to localized tension and compression forces, conforming slightly to the small area of high load. This is often referred to as the passive moldability of leather. In contrast, the active moldability is readily accomplished by moistening the leather and shaping it to almost any configuration. The passive moldability serves to minimize edge effects and as a diagnostic aid to locating interference between the orthosis and an anatomical feature insofar as the leather becomes slightly burnished at this point and a subtle impression can be felt. The active moldability enables the appliance to be accurately molded to the foot, provides for shaping, efficient pressure distribution areas at three or four sides of the lesion, and offers the ease of adjustability for necessary location of corrections and ongoing patient care.

If leather were to have a drawback, it is the extra time and care needed in the construction of the orthosis.

Material selection in light of orthosis requirements reveals the answer to be leather. Flexible, yet non-compressible, an ideal vehicle for broad posting, it is also moldable and easy to adjust. Its lack of edge-irritating characteristics enable initial patient acceptance of the orthoses.

If leather were to have a drawback, it is the extra time and care needed in the construction of the orthosis. Craftsmanship and attention to detail must complement the design to a degree unnecessary with other materials. Experience, however, has shown that the benefits realized in patient care warrant this extra effort. **PM**

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Dr. Schuster was a pioneer in podiatric biomechanical research and foot orthotics prescription. He first graduated from the First Institute of Podiatry (which later became the New York College of Podiatric Medicine) in 1937. He later served in many different capacities at the College: Professor and Chairman of the Department of Orthopedics, Acting Dean, and President of NYCPM, Member of the Board of Trustees and later, as a Visiting Professor. Dr. Schuster was widely published in both the professional and lay literature, frequently writing for *Runner's World* magazine. NYCPM holds an annual Memorial Biomechanics Seminar in his honor.