# Foot Orthoses

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**This review article describes shoe inserts and provides information to assist physical therapists to identify patients who may benefit from foot orthoses. The article discusses goals for and types of shoe inserts, in addition to the materials and methods that can be used in fabricating appliances. Clinical considerations for the use of shoe inserts and application to specific patient populations are presented.**

**Key Words:** *Foot; Foot deformities; Lower extremity, ankle and foot; Orthotics/splints/casts, lower extremity; Podiatry.*

Foot orthoses, including shoes, shoe modifications, and shoe inserts, have applications for a variety of patients and conditions ranging from children with flatfeet to arthritic elderly individuals with metatarsalgia.[1] Foot orthoses are particularly popular in the management of athletic injuries. Nevertheless, to avoid overuse, underuse, or stereotypical utilization of foot orthoses, the need for an appliance must first be determined by performing a thorough physical evaluation and biomechanical assessment of the foot in addition to the trunk and lower limb (see article by Giallonardo in this issue). When this evaluation identifies problems that can be improved by use of a foot orthosis, specific goals must then be established to guide selection of appropriate shoes, shoe modifications, or shoe inserts that will provide maximum benefit to the patient.

A general goal for use of foot orthoses is to support the foot in a desired position and redistribute weight-bearing patterns for comfort and protection.[1] Foot orthoses are used to accomplish this general goal in several specific ways. First, foot orthoses are used to provide softness or cushioning to increase shock absorption. The impact of limb loading encountered at heel-strike is normally dissipated by a variety of joint movements including subtalar joint pronation and other proximal mechanisms. When subtalar joint range of motion is restricted, as in high-profile pes cavus or in the foot with arthritic joint limitations, mechanisms external to the foot may be required to provide additional dampening of this impact. A soft and resilient insert made of an appropriate material can provide this cushioning effect. Additional softness may also be required for patients in whom the anatomical plantar fat pad and other soft tissue cushions have become thinned or displaced, thus reducing their effectiveness in padding plantar bony prominences. This condition is typical in patients with arthritis and may also occur in patients with conditions producing insensitivity in the foot.

A second goal for shoe inserts is to provide relief to pressure-sensitive plantar areas to reduce pain under bony prominences. One method of accomplishing this goal is to provide a custom-contoured, total-contact insert or shoe that will reduce the amount of pressure per unit of surface area. Pressure relief can also be accomplished by the addition of a noncompressible pad or build-up around or next to the painful bony prominence. The relief pad will increase pressure on weight-bearing in pressure-tolerant areas and reduce it in pressure-sensitive areas. These two methods of pressure relief, total-contact support and relief padding, are commonly applied in combination to relieve the metatarsal heads, which are common sites of foot pain or ulceration in various conditions.[2,3] These combined methods are also used to accommodate and relieve fixed bony deformities.

A third application of shoe inserts is to reduce plantar shearing forces. Shear or frictional forces are an important cause of blisters, calluses, and trophic ulcers.[4] The shear forces that act on the sole of the foot during locomotion include fore and aft shear, lateral shear, and rotary shear or rotation of the foot on the floor.[4] When an appropriate material is selected, a shoe insert can be used to absorb these shearing forces. Materials that can absorb shearing forces do so by allowing internal horizontal movement. Patients who have difficulty with weight-shifting during gait, such as unilateral lower limb prosthesis wearers, may benefit from this type of appliance to protect the sound foot from potential ulceration attributable to excessive plantar shear.

Fourth, shoe inserts can be used to support or "balance" the joints of the foot in the position most desirable for weight-bearing. This support eliminates the need for the foot to compensate for structural deformity or malalignment between the leg, forefoot, and rear foot (see article by Tiberio in this issue). The desired foot position for weight-bearing is a neutral position of the subtalar joint with maximal eversion of the midtarsal joint. This position allows the plantar aspect of the forefoot to be in the same plane as the plantar aspect of the rear foot.[5] When deformity or malalignment prevents the planes of the forefoot and rear foot from being the same or parallel to one another and the floor while maintaining a subtalar neutral position, a shoe insert can be used to "bring the floor up" to the planes of the foot. This device eliminates the need for the joints of the foot and leg to compensate to get the entire plantar aspect of the foot flat on the ground. For example, to prevent excessive pronation from occurring to compensate for a hindfoot or forefoot varus deformity, material can be added to a shoe insert under the offending region of the foot. When compensated

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foot deformities are not balanced orthotically, the soft tissue supporting the joints becomes overstressed, and the patient may develop symptoms in the foot, leg, or trunk associated with overuse or cumulative trauma disorders.[6]

Lastly, shoe inserts can be used to correct functional deformities. A functional deformity is characterized by an abnormal change in function, but involves no structural alteration. Functional deformities are flexible ones. Because the joints and alignment of the foot with a functional deformity are normal, a shoe insert can be used to shift the location of weight-bearing on the foot when it is occurring abnormally because of altered neuromuscular function. For example, lateral heel wedging can be used to shift weight medially at heel contact for the patient who experiences lateral instability. When shoe inserts are used in this way, care must be taken to ensure that the affected joints in the foot have adequate ROM to accommodate the appliance and the resultant weight shift.

Although shoes, shoe modifications, and shoe inserts can be used alone or in combination to accomplish these goals, the purpose of this article is to review only applications of shoe inserts in achieving these goals. The types of inserts and the materials and methods used in fabrication are presented.

## TYPES OF SHOE INSERTS

A variety of classification systems have been used by those writing about shoe inserts. Shoe inserts have been classified as "soft," "semirigid," or "rigid" based on the physical properties of the materials used in construction of the appliances.[7,8] Others have classified inserts as "molded" or "nonmolded," reflecting the method of fabrication.[9] Still others identify inserts as "functional," "biomechanical," and "accommodative" based on the function or goal of the appliance. The classification system described in this article identifies inserts as soft, semirigid, or rigid. This system is commonly used by the various professionals who prescribe, design, and fabricate shoe inserts, in addition to orthotic laboratories and materials catalogs.

### Soft Inserts

Soft inserts are constructed of soft, or low-durometer, materials. Soft inserts are commonly used to provide cushioning to improve shock absorption, to reduce plantar surface shearing, or to relieve pressure-intolerant areas. Occasionally, soft appliances are used to control abnormal foot movement in cases of mild biomechanical imbalances. For example, the "Cobra" pad has been suggested as a valuable asset in the management of forefoot imbalances, such as forefoot varus or valgus.[10] Soft inserts are also used as temporary appliances to determine whether a permanent insert is needed.[11] Soft inserts do not require custom molding; thus, fabrication is simple, requiring a minimum of time, equipment, and experience.[12] Commercially available orthotic devices containing precut insoles accompanied by precut relief or balancing pads are available in low-durometer materials such as PPT® (Poron),* Sorbothane®,† and Viscolas‡®. Nonprescription orthoses are usually soft inserts. They are often sold in sporting goods stores and are popular among runners with minor injuries to provide additional shock absorption.[11] Some materials used in soft inserts are "cold moldable," meaning they will mold or compress, without heating in an oven, to the shape of the weight-bearing foot during use. An example of a cold-molding material is Plastazote®.§ Because of their compressibility, soft inserts often have a limited lifetime (6–12 months depending on the specific material and usage) and require periodic replacement or refurbishing. Although these soft, shock-absorbing materials are available in various thicknesses, to be effective the insert must be at least 3 mm thick. This requirement limits the application of soft inserts to use with shoes having adequate space to accommodate the added material.

### Semirigid Inserts

Semirigid inserts are constructed of a combination of low-temperature thermoplastic materials having a range of durometers from soft to firm. Semirigid inserts are used to provide some softness; however, they are more commonly selected to provide relief for pressure-sensitive plantar areas or to balance the malaligned foot in a neutral position to reduce abnormal foot or leg movements.[7,13] Fabrication of a semirigid appliance requires molding. Custom molding can be performed directly on the partially weight-bearing foot or indirectly over a positive mold of the foot made from a negative cast taken with the foot maintained in a subtalar neutral position (see article by Oatis in this issue).[13–15] These molding techniques require more equipment and skill to fabricate than do soft inserts. Prefabricated, premolded, semirigid shells are commercially available in a variety of materials and can be fit to an undeformed foot by simple measurements and adjustments.[16,17] The foot with complicated structural deformities, however, requires custom casting and molding to achieve effective orthotic control. To achieve balancing of a malaligned foot, additional material, often in the shape of a wedge, is added to the appropriate portion of the insert. This additional material, added to the inferior aspect of the insert, is called a *post*. This posting material adds bulk to the insert, which limits the type of shoes with which semirigid inserts can be used to those having adequate space or depth. Shoes appropriate for use with inserts are described later in this article in the section on clinical considerations.

The durability of semirigid appliances varies with the type of usage by the patient, the type of problem for which the insert is prescribed, and the properties of the materials used.[8] The semirigid insert can be adjusted or refurbished several times by resurfacing the plantar aspect of the device, thus increasing the life of the insert.[18] This adaptability has contributed to making semirigid orthoses a commonly used permanent insert.[11] Semirigid inserts are well tolerated by most patients because they allow some flexibility and shock absorption while supporting the malaligned foot.[8] These properties are particularly desirable in sport applications and in other situations where correction is required under high-impact loading.[7,8,18]

### Rigid Inserts

Rigid inserts are designed primarily to control abnormal foot and leg motion caused by compensated joint malalignments (see article by Tiberio in this issue).[8] They are made of hard, usually high-temperature, thermoplastic materials and are molded over a positive cast of the foot maintained in a neutral position or as near to neutral as possible. Rigid inserts may also be molded di-

* Professional Protective Technology, 21 E Industry Ct, Deer Park, NY 11729.

† IEM Orthopaedic Systems Inc, 251 W Garfield Rd, Aurora, OH 44202.

‡ Chattanooga Corp, 101 Memorial Dr, PO Box 4287, Chattanooga, TN 37405.

§ Bakelite Xylonite Ltd, London, England, distributed by AliMed Inc, 297 High St, Dedham, MA 02026.

rectly on the patient's foot using certain low-temperature thermoplastic materials.[19] This application is most commonly used with, although is not limited to, pediatric foot problems. Unlike semirigid appliances, rigid devices are manufactured from a single layer of plastic, usually no more than 3 mm in thickness.[20] Thus, fitting rigid appliances into most conventional shoes is less difficult than for semirigid appliances. Because of the rigid nature of the materials used, however, the shock-attenuation ability and energy-absorbing movements of the foot are reduced. Thus, rigid appliances should be used with shoes with a resilient sole to provide cushioning during impact. Rigid orthoses are used most often for everyday activities, such as walking, and are rarely used in sports or activities with high-impact loading.[8,11,21] Because of the nature of the materials and techniques used to fabricate rigid inserts, special equipment and skills are required in the manufacturing process. Although some prefabricated rigid shells are marketed, most rigid inserts are custom manufactured in professional orthotic or podiatric laboratories. Modifications to the completed orthotic device are difficult; thus, precision and accuracy in the casting and fabrication process are critical for successful fitting.

## MATERIALS

Leather, rubber, cork, and metal have been used traditionally in the fabrication of shoe inserts. With the advancement of the technology surrounding plastics and their applications, newer materials such as foamed polyethylene and polyurethane, synthetic rubber, solid viscoelastic urethane polymers, polyester, and acrylics have largely replaced the traditional materials in orthotic applications. Plastic materials can be classified as either *thermoplastics* or *thermosets*.[22,23] Thermosetting plastics are formed by molding liquid plastic over a positive mold. The liquid plastic is often impregnated into fabric as in laminated plastic. When solidified, or "cured," thermosets are rigid and cannot be reshaped by subsequent heating.[22] To modify appliances made of laminated plastic, material must be removed by grinding. Because of these properties, thermosets are rarely used in the fabrication of shoe inserts.

Thermoplastic materials become moldable when heated and rigid when cooled. After they have cooled, they can be reheated and reshaped many times. Thermoplastics can be identified as low- or high-temperature materials. Low-temperature thermoplastic materials become malleable at temperatures of 160° to 180°F (82°-89°C); thus, they can be heated in simple devices such as convection air ovens and electric frypans. Foamed plastics must be heated to slightly higher temperatures (200°-300°F or 93°-149°C); however, they are still considered low-temperature materials because air convection cools their surfaces quickly, and they have low thermal conductivity.[22] Toaster ovens are not recommended for heating these materials; if not closely monitored, they can melt the surface of the plastic causing a fire hazard. Low-temperature thermoplastic materials can be cut with scissors when warm, and most can be molded directly onto the patient's foot. Only the stiffer foamed plastics may retain too much heat for direct molding. Many of the low-temperature materials are self-adhesive. That is, they have the ability to weld to themselves or to other materials when hot. Plastics with smooth or coated surfaces, or those that are less self-adhesive, may require abrading and application of a contact cement for welding to other materials. These low-temperature thermoplastic materials are most commonly used in fabrication of soft and semirigid shoe inserts. Low-temperature polyester thermoplastic and synthetic rubber sheet plastics, however, can also be used to fabricate rigid inserts.

High-temperature thermoplastics require temperatures above 300°F (149°C) and in many cases above 400°F (204°C) for forming. Thus, orthoses made from these materials require special equipment and skills for fabrication and must be molded over a positive mold of the patient's foot. These materials are used in constructing rigid orthoses.

A thorough knowledge of the properties of the plastics that can be used in shoe inserts is essential before recommending or attempting to fabricate foot appliances. Several review articles and product information catalogs provide comprehensive descriptions of the materials, their properties, and their most common applications.[4,9,12,22–27]

When evaluating different materials for specific orthotic applications, the following material characteristics must be considered. *Elastic memory* refers to the ability of a material to return to its original state by reheating after molding.[9] Materials with good elastic memory can be reheated and remolded to achieve the desired orthotic fit. That is, if an error is made in molding, the material can be reheated, and it will resume its premolded, flat form. If the material is also self-adhesive, however, folds in the material made during the original molding process will not flatten out. Some materials shrink or stretch with heating. It is important to know this response of the selected material to heating before molding to avoid a poorly fitting appliance or wasted material. *Durometer* is a measurement of firmness.[9] A high-durometer material is firm and will not dissipate pressure, whereas a low-durometer material is soft. Low-durometer materials are selected to achieve cushioning for shock attenuation. High-durometer materials are often used as relief or balancing pads or posts. A system of numbers, called *Shore numbers*, exists to identify the durometer. These numbers, however, are rarely used in materials catalogs and are not necessary for materials selection. *Compression set*, expressed numerically as a percentage, represents the deformation or compression of a material after exposure to a given load for a fixed period of time as compared with the initial thickness of the material.[26] Compression set provides information about a material's ability to resist deformation and its durability. A term often used clinically to express compression set is "bottoming-out." A material that bottoms-out quickly has a high compression set and is not a good selection for use in an insert to enhance shock absorption.[27] A summary of some commonly used low-temperature thermoplastic materials is contained in Table 1.

Table 1 demonstrates that a large number of low-temperature thermoplastics are marketed under a variety of names for use in fabrication of shoe inserts. Without knowledge of the generic properties of these plastics, material selection to achieve a desired goal can be confusing. Low-temperature materials can be grouped as solid rigid materials, solid viscoelastic urethane polymers, and foamed plastics. The foamed plastics can be subdivided as open-cell or closed-cell foams. Cellular materials are formed by exposing rubber products or polymers to a gassing process under intense pressures. In closed-cell foams, each individual cell is independent from its surrounding cells. In open-cell foams, there are connections from cell to cell. These cellular foams are able to move

**TABLE 1**
**Low-Temperature Thermoplastic Materials Used in Shoe Inserts**

| Application | Material |
|---|---|
| Soft inserts | PPT® (Poron)[a] |
| | Spenco®[b] |
| | Viscolas®[c] |
| | Evazote®[d] |
| | Plastazote® (#1, #2)[e] |
| | Sorbothane®[f] |
| | Aliplast® 4E[g] |
| | Lynco[d] |
| | microcellular rubber (neoprene foams) |
| Base—molded semirigid or rigid inserts | Aliplast® 6A[g] |
| | Plastazote® (#2, #2.5) |
| | San Splint®[h] |
| | Pe-Lite® (medium, firm)[i] |
| | Aliplast® XPE[g] |
| | Aquaplast®[d] |
| Sock liners—molded semirigid inserts | Aliplast® 10[g] |
| | PPT® |
| | Plastazote® (#1) |
| | Spenco® |
| Posting materials | Nickelplast®[g] |
| | orthopedic felt |
| | Pe-Lite® (firm) |
| | Aquaplast® |
| | Plastazote® (#2.5, #3) |
| | Kemblo[d] |
| | Thermocork[d] |
| | Adapt-it Pellets®[j] |

[a] Professional Protective Technology, 21 E Industry Ct, Deer Park, NY 11729.
[b] Spenco Medical Corp, PO Box 8113, Waco, TX 76701.
[c] Chattanooga Corp, 101 Memorial Dr, PO Box 4287, Chattanooga, TN 37405.
[d] Apex Foot Products Inc, 330 Philips Ave, South Hackensack, NJ 07606.
[e] Bakelite Xylonite Ltd, London, England, distributed by AliMed Inc, 297 High St, Dedham, MA 02026.
[f] IEM Orthopaedics Systems Inc, 251 W Garfield Rd, Aurora, OH 44202.
[g] AliMed Inc, 297 High St, Dedham, MA 02026.
[i] Durr-Fillauer Medical Inc, 2710 Amnicola Hwy, Chattanooga, TN 37406.
[h] Smith & Nephew Rolyan Inc, N93 W14475 Whittaker Way, Menomonee Falls, WI 53051.
[j] WFR/Aquaplast Corp, PO Box 635, Wyckoff, NJ 07481.

both laterally and vertically, because of a gliding motion of the individual cell structures upon each other. This property makes them particularly suitable for reduction of shear forces. Table 2 groups low-temperature thermoplastics generically by composition and applications.

Despite the availability of information on the properties of these materials, considerably less information is available concerning objective assessment of the suitability of these materials for use as shoe insoles. Choice of materials appears to be based on personal experience, cost, and availability.[26] The most common materials used in rigid shoe inserts are polypropylene, cross-linked copolymer (Rohadur®‖), laminated carbon graphite, fiberglass, polyester laminates, and injection-molded polyester resins. Studies comparing their relative effectiveness in providing rigid control when used in shoe inserts are not available. Some objective studies have been published to compare materials used in soft and semirigid inserts.[25–27] Campbell and associates examined the compression characteristics of the foamed materials and their effectiveness in transferring load.[26] The materials tested were classified according to stiffness, and 17 of the 25 insole materials were judged to exhibit appropriate characteristics for clinical application as shoe inserts for pressure reduction. Pratt and associates compared the effectiveness of three foamed plastics and two solid viscoelastic polymers as shock absorbers and reported that PPT® and Viscolas® were most effective in this capacity. In addition, they tested used Plastazote® (worn for 72 hours) and unused Plastazote® and found that the Plastazote® that had been used for only 72 hours had no effective shock-absorbing ability.[27] Another clinical study quantitatively measured plantar pressures with shoe insole materials commonly used to reduce planter pressures.[25] Of the seven materials tested, PPT®, Plastazote®, and Spenco® were found to be the most effective.

‖ Rohm & Haas GmbH, Darmstadt, West Germany, distributed by Apex Foot Products Inc, 330 Philips Ave, South Hackensack, NJ 07606.

## FABRICATION TECHNIQUES

### Nonmolded Inserts

Soft, nonmolded shoe inserts are effective in reducing impact shock and plantar surface shear, as well as in balancing minor malalignments in the foot.[10,28,29] Thus, they have broad application for patients typically seen in physical therapy.[12] These inserts can be made quickly in a clinical setting with a minimum of equipment and space and do not require casting or special fabrication skills. Appropriate materials are listed in Tables 1 and 2. Specific fabrication methods are described in several sources.[9,10,12,20] A paper template is made by tracing the outsole or a removable insole of the shoe to be fit. Modifications are made to the tracing such that when the pattern is cut out, it will fit the interior of the shoe appropriately. Selected bony prominences on the plantar surface of the foot are marked and transferred to the template. The pattern is traced on the selected soft material and cut out with scissors. If needed, posting can be added to the inferior surface of the insert. These pads can be used to provide relief for painful bony prominences such as the metatarsal heads or the calcaneal tubercle, to balance minor alignment abnormalities such as forefoot varus, or to reduce pain from overuse injuries. Specific explanations of the selection and application of these pads are described in the literature.[10,12,20]

### Molded Inserts

When a patient demonstrates high plantar pressures or more severe malalignments in the foot, a molded insole is required to help maximize the distribution of pressures on the plantar surface of the foot. Molding can be accomplished by direct or indirect methods. When direct molding is done, the heated, malleable material is applied directly to the foot. Thus, only low-temperature thermoplastic materials

**TABLE 2**
**Classification and Applications of Low-Temperature Thermoplastics in Shoe Inserts**

| Classification | Material | Applications |
|---|---|---|
| Solid rigid materials | | |
| Polyester sheets | Aquaplast®[a] | 1. Rigid insert base |
| Synthetic rubber sheets | San Splint®[b] | 2. Posting |
| Solid viscoelastic urethane | Sorbothane®[c] | 1. Shock absorption |
| | Viscolas®[d] | 2. Shear absorption |
| Foamed plastic or rubber | | |
| Open-cell | | |
| Polyurethane | PPT® (Poron)[e] | 1. Shock absorption |
| | | 2. Shear absorption |
| Closed-cell | | |
| Neoprene | Spenco®[f] | 1. Shock absorption |
| | microcellular rubber | 2. Shear absorption |
| Polyethylene | Aliplast®[g] | 1. Semirigid insert base |
| | Plastazote®[h] | 2. Shock absorption |
| | Pe-Lite®[i] | 3. Posting (firm grades) |
| Ethyl vinyl acetate | Nickelplast®[g] | 1. Posting |
| | Aliplast® XPE[g] | 2. Semirigid insert base |

[a] WFR/Aquaplast Corp, PO Box 635, Wyckoff, NJ 07481.
[b] Smith & Nephew Rolyan Inc, N93 W14475 Whittaker Way, Menomonee Falls, WI 53051.
[c] IEM Orthopaedics Systems Inc, 251 W Garfield Rd, Aurora, OH 44202.
[d] Chattanooga Corp, 101 Memorial Dr, PO Box 4287, Chattanooga, TN 37405.
[e] Professional Protective Technology, 21 E Industry Ct, Deer Park, NY 11729.
[f] Spenco Medical Corp, PO Box 8113, Waco, TX 76701.
[g] AliMed Inc, 297 E High St, Dedham, MA 02026.
[h] Bakelite Xylonite Ltd, London, England, distributed by AliMed Inc, 297 E High St, Dedham, MA 02026.
[i] Durr-Fillauer Medical Inc, 2710 Amnicola Hwy, Chattanooga, TN 37406.

can be selected. The resulting appliance, depending on the properties and combination of materials used, can be soft, semirigid, or rigid. The technique of direct molding is described in several sources.[9,13,21] One direct-forming technique requires pressing the partially weight-bearing foot onto the heated material on a foam block. Although the foam block compresses under weight-bearing, pushing the material around the foot, additional manual molding of the material around the foot is required to achieve the desired fit. If the patient has a normally aligned foot, this technique is not difficult to perform. If the patient, however, has a malalignment such that the weight-bearing foot does not assume a subtalar neutral position, then the practitioner must simultaneously hold the foot manually in maximum correction and mold around the contours of the foot.[30,31] This procedure is technically difficult to perform, requires an assistant, and may result in a less-than-optimal mold. As an alternative, some podiatrists and physical therapists recommend direct molding on the nonweight-bearing foot with the subtalar neutral or maximally corrected position maintained manually.[21,31,32]

Indirect molding means that the orthotic material is formed over a positive cast of the foot. Thus, both high- and low-temperature thermoplastic materials can be used, and the resulting appliance, depending on the selection of materials, is either semirigid or rigid. The positive mold is made from a negative cast of the foot taken in a position of subtalar neutral with the midtarsal joint locked or fully pronated against the rear foot.[14] Various casting techniques are available to obtain the neutral-position cast described above. Valmassy describes the techniques, advantages, and disadvantages of the four most common casting methods used by podiatrists.[14] The methods he describes include suspension, prone, partial weight-bearing, and in-shoe vacuum casting. These techniques are also used by other health care professionals such as orthotists and physical therapists to fabricate negative casts. Physical therapists seem to use the prone and suspension methods most often.[9,19] Although the partial weight-bearing casting technique described by Schuster[15] has been labeled by some as unsatisfactory for making neutral functional orthoses, another weight-bearing casting technique is designed specifically to achieve and maintain the desired neutral position in the presence of pes planovalgus and other mechanical disorders.[14,33] This technique is based on the observation that lateral (external) rotation of the leg about its long axis causes the calcaneus to invert and the forefoot to supinate while the longitudinal arch rises simultaneously.[33] This method of casting was developed as the basis of the UC-BL (University of California Biomechanics Laboratory) shoe insert. With this method, the patient stands with partial weight-bearing on the involved leg after application of a plaster wrap to the foot. As the cast hardens, the leg is laterally rotated while the forefoot is held in pronation and slight adduction.[33] All of these techniques require that the practitioner making the cast have considerable skill and experience with casting.

A simple alternative to taking a negative cast is use of a foam impression tray.[9] This technique involves merely pressing the foot into a box of open-cell foam. When the foot is removed, the impression remains. This impression can be filled with plaster to form a positive mold, or the boxed impression can be sent to an orthotic laboratory for fabrication of an appliance to specifications. Despite its simplicity, there are disadvantages to this method. Because vertical pressure or partial weight-bearing is required for making the impression, the subtalar neutral position is difficult to maintain in the foot demonstrating weight-bearing malalignment. Thus, it is difficult to obtain effective orthoses from molds made by this method when the goal of the insert is to balance malalignments in the foot.

Another alternative can be considered when a molded device is desired. Prefabricated insert shells can be purchased in a variety of semirigid and rigid materials.[16,17] An appropriately sized shell can be selected and modified to individual needs. Semirigid shells constructed from low-temperature foamed materials can be modified by heating and grinding. Preformed rigid shells are typically fabricated from acrylic or injected molded polyester resin and are more difficult to modify. Shells of polyester resin can be modified by grinding to remove material. Acrylic shells can be heated with a heat gun and modified to some extent over a positive mold of the foot. Posting of these devices requires more skill and is usually done with acrylic. Because these shells are premade, fit to each individual patient is approximate. Prefabricated shells, semirigid and rigid, are not appropriate for the foot with severe structural deformities.

## Forming Methods

With direct molding, the insert is formed under weight-bearing during the molding process. Because most of the semirigid materials are self-adhesive when heated, no additional gluing is needed, except for the addition of posting or relief pads.

When an indirect molding technique is used, the positive cast must be dried, modified, and smoothed before molding the materials over the cast. The thermoplastic materials must be heated and then placed on the cast for molding. Even when the materials are self-adhesive, application of a contact cement is often necessary for complete adhesion between multiple layers of materials. Forming techniques include draping and manually pressing the heated materials onto the cast, use of a hand press, and vacuum forming.[9,19] Any of these techniques can be used with low-temperature thermoplastic materials. High-temperature, rigid materials, however, require vacuum forming. Because of the skill and equipment required to handle high-temperature thermoplastics, when a high-temperature material is required for an insert, the negative cast is usually sent to an orthotic laboratory for fabrication of the insert, or an orthotist or podiatrist is requested to cast and fabricate the appliance.

## Finishing

The finished shoe insert must have a superior surface that matches the contour of the foot to provide maximum support and distribution of pressure. The inferior surface must be flat and match the interior of the shoe so that the insert will be stable within the shoe without moving or rocking during gait.[34] This flat inferior surface is usually accomplished by posting and grinding. The inferior surface of semirigid and rigid inserts must also match the pitch, or "downslope," of the interior of the shoe caused by the difference in height from the floor to the sole and to the heel.

Posting or wedging can be extrinsic or intrinsic.[35,36] Extrinsic posting is the addition of rigid or semirigid material to the inferior aspect of the orthotic base to accommodate or balance malalignment of the foot. The post then, in a sense, brings the floor up to the foot so that the forefoot and rear foot can be held in a neutral position with respect to each other and the supporting surface.[36] Materials used for extrinsic posting on a semirigid appliance are listed in Table 1. An appropriate posting material has a high durometer and resists compression so that a small thickness of material will be durable and provide adequate control. The advantage of extrinsic posting is that adjustments are easily made by adding or grinding away posting material. As wear occurs, posting material can be added or replaced to extend the life of the appliance. The problem with extrinsic posting, however, is that it is bulky. It may interfere with shoe fit, causing the patient's heel to slip out of the shoe, or it may require use of a special shoe with extra depth.[35] An alternative method that prevents this disadvantage is intrinsic posting.

Intrinsic posting can be used only with a rigid insert. When intrinsic posting is used, the positive mold is modified by adding or sanding away plaster so that the finished appliance accommodates and balances the foot in a neutral position without the addition of material to the insert.[35] Because additional material is not added to the insert, fitting with shoes is usually less difficult. With this method of posting, precision in measurement of the degree of malalignment and fabrication of the correction is critical because there is little opportunity for adjustment after completion of the insert other than the addition of extrinsic posting.

The length of the shoe insert can be varied by adjusting the location of the distal trimline. Shoe inserts are usually three-quarters length, with the distal trimline cut just proximal to the metatarsal heads, or full length, with the orthotic base extending under the toes to the end of the foot. Only soft inserts can be full length without interfering with the timing of toe-break, which would have an effect on gait.[18] Semirigid inserts are typically three-quarters length, with the base and posting material beveled to end about 1 cm proximal to the metatarsal heads.[13,16,17] This trimline is necessary to avoid adding extra pressure under the metatarsal heads in the late stance phase of gait. For patients who require the support provided by a semirigid insert but also need additional softness under the metatarsal heads, a low-durometer forefoot extension can be added to the three-quarters length semirigid base.[16,17] Thus, the finished full-length insert consists of two or more materials producing the combined effect of semirigid support under the tarsals and bases of the metatarsals and flexibility and softness under the metatarsal heads and toes.[16] Some semirigid inserts may extend to the toe sulcus, provided the material under the metatarsal heads is flexible and does not interfere with the timing of toe-break during locomotion. Rigid inserts are almost always three-quarters length. This distal trimline is modified only under special circumstances or to accomplish a specific goal, because lengths beyond toe-break affect proximal joints and interfere with the biomechanics of the gait sequence.[37]

## CLINICAL MANAGEMENT

Although the types of shoe inserts described are effective in correcting or balancing mechanical abnormalities in the foot, caution must be taken so that an orthotic solution for one problem does not cause another.[38] Excessive orthotic control with shoe inserts has caused iliotibial band syndrome or trochanteric bursitis from excessive varus control in the foot, exacerbation of low back pain or hip rotator muscle strain from excessive neutral foot control, and plantar fasciitis caused by devices pressing into the plantar fascia during the mid-stance to late-stance phases of gait.[20] After initial delivery of the appliance to the patient, follow-up visits are required to provide any necessary adjustments and to ensure that the insert is functioning as desired.[18] When semirigid and rigid inserts are used, a schedule of gradually increasing wearing time is recommended to allow adjustment to the change in foot position.

Shoe inserts for any purpose are rarely successful by themselves. Selection of the appropriate footwear to be used with a shoe insert is as important as proper design and fabrication of the orthotic appliance (see article by McPoil in this issue). Care must be taken so that the shoe can adequately accommodate and complement the insert. Inserts are most effective when used in shoes with a closed heel, heel height less than 4 cm, adequate height in the toe box, a Blucher throat style, and closure by laces or straps.[17]

Although shoe inserts are usually fabricated to be transferable from one pair of shoes to another, all shoes with which an insert is worn must have the same last and heel height. When the insert does not match the pitch within the shoe caused by the shoe's heel height, it will be uncomfortable and produce excessive pressure.

Shoe inserts are most commonly used in pairs, even when the pathological condition of the foot for which the appliance is prescribed is unilateral. The inserts are worn in pairs to avoid production of a leg-length discrepancy by wearing an insert in one shoe only.

The shoe and insert must complement one another to accomplish the desired therapeutic goal. For example, it is important to use a cushion-sole shoe with a rigid orthosis to provide adequate shock absorption. Conversely, when a soft appliance is used, the shoe must provide control so that abnormal foot or leg movement does not occur. Johnson demonstrated that the fit between the shoe and foot can have a major influence on shock transmission and the effectiveness of some soft insoles in reducing shock.[39] Some shoe inserts may be more effective when used with shoe modifications. For example, an insert fabricated with medial rear-foot posting or wedging to balance a structural rear-foot varus may require a lateral heel outflare on the shoe to ensure rear-foot stability at heel contact. Another example is the addition of medial counter reinforcement or buttressing on the shoe to be worn with an insert designed to correct pes planovalgus.

Finally, shoe inserts should be part of a total program that addresses not only the foot, but the trunk and lower extremity as well. Orthoses of any type should be accompanied by appropriate exercises or therapeutic activities to increase ROM and muscle strength, improve postural alignment, and modify functional activity to decrease deleterious forces contributing to the pathological condition.[20]

## PATIENT APPLICATIONS

Selection of a shoe insert for a specific patient can be confusing. The selection process can be clarified by considering several important factors. First, before an appliance is recommended, a specific need must be identified. A physical and biomechanical evaluation of the patient should reveal a specific patient problem that can be solved by a shoe insert. For example, just because excessive pronation in gait is observed is not adequate evidence to justify recommendation of a shoe insert. The pronation may be a result of a structural malalignment in the foot, but it might also be caused by factors proximal to the foot such as a tight tendo Achillis or excessive tibial or femoral medial rotation. If the latter factors are the cause, treatment with a shoe insert may not be effective.

Second, specific goals for the appliance should be established. The primary goals for shoe inserts are discussed in the beginning of this article. Establishing vague goals has little usefulness. A goal statement such as "to decrease foot pain" has little relevance in selecting or designing an orthotic appliance. If a patient complains of foot pain, the orthotic goals should address the specific cause of the foot pain. For example, is the pain related to inadequate cushioning of bony prominences, or does the patient have a structural malalignment causing painful overstress of supporting soft tissue structures?

Third, how the orthotic appliance is going to be used must be determined. What is the activity level of the patient? Will the appliance be used in walking only, or in running and other high-impact activities as well? Will the insert be used full-time or part-time? Answers to these and other similar questions are needed to select materials with appropriate characteristics in terms of durability, compressibility, and rigidity. The type of footwear that the patient is willing to wear must also be known. Appropriate shoes for use with inserts have already been described.

A clear understanding of the patient's medical and biomechanical pathology and specific orthotic goals make selection of the type, design, and materials for insert construction less confusing. Obtaining a shoe insert for a patient also includes selection of a fabrication process. All of the resources available to the prescribing practitioner and patient should be considered and selected appropriately for each individual patient. Only practitioners with knowledge and experience with fabrication techniques and appropriate materials and equipment should attempt to construct the more complex custom-molded inserts. The financial resources of the patient should also be considered because few medical insurers cover shoe inserts.

Patients who may benefit from shoe inserts include the following groups. Arthritic patients often have painful bony prominences attributable to the thinning and displacement of plantar soft tissue pads, as well as the development of fixed bony deformities. Orthoses that provide a soft tissue supplement as well as relief for bony prominences may reduce weight-bearing foot pain.[40] As arthritic joints deteriorate, structural malalignments may develop that require orthotic balancing or correction.[41] Care must be exercised in selecting orthotic foot appliances for arthritic clients. Foot disorders may have causes intrinsic to the foot that can be improved with shoe inserts, but additional proximal deformities often exist that aggravate or intensify the foot complaints. Shoe inserts are less effective when foot disorders are related to proximal causes.

Patients with insensitivity in the foot, such as those with diabetes, are susceptible to blisters, calluses, and ulcerations from repetitive, continuous, and shearing stresses applied to the foot during walking. These patients may benefit from inserts that provide softness to decrease plantar pressure and reduce the shearing forces during locomotion (see articles by Sims et al and Mueller and Diamond in this issue).[2] Inserts to relieve bony prominences or areas of the foot that receive high concentrations of weight-bearing stress during walking may also be beneficial to these patients.[42–44] The metatarsal heads, common sites of ulceration in this patient population, can be relieved orthotically.

Neurologically impaired patients, such as those with cerebral palsy or similar functional disabilities, may benefit from heel stabilizers or shoe inserts to reduce pes planovalgus secondary to ligamentous laxity or hypotonia during weight-bearing (see article by Selby in this issue).[21,45] Neurologically unimpaired children with symptomatic hypermobile pes planovalgus also are often treated with shoe inserts.[46–53]

Patients engaging in recreational or competitive athletic activities often develop painful overuse symptoms when there are structural malalignments in the foot and leg.[6,54] These malalignments are often asymptomatic during walking and less stressful activities of daily living. The repetitive nature of force application and the increase in high-impact limb loading that accompany many sports activities, however, stress the soft tissue structures that provide support to the malaligned joints. Orthoses to balance these joints, eliminating the need for joint compensation, can often relieve these symptoms.[55] Additionally, athletes who participate in sports that require much high-impact loading, such as running and jumping, may benefit from inserts that improve shock absorption and absorption of shearing forces.[56–59]

## SUMMARY

This article summarizes and describes the goals and types of shoe inserts, as well as the materials, designs, and methods of fabrication. A wide range of foot orthoses are available with varying requirements for fabrication skills, equipment, and time. It is evident that one appliance cannot benefit all patients optimally. A process for designing or selecting the most appropriate shoe insert for individual patients is presented. Patient conditions and problems that can be improved with an appropriately constructed insert are reviewed, and physical therapists are encouraged to integrate the use of shoe inserts for management of foot and leg problems with other treatment techniques.


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