Shoe Modification and the Use of Orthoses in the Treatment of Foot and Ankle Pathology

Dennis J. Janisse, CPed

Erick Janisse, CPed, CO

Abstract

Shoe modification and foot orthoses can play an important role in the nonsurgical management of foot and ankle pathology. Therapeutic footwear may be used to treat patients with diabetes, arthritis, neurologic conditions, traumatic injuries, congenital deformities, and sports-related injuries. These modalities may improve patient gait and increase the level of ambulation. They also may be used to treat acute problems such as plantar fasciitis or metatarsalgia and as preventive tools in patients with diabetic neuropathy. Shoe selection is primarily based on the condition of the patient, the foot shape and type, and the patient's daily activities. Modifications include flares, which provide stability; extended shanks to reduce bending stresses; rocker soles to rock the foot from heel strike to toe-off; and relasting, or reshaping, shoes to accommodate deformities. The four main types of custom orthoses are the accommodative, which cushions and protects the foot; the semi-rigid, which cushions and protects as well as provides support, control, and weight redistribution; the rigid, which offers arch support; and the partial foot prosthesis, which addresses partial amputations and helps protect the foot.

Mr. Dennis Janisse is Certified Pedorthist and Clinical Assistant Professor, Department of Physical Medicine and Rehabilitation, Medical College of Wisconsin, Milwaukee, WI. Mr. Erick Janisse is Certified Orthotist and Vice President, National Pedorthic Services, Inc, Milwaukee.

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Reprint request: Dennis Janisse, Department of Physical Medicine and Rehabilitation, Medical College of Wisconsin, 7283 West Appleton Avenue, Milwaukee, WI 53216.

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Therapeutic footwear, shoe modifications, and foot orthoses are important tools in the nonsurgical management of the foot and ankle.[1] Foot orthoses can be used to manage a variety of pathologies and conditions, from overuse or sports-related problems (eg, plantar fasciitis, posterior tibial tendonitis) to systematic diseases with complications (eg, diabetes, arthritis). Orthoses may be designed to off-load areas of high pressure, decrease shear, correct flexible deformities, cushion tender sites, or provide support and control for the foot. Shoe modifications such as rocker soles and flares are useful for eliminating painful motion, replacing lost motion, accommodating and compensating for deformities, and providing additional support to improve gait and ambulation.[2]

The Certified Pedorthist

Pedorthics focuses on the design, manufacture, fit, and modification of shoes and foot orthoses to alleviate foot problems caused by disease, overuse, or injury.[3] The pedorthist provides footwear for the patient, including shoes, orthoses, and hosiery.

The pedorthist helps the patient properly fit shoes and constructs custom-made foot orthoses to fit inside the shoes. The pedorthist also may modify the shoes themselves. The pedorthist not only fits and dispenses these items but also adjusts and maintains them. In addition, the pedorthist provides patient education and serves as a resource for teaching patients about proper shoe fit, selection, and usage. As a member of the foot care team, along with physicians, nurses, physical therapists, and orthotists, the pedorthist reinforces the information and instructions provided by the other team members while monitoring the patient's progress.

Shoes

Improper footwear can to be a common cause of many types of foot-related complaints.[4] Modified or corrected shoes can play a significant role, for example, in lowering a diabetic patient's chance of developing foot ulcers.[5] Important objectives when providing specialized shoes include protecting the foot, relieving areas of excess pressure, reducing shock and shear, and accommodating, stabilizing, and supporting deformities.

The foot needs to be protected from external sources of injury and the elements. Repetitive high pressure during daily activities can lead to skin breakdown on the foot. An example is plantar pressure under prominent areas such as the metatarsal heads. Reduction in the overall amount of vertical pressure, or shock, is especially important for a foot with bony prominences or abnormal bone structure. The reduction of shear (ie, the fore and aft movement of the foot inside the shoe) can help reduce callus build-up, blisters, and heat as a result of friction.

Deformities such as those resulting from posterior tibial tendon dysfunction, Charcot arthropathy, and amputation must be accommodated. Also, it is important to consider forefoot deformities such as bunions and claw toes. Many deformities need to be stabilized and supported to relieve pain and to prevent further destruction or progression of the deformity. Foot orthoses affect the way a shoe fits and must be taken into consideration; however, not all shoes will accommodate such devices.

Shoe Types

Therapeutic footwear includes Oxford-type shoes with an additional 0.25- to 0.375-inch depth. These shoes offer even more depth when the removable factory inlays are taken out. Thus, the shoe can accept a foot orthosis without affecting the overall fit. The extra depth is also useful for accommodating deformities. Many athletic shoes are considered in-depth and are more cosmetically acceptable than the traditional Oxford-type shoe. Off-the-shelf depth shoes are manufactured in multiple widths.

When an off-the-shelf shoe is inappropriate as a result of extreme deformity (eg, Charcot foot) or because of great variance in size from left foot to right, modification of the shoe may be necessary. Occasionally, a shoe cannot be modified to fit; the alternative is a custom shoe.[6]

Custom shoes are fabricated by creating a positive model from a mold or three-dimensional computed tomography scan of the patient's foot. The shoe is constructed around this model. Because they are built directly from molds of the feet, custom shoes offer the best possible accommodation and protection; however, they can be expensive compared with off-the-shelf shoes.

Shoe Selection

Shoe selection is primarily based on three considerations: the condition or disease affecting the patient, the patient's foot shape and type, and the patient's daily activities. For a patient with a structurally normal foot and no history of neuropathy, a properly fitting off-the-shelf shoe should be adequate. However, a more complex footwear prescription is required for the patient with loss of protective sensation and/or a history of ulcers, with Charcot arthropathy, and/or with amputations. Such a prescription would include a shoe made of a soft, moldable upper material that offers sufficient room for a custom foot orthosis.

The construction of the shoe should correspond to the patient's body type. A heavy person requires a sturdy, well-constructed shoe that will not quickly wear out. A smaller individual may use a lightweight shoe. The primary component of both shoe selection and shoe fitting is choosing a shoe that fits the shape of the patient's foot. The shoe must be of the correct shape and depth (eg, 0.375 inch longer than the longest toe) to properly accommodate additional devices (eg, foot orthosis, ankle-foot orthosis).

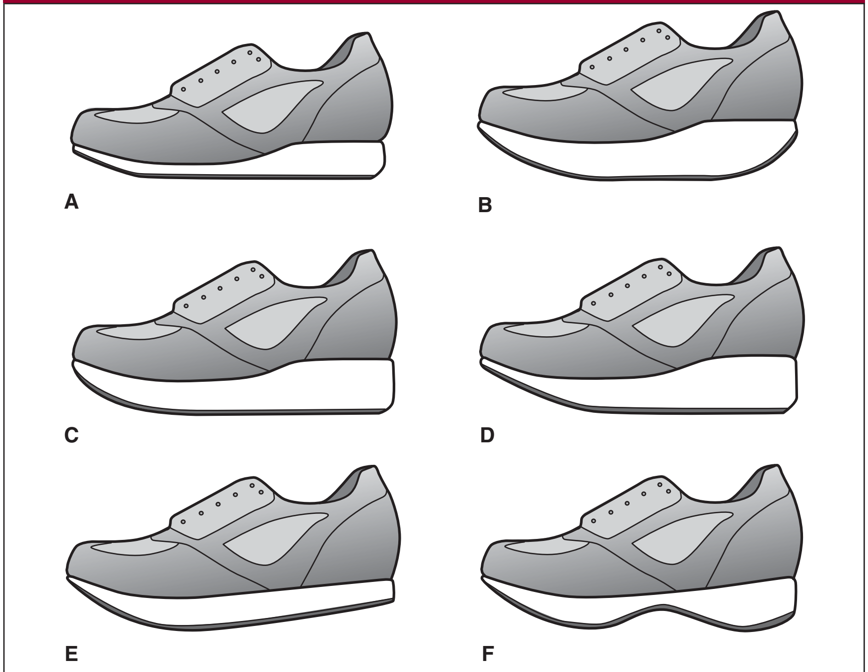
For the patient with a very flexible flatfoot, a stiff, supportive shoe is recommended. A rigid, bony foot can benefit from a soft, accommodating shoe with a shock-absorbing sole similar to a walking or running shoe.

The depth of the shoe is important in the toe and across the instep. The shoe design should prevent pressure across the dorsum of the foot. Patients with neuropathy or forefoot pathology find it helpful to avoid slip-on shoes because they are often too short and tight. Shoes with laces or hook-and-loop closures tend to fit better.

Shoe Modification

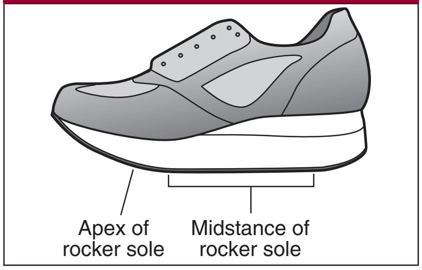
Shoes are modified for one or more of the following reasons: to aid in forward propulsion or to make ambulation more efficient; to replace motion lost as a result of pain, fusion,

Figure 1



The six different types of rocker sole. **A,** Mild. **B,** Heel-to-toe. **C,** Toe only. **D,** Severe angle. **E,** Negative heel. **F,** Double.

Figure 2



The two important landmarks of a rocker sole: the apex and midstance.

arthritis, injury, or deformity; to restore lost function; to decrease or eliminate painful motion; to increase stability and proprioception; to off-load areas of high pressure; and to help the shoe better fit the foot. Other common modifications include flares, extended shanks, rocker soles, and relasting (ie, reshaping).

Flares

The flare acts as an outrigger, adding to the medial-lateral stability of the shoe and the foot. It consists of a strip of firm material added to one or both sides of the shoe and provides a wider base of support for the foot.[7] The flare can be helpful in the patient who has had a partial foot amputation or has a fixed varus or valgus ankle deformity. It can also help stabilize an unstable foot or ankle.

Extended Shank

The extended shank is made of either spring steel or carbon graphite composite. It is embedded between the layers of the sole, extending from the heel to the toe, and may be placed in nearly any type of shoe. The carbon fiber shank is lighter than the spring steel shank; however, the carbon fiber is susceptible to breakage when subjected to extreme repetitive force. The extended shank is often used with a rocker sole and can enhance the function of the rocker sole.

The shank can be used to splint and keep the shoe from bending, thus reducing forces (bending stresses) through the midfoot and forefoot. It strengthens the entire sole and shoe and maintains the continuity of the rocker sole. The extended shank is a useful application to replace the lever arm that is lost when the great toe or the entire forefoot has been amputated. Its application is also indicated for hallux limitus or hallux rigidus and for limited ankle motion.

Rocker Soles

One of the most prevalent shoe modifications is the rocker sole. The primary function of a rocker sole is to rock the foot from heel strike to toe-off without requiring the shoe or foot to bend. Six types of rocker soles exist: mild, heel-to-toe, toe-only, severe angle, negative heel, and double rocker (Figure 1). The actual shape and type of rocker depends on the desired effect and the individual patient's foot problem. The biomechanical effects of rocker soles are restoring lost motion in the foot and ankle and off-loading plantar pressure on some part of the foot. Motion can be lost in the foot and ankle because of pain, deformity, stiffness, or surgical fusion; use of the rocker sole can result in overall improvement in gait.[8,9] All six types of rocker soles can off-load the forefoot; this shoe modification is considered the most effective way to off-load the forefoot with a shoe modification.[10-12]

The midstance is the section of the rocker sole that is in contact with the ground when standing erect (Figure 2). The apex, or high point, of the rocker sole is located at the distal end of the midstance.[13] Proper placement of the apex is critical to the success of the modification. The apex should be placed proximal to any area in which pressure relief is desired. That is, for example, if the desire is to offload the ball of the foot, then the apex is placed directly behind the metatarsal heads.

Many off-the-shelf walking shoes and running shoes are built with a simple, generic rocker that is adequate for mild problems. These generic rockers provide some metatarsal head relief and gait assistance. However, a custom rocker sole is indicated for the patient who requires further relief or who has a significant deformity.[13]

Mild Rocker Sole

The most widely utilized rocker sole is the mild rocker sole. Using a mild rocker at the heel and at the toe can relieve mild metatarsal pressure and assist in gait by increasing forward propulsion. The other types of rocker soles are essentially variations of this basic rocker (Figure 1).

Heel-to-toe Rocker Sole

This type of sole is shaped with an accentuated rocker angle at both the heel and toe. It is intended to increase propulsion at toe-off, decrease pressure on heel strike, and reduce the need for ankle motion. This modification may be indicated for the patient who has undergone ankle or subtalar joint fusion, has fixed claw- or hammer toe deformities, has had a midfoot amputation, or who has calcaneal ulcers.

Toe-only Rocker Sole

The toe-only rocker has no heel rocker, only a rocker angle at the front with the midstance extending to the back of the heel. This rocker is designed to increase weight bearing proximal to the metatarsal heads, provide a stable midstance, and reduce the need for toe dorsiflexion. It is useful for addressing forefoot problems in the patient who experiences difficulties with stability or proprioception.

Severe Angle Rocker Sole

This rocker sole has a more severe angle at the toe than do the other sole designs. It has no heel rocker angle, thereby significantly reducing weight-bearing pressures distal to the ball of the foot. The severe angle rocker sole is indicated for extreme relief of metatarsal head or toe tip ulcerations.

Negative Heel Rocker Sole

The negative heel rocker is shaped with a rocker angle at the toe and under the ball of the foot, with the heel height actually lower than the height of the sole. The purpose of this design is to accommodate a foot fixed in dorsiflexion or to relieve forefoot pressures by shifting them to the midfoot and heel. This modification is contraindicated for patients with balance or proprioception deficiencies or those unable to attain the necessary ankle dorsiflexion as a result of arthritis, fusion, or contracture of the Achilles tendon.

Double Rocker Sole

This type of rocker sole actually consists of two shorter rocker soles with two short midstances. The double rocker sole is used to treat midfoot pathology. Whereas shoes with the other types of rocker soles actually increase pressure under the midfoot, the double rocker sole does not.[11] This modification can be used to off-load midfoot prominences, such as those associated with a Charcot foot deformity.

Relasting

Many off-the-shelf shoes can be relasted to accommodate severe deformities.[7,14] Custom shoes may be expensive. Also, patients are often unreceptive to the idea of wearing them. Relasting is therefore a viable alternative to custom shoes for many patients.

This process involves customizing an off-the-shelf shoe by widening it through the midfoot or forefoot to accommodate a foot that otherwise would be unable to use a generic shoe. The reshaping is achieved by removing the outsole and making a cut through the sole, midsole, and inner sole and widening the shoe according to a pattern of the foot. A new outsole is then applied. To the casual observer, the shoe appears to be normal.

Relasting a shoe may be indicated for a severe rigid pes planus deformity or a midfoot that has widened as a result of Charcot arthropathy.

Foot Orthoses

Foot orthoses are available as custom-made devices made directly from a mold or model of the patient's foot. Also, foot orthoses may be prefabricated, off-the-shelf devices. Both are manufactured from a variety of materials that differ in density, cushioning, shock absorption, support, and control. The use of a prefabricated device significantly reduces the cost and time investment of both practitioner and patient; however, use of a prefabricated orthosis sacrifices the intimate fit, longevity, and adjustability of a custom foot orthosis. A custom device is necessary for a patient with a significant deformity, loss of protective sensation, and a history of ulcers and/or arthropathy.[15]

There are four main types of custom foot orthoses. They are the accommodative, semi-rigid, rigid, and partial foot prosthesis. All except the partial foot prosthesis are available in off-the-shelf versions.

To provide the patient with the best possible orthosis, the practitioner must understand lower-limb biomechanics and be able to identify areas of high pressure. The practitioner also must use the proper molding technique and be able to select the best material given the desired function of the orthosis.[14]

The eight objectives of using a foot orthosis are the following: (1) to provide shock absorption and shock attenuation; (2) to provide cushion for tender areas of the foot; (3) to relieve areas of high plantar pressure by evenly redistributing weight-bearing pressures covering the entire plantar surface; (4) to support, splint, and protect healed fracture sites by using the total-contact concept; (5) to reduce shear through the use of the total-contact concept; (6) to control, stabilize, support, or correct flexible deformities by using combinations of soft and semi-rigid materials; (7) to limit the motion of joints by using combinations of soft and semi-rigid materials; and (8) to accommodate fixed deformities by using soft, moldable materials.[16]

Accommodative Foot Orthoses

An accommodative foot orthosis is primarily designed to cushion and protect the foot. It offers shock absorption and ample padding, but it may not perform at a high level for a long period of time. Softer, less dense materials tend to wear out quickly, so this type of orthosis requires vigilant follow-up and must be repaired or replaced regularly. The accommodative type of orthosis is good for a patient who has little or no deformity, who is not a large, active person, and who needs only preventive padding in his or her shoes.

Some accommodative orthoses can be molded directly to the patient's foot using external heat and pressure. Accommodative orthoses also can be fabricated over a positive model of the patient's foot. This model can be a plaster model made from a negative mold of the foot or a computer-generated model based on a three-dimensional scan. There are three widely used methods to create a positive model of the patient's foot. The first is a box of crushable foam used to obtain an impression of the patient's foot; this impression is then filled with plaster to make a model of the foot. Another method of making accommodative foot orthoses is the plaster cast. This is done while the foot is held in the desired position; the resulting plaster shell is filled with plaster to make a replica of the patient's foot. The final method is computer-aided design and manufacturing (CAD-CAM). This consists of scanning the foot via a computerized system to create a virtual model of the patient's foot. This information is relayed to a milling machine, which mills out an orthosis that mirrors the bottom of the patient's foot. Turnaround time for CAD-CAM orthoses can be as short as 1 day or less. However, a criticism of the CAD-CAM systems is the limited selection of firmer, less shock-absorbing materials available for milling.[17]

Accommodative foot orthoses are made of soft, moldable materials fabricated from such substances as the following. Soft cross-linked polyethylene foams are heat-moldable and very soft, but they compress very quickly.[16] Open-cell polyurethane foams are good for reducing shear and absorbing shock. Sponge rubber is available in varying densities and does not compress rapidly. Closed-cell expanded rubber can maintain up to 90% of its thickness under heavy loads. In general, moldable materials possess better pressure distribution properties than do nonmoldable materials; however, moldable materials are not as durable, and they compress permanently more rapidly.[18]

Semi-rigid Foot Orthoses

Semi-rigid foot orthoses combine the support, control, and weight redistribution of rigid orthoses with the cushion and protection of accommodative foot orthoses. They also offer greater longevity than do accommodative foot orthoses.

A semi-rigid orthosis often consists of a soft, cushioned top layer with a firm, supportive base material. Whereas the rigid orthosis supports the foot using a thin layer of firm, inflexible material, the semi-rigid device relies on a thick layer of semiflexible material that offers support as well as shock absorption and cushioning.

The molding techniques previously described can be used to create semi-rigid orthoses. The foam box and the CAD-CAM systems are most commonly employed.

To alleviate areas of high pressure, the semi-rigid orthosis redistributes and equalizes plantar pressures. The soft materials in an accommodative orthosis accomplish this goal for only a short period of time because the soft materials compress rapidly. The semi-rigid device uses a firm material to support the arch and cradle the heel so that the soft materials in the top layer of the prosthesis do not compress as rapidly; thus, plantar pressures are more evenly distributed.[16] In an insensate foot, the areas of highest pressure are under the heel and the ball of the foot.[10] With a weight-redistributing, total-contact, semi-rigid foot orthosis, the entire plantar surface of the foot participates in the weight-bearing process (Figure 3). A semi-rigid orthosis is an invaluable tool for off-loading plantar prominences such as dropped metatarsal heads or bony prominences associated with Charcot arthropathy or arthritis.[19]

The top layer or layers of a semi-rigid orthosis generally consist of thin sheets of accommodative materials. Semi-rigid orthoses are made of combinations of two, three, four, or more different materials, such as cross-linked polyethylene foams, ethylene vinyl acetates, and cork composites. The firm, cross-linked polyethylene foams containing closed-cell materials are available in different densities and have excellent shock-absorbing qualities. The cells of ethylene vinyl acetates are smaller than those of the polyethylene foams; thus, they last longer and hold up better under weight-bearing loads. Cork composites contain many different cork-based composites that are good shock absorbers and do not quickly compress. Cork composites are among the commonly used materials for the solid base of the semi-rigid foot orthoses.

Semi-rigid orthoses are easily adjusted and can be modified to accommodate minor changes in the foot. These devices will require follow-up and must be replaced periodically.

Special attention needs to be given to the orthosis for the diabetic foot. In a study of five commonly used materials, Brodsky et al[18] found that the soft polyethylene foams had better pressure-distribution characteristics when first applied but that exposure to repeated pressures caused them to bottom out more rapidly than some of the more durable polymers. Other orthotists give credence to this concept and reported that loss of thickness of the molded polyurethane foam is inversely related to its density.[20]

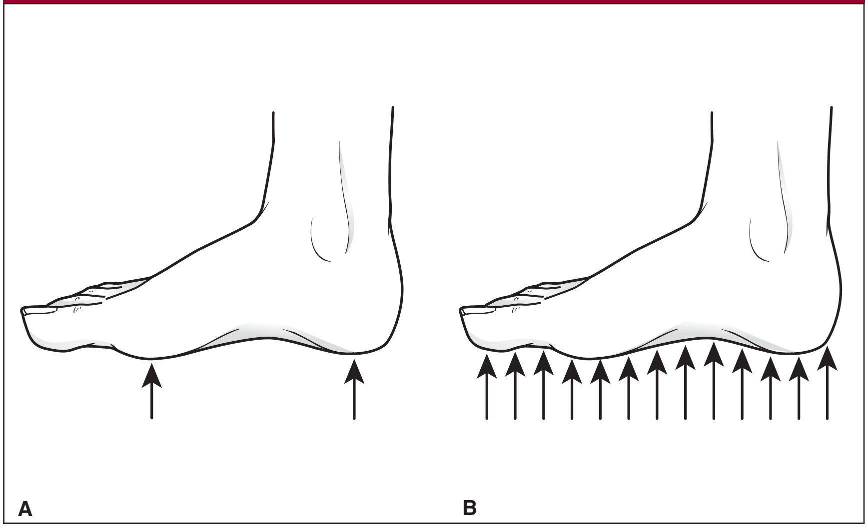
These studies indicate that, to achieve total contact as well as to provide adequate shock absorption and support, a foot orthosis for use in treating the diabetic foot should be composed of a combination of materials. A triple-layer molded orthosis has been suggested to provide the necessary combination of support and accommodation.[13,16] The three layers are made up of a soft, moldable polyethylene foam next to the foot, a middle layer consisting of a urethane polymer that resists bottoming out and offers good shock absorption, and a firm molded cork or dense ethylene vinyl acetate base for support and control.

Orthoses made of material with excellent shock-absorbing qualities, such as a viscoelastic polymer, have been shown to significantly reduce abnormally high plantar pressures in the foot.[14] In addition to reducing plantar pressures, decreasing shear can be helpful in eliminating and preventing blisters and calluses. This can be accomplished by using a low-friction interface.[21]

Rigid Foot Orthoses

Rigid orthoses offer excellent arch support for flexible deformities and are often easy to fit into fashionable shoes; however, they can be difficult to fit into other types of shoes.[9] Rigid orthoses are not forgiving; they do not mold or conform to prominences on the plantar surface of the foot and may actually cause injury.[17]

Figure 3



A, Areas of high pressure (arrows) without a foot orthosis. **B,** With a foot orthosis, pressure is more evenly redistributed (arrows).

Rigid orthoses are often made of carbon fiber composites or thermoplastics. They are not easily adjusted. They are durable and offer excellent support and control but provide only minimal cushion, shock absorption, and protection.[13]

Partial Foot Prostheses

The partially amputated foot requires the use of a semi-rigid device with an accommodative top cover and a soft buffer material between the orthosis and the foot remnant. The device is molded around a model of the foot and the void, where the amputated portion is filled in using a firm material. The prosthesis also protects the foot by reducing fore-and-aft and side-to-side motion inside the shoe.

Off-the-shelf Orthoses

Off-the-shelf orthoses are suitable when the patient has no deformity, neuropathy, or ulcers.[9] However, as mentioned, in a patient with a history of ulcerations or sensory limitations, custom orthoses are necessary.

Summary

Pedorthics is the design, manufacture, fit, and modification of shoes and foot orthoses. Appropriate shoe modifications and foot orthoses can aid in healing acute injuries, relieving foot pain, restoring or replacing lost motion and function, and, ultimately, improving gait and ambulation. Modifications include flares, which add to medial-lateral stability; extended shanks, which reduce bending stresses through the midfoot and forefoot; rocker soles to rock the foot from heel strike to toe-off; and relasting, or reshaping, off-the-shelf shoes to accommodate severe deformities.

The four main types of custom orthoses are the accommodative, designed to cushion and protect the foot; the semi-rigid, which offers cushioning and protection as well as support, control, and weight redistribution; the rigid, which offers arch support for flexile deformities; and the partial foot prosthesis, which uses a semi-rigid device with an accommodative top cover to address the void and protect the foot. The pedorthist is trained to assist and advise patients in evaluating footwear and provides shoes, shoe modifications, and foot orthoses.

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Evidence-based Medicine: References 1 and 4 are level I/II randomized controlled studies.

Citation numbers printed in **bold type** indicate references published within the past 5 years.

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