



Prescribing Foot Orthoses

The authors review the history, composition, and application of orthoses.

Objectives

1) To be familiar with the definitions of foot orthoses, including custom foot orthoses, and prefabricated foot orthoses.

2) To know the theories and their corresponding therapies for foot orthoses.

3) To know the findings of the current literature on the effectiveness of foot orthoses in controlling excessive pronation.

4) To know the different types of materials used in the construction of foot orthoses.

5) To be aware of the necessary information required by the orthotic laboratory when writing a prescription for custom foot orthoses.

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Following this article, an answer sheet and full set of instructions are provided (p. 118).—Editor

By Steven J. Levitz, DPM., and Ellen Sobel, DPM, Ph.D.

Introduction

In view of all of the many different orthotics laboratories and the great variety of different kinds of custom foot orthoses, it may sometimes seem difficult to determine the correct custom foot orthoses for a given orthopedic foot problem. A historical review of the theories and corresponding therapies may be helpful since many of the orthoses used today are fabricated partially from the previous theories of others (i.e., Whitman brace, Shaffer Plate). The authors will also discuss what the orthotic laboratory really needs to know to make the best possible foot orthosis for your patient. Also, since the basis of any foot orthosis is the biomaterials, we'll provide a review of the different materials used in the fabrication of foot orthoses. Finally, the most common orthotic modifications will be described.

Definitions

Orthosis means to straighten. There are orthoses for every part of *Continued on page 104*

the body from the head to the toe. An orthosis is named for the joints that it crosses. The type of orthosis used in podiatric orthopedics for arch support and cushioning for painful submetatarsal calluses is a foot orthosis (FO).

A custom-molded foot orthosis is made from a positive model of the individual's foot and made of suitable materials with regard to the individual's condition.¹ It can be accommodative or functional and is removable from the patient's footwear.

A functional foot orthosis limits pathologic pronation at the subtalar joint and leads the foot into an active phase and realigns the foot in relation to the supporting sur-

face, reestablishing a normal propulsive sequence.

An accommodative foot orthosis increases the weightbearing area of the foot by bringing the supporting surface up to the foot, thus improving weight distribution and alleviating symptomatology. In general, the more subluxated, rigid, and deformed the foot has become, the more accommodative in nature the orthoses to be prescribed. A prefabricated orthosis is formed to a stock positive or last. It can be ordered in various sizes, shapes, and materials. These devices have been used by the general public and by doctors for their patients since the 1880's. Although it can surely be said that prefabricated orthoses are not custom orthoses by definition, gray

areas exist in which a prefabricated orthosis can be made into a custom device. A prefabricated foamed polyethylene or prefabricated thermoplastic device can be either heat molded directly to a foot or heat molded to a positive cast of a foot, thus producing a custom made orthosis. Postings, extensions, metatarsal raises, and accommodations can all be incorporated into prefabricated devices, making these orthoses therapeutically viable.

When Ordering a Foot Orthosis

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to be prescribed.

When ordering a foot orthosis, there is certain information that the laboratory needs to know.² Knowing the patient's gender allows the lab to properly shape the width and length of the orthotic extension. The weight of the patient is important because light weight or obese patients might need stronger or more flexible orthotic shells based on their weight and the amount of control required. The symptoms and diagnosis should be included. Manufacturing techniques and accommodations will vary with the diagnosis of the patient. In order for the lab to minimize the sources of error associated with shoe fit, the lab should know the type of shoes to be worn with the orthosis and the patient's shoe size. Previous foot orthoses should be noted. If the patient is currently wearing foot orthoses and is satisfied with them, you should not change the prescription. The general rule is that if you make new orthoses for someone who is happy with his old ones, do not change materials, shape, size or sometimes even color.

Foot type, flexibility of the foot and the relaxed calcaneal stance position are important. In most cases the doctor will specify the amount of posting required based on neutral position measurements. When this is not specified, the rearfoot is posted 3-4° varus extrinsically with a rubberized material. The forefoot/rearfoot relationship is evaluated and in most cases corrected in the positive cast to be perpendicular to the heel bisection. Finally, relevant medical conditions such as neuromuscular diseases, previous lower extremity injuries, previous orthopedic surgeries and gait abnormalities may be relevant. Limb-length discrepancies are commonly addressed with orthoses. A general rule to follow is to not exceed 1/8 inch lift in a stylish shoe and 1/4 inch lift in athletic shoes to assure that the orthotic will fit the shoe.

Theories

In 1889, Royal Whitman³ theorized that weakness and imbalance of the associated musculature was the causative factor for the abundance of hyperpronated *Continued on page 105*

feet, which he classified as strained foot, weak foot, and flat foot. Whitman (Whitman, 1917) developed a foot brace made of steel that forced the foot into an exaggerated supinated position. This steel orthosis was fabricated from an off weight bearing supinated plaster cast of the foot. The plaster positive served as the last to construct the orthosis, with the device having a high medial flange, which plantarly extended beneath the plantar anterior tubercle of the heel, connecting to a lateral clip just posterior to the base of the fifth metatarsal. This brace did not have a heel cup.

O. F. Schuster stated "that the Whitman brace functioned by its "element of suggestiveness" where the high medial flange would abut against the navicular, forcing the foot to supinate". This was not the concept that Whitman had developed the brace upon; but since O. Schuster was Dr. Whitman's bracemaker at the time of the development of the brace and for years after, his opinions and more importantly observations were deemed valid. Whitman believed that by instituting a corrective gait pattern, the tibialis posterior muscle would strengthen and the plantar medial ligaments would shorten, *therefore correcting foot structure and function*.

In 1912 P.W. Roberts⁴ developed a brace based on the principle that the calcaneus could be tilted over its inferior surface into an inverted position and held in this position using a small metal brace with a tilted and inverted *heel cup*, as well as medial and lateral clips. The Whitman and Roberts orthoses were considered the only corrective and functional orthoses in their time.

The Roberts-Whitman device was developed by Dr. Otto F. Schuster⁴ by combining the Whitman principle with the deep and inverted heel cup of the Roberts device. This Roberts-Whitman device was much more tolerable to wear because the medial flange and high arch were lowered in favor of the deep heel cup, which was inverted to give medial correction to the heel. Prior to the 1940's the basis of the functional foot orthosis was to control the rearfoot to prevent the pathologic pronation of the foot and the resultant compensatory deformities.

Dudley Morton^{5,6} actually originated the concept of the hypermobile first ray. Morton viewed the normal human foot as a tripod, bearing weight on the heel, the first metatarsal, and the fifth metatarsal. Observing and dissecting the feet of gorillas and chimpanzees, Morton became fascinated by the apposable hallux and short flexible first ray. He then theorized that a human foot with a short and hypermobile first ray, as the gorilla foot was structured, was an atavistic (retention from a previous ancestor) trait which could be found in most feet. This atavistic foot could not bear Continued on page 106

weight evenly and would therefore pronate pathologically. Morton's etiology for this pathologic pronation was the atavistic hypermobile and short first ray, and not that of weakness of associated foot and leg musculature as was previously thought. Morton advocated a compensating insole to functionally stabilize and lengthen the first ray. This became incorporated with modifications into the podiatric foot orthoses of the 1940's as the Morton's "Extension".

Morton's theory resulted in emphasis on forefoot imbalance as the etiology of all foot ailments. Schreiber and Weinerman⁷ in 1948 proposed that in order to functionally treat the foot, the *forefoot must* be balanced. Their concept was that an inverted or everted forefoot (with respect to the rearfoot) was the primary osseous deformity and that the position of the forefoot must be accurately measured and precisely balanced to restore normal function of the foot. Medial imbalance was defined as an inverted forefoot and lateral imbalance was defined as an everted forefoot (both with respect to the rearfoot).

The rearfoot was aligned perpendicular to the leg for the measurement of the degree of forefoot imbalance or deviation. This was one of the first examples in biomechanical literature pertaining to the foot, where a so-called deformity was measured and then treated using this clinical measurement. The forefoot balancing of Schreiber and Weinerman in the late 1940's was resurrected 10 years later with forefoot varus and valgus posting by Merton Root.⁸

Also in the 1940's, Allen E. Murray⁴ developed a method of producing a plaster cast of a foot with the intent to custom design ice skates. Unfortunately, his one piece steel skate was not approved by the Olympic Ice Skating Committee. He subsequently developed an unusual shoe that was directly molded to the plaster cast of the semi-weight bearing foot, and this was termed the Murray "Space Shoe." Podiatrists worked with this idea and modified it for the benefit of patients having severely deformed feet and for use in cases of children having cerebral palsy. Murray thought that everyone should have a pair of his shoes, which were made by him to the end of the digital nails. According to Murray, extra room distal to the toes was detrimental to foot function.

In 1950, Ben Levy,³ interested in the molded shoe concept of Murray, developed a technique for making the inner sole of the molded shoe separately, so that it could be worn in regular shoes. The Levy mold was thus developed with the intent to increase the weight-bearing surface area of the foot by incorporating a toe crest in order to induce a tonic exercise to facilitate lesser digital motion for digital purchase; therefore, according to Levy, strengthening the intrinsic muscles around the lesser MPJ'S. This sulcus-length de-

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vice was fabricated out of multiple layers of latex with a thin leather cover. This was achieved with the use of a semi-weight or full weight bearing cast of the patient's foot. The Levy mold could be balanced within the forefoot according to the imbalance theory that was prevalent at the time. This orthosis was later modified by Richard O. Schuster in 1950, using latex mixed with a filler of cork and leather, with the orthosis covered with thick leather acting as the main body of the orthosis.

The Root Functional Foot Orthosis

In 1958 Merton Root⁸ developed theories of functional biomechanics that revolutionized the field of podiatric mechanical therapy. Root stated that a *functional foot orthosis could only* be fabricated from a cast of an off-weight bearing foot with the subtalar joint held in his neutral position, and the forefoot pronated and locked on the rearfoot. With the attitude of the foot captured in the cast, a specifically balanced (posted) orthosis could be constructed. Root advocated varus forefoot posting for a forefoot varus deformity and valgus forefoot posting for a forefoot valgus deformity. Root advocated rearfoot varus posting to the degree of varus attitude of the calcaneus in relation to the lower third of the leg when the subtalar joint was in his neutral position.

All of Root's original devices were modifications of the Levy mold, but he found that these devices required constant re-adjustments and would eventually mold to the foot. Root then used various acrylic thermoplastics which all fatigued and cracked except for a German thermoplastic material known as Rohadur, which he deemed suitable for making his functional orthoses without the problem of the material fatiguing.

The Root Functional Foot Orthosis originally was designed to place the foot in what Root considered its most functional position, decrease the amount and rate of subtalar joint pronation, control function of the midtarsal joint, and support compensatory osseous deformities of the forefoot.

The patient must be casted offweight bearing in the Root subtalar joint neutral position. The Root Functional Foot Orthosis consists of a thermoplastic shell made of polypropylene, polyethylene, acrylic, or composite materials. Angular posts added to the plantar aspect of the shell maintain the position of the rearfoot around the subtalar joint neutral position and support compensatory deformities of the forefoot. The Root Functional Foot Orthosis may be made with a shallow or deep heel seat. Even though Root's theory can be criticized on numerous points,⁹⁻¹³ it has to stand on itself as a major advancement in the diagnosis and treatment of pathomechanics.

Jack Silverman¹⁴ in the 1950's developed the Heel Stabilizer, which was contrary to some of the Root theory. Silverman's heel stabilizer *Continued on page 108*



directed his stabilization posteriorly to the rearfoot in order to control the pronating foot.

In summary, biomechanical theory has been directed at the rearfoot, the forefoot, and the midfoot as the primary deformities leading to pathologic function. These deformities have been characterized as congenital or atavistic in nature, and it is these theoretical congenital or atavistic deformities that cause

pathologic compensation leading to secondary deformity with the foot.

Results of Current Research

What does the recent research show about the effect of foot or-*Continued on page 109*

TABLE 1: PRESCRIBING FOOT ORTHOSES— WHAT THE LAB NEEDS TO KNOW

(Adapted from Levitz S: What the Orthotics Lab Really Needs to Know. Podiatry Management, Sept. 1996, pp. 51-57.)

INFORMATION	RATIONALE
Patient's Name	
Gender extension	Allows the lab to properly shape the width and length of the orthotic
Patient's Weight	Lightweight or obese patients might need stronger or more flexible materials based on their weight and the amount of control required.
Patient age	
Activity level	
Diagnosis including symptoms	Diagnosis relates to both product selection or material choice. Manufacturing techniques and accommodations will vary based on diagnosis.
Shoes to be worn with orthoses and shoe size	The lab wants to minimize the source of error associated with shoe fit. If the sock liner of the shoe is traced and sent to the lab a full length orthosis can be made to fit the shoe.
Previous orthosis use satisfactory	If the previous orthoses are currently worn by the patient and are satisfactory, they should probably simply be duplicated.
Previous orthosis use unsatisfactory	Old orthotics may have been uncomfortable because they were too hard, soft, thick, high, wide, narrow, flat, flexible, etc.
Foot type/cavus/planus/average	This will effect the cast corrections the lab makes and the flexibility of the materials used.
Foot flexibility/rigid/flexible/average	The flexibility of the foot determines the degree and durometer of the posting, use of accommodations such as flanges, deep heel cups, etc. This also affects cast corrections and flexibility of materials used.
Relaxed calcaneal stance position/varus/ valgus/straight	This information acts as a double check, because the lab cannot tell range of motion in the cast.
Other conditions such as neuromuscular disease, previous hip, back, knee surgery, etc.	
Limb length discrepancy	This is important to know because the Limb length discrepancy may be accommodated for in the orthosis. A general rule is to not exceed 1/8 inch lift in a stylish shoe and not to exceed 1/4 inch lift in an athletic shoe.

thoses in reducing excessive pronation? In several studies subjects running with semi-rigid orthoses in their shoes demonstrated significant decreases in maximal pronation as compared with subjects running with shoes alone.¹⁵⁻¹⁸ Rigid orthoses and orthoses inverted 25 degrees also reduced pronation in runners.¹⁹ Maximal pronation during walking has also been reported to decrease in subjects ambulating in shoes with orthoses when compared with the same subjects ambulating in shoes alone.^{16,20,21} By contrast, others found that pronation was not significantly reduced in runners by a functional polypropylene foot orthosis.²² There was no significant difference in reduction in rearfoot pronation in patients wearing Spenco[™] inserts versus custom foot orthoses²³ nor between casted foot orthoses and Vitrolene[™] over-the-counter arch supports.²⁴ Rearfoot orthotic devices were found to reduce vertical and anteroposterior ground-reaction forces during ambulation, but not mediolateral ground reactive force, which the authors felt was contrary to current hypotheses about the use of orthotic devices.25

Orthotic Device Modifications

A post is a wedge that is added beneath the exterior surface of the orthotic shell (extrinsic post). The post may be made by making modifications to the shape of the positive impression, altering the shell itself (intrinsic posting).

Rearfoot Varus Post

A rearfoot varus post is an added wedge under the medial heel of the orthotic shell. The thickness or apex of the post is under the medial side. The rearfoot varus post is the most common type of posting added to the functional foot orthosis. The indications are for a flexible pronated foot type to prevent subtalar joint pronation and to hold the rearfoot in a more inverted position. The rearfoot varus post may be an extrinsic post, which is most commonly directly added to the shell of the orthosis, or it may be an intrinsic post, which is built into the shell of the orthosis. Generally, the rearfoot varus post is no greater than 4°.

A rearfoot varus post has frequently been added to a functional foot orthosis in order to allow normal but not excessive subtalar joint pronation during the contact phase of gait.²⁶ Empirically, the effect of adding a rearfoot post to the functional foot orthosis is variable. In one study a semi-rigid total contact foot orthosis reduced forefoot vertical forces; however, adding a 6 degree rearfoot varus post had no effect on the results.²⁷ The orthosis in this study was made of Aliplast XPE[™] (Alimed, Inc., Dedham, MA).²⁷ Rearfoot posts made of methylmethacrylate (rigid) and Birko cork (compressible) were found to decrease initial pronation velocity in runners, which is associated with lower extremity injuries.²⁸ However, there were no differences in controlling pronation between the rigid posting material and the compressible posting material. In another study combined posting of the Continued on page 110



forefoot and rearfoot or rearfoot posting alone controlled abnormal pronation better than forefoot posting in subjects during ambulation.²⁹ Finally, Tollafield and Pratt³⁰ found that *externally posting the rearfoot more than four degrees actually increased pronation, as the foot rotates on the device.*

Forefoot Varus Post

A forefoot varus post is an added wedge under the medial forefoot of the orthotic shell (Table 1). The thickness or apex of the post is under the medial side of the forefoot. The forefoot varus post can be used with a rearfoot varus post according to prescription. The forefoot varus post supports a compensatory rigid forefoot supinatus deformity.

Forefoot Valgus Post

A forefoot valgus post is an added wedge under the lateral forefoot of the orthotic shell (Table 1). The thickness or apex of the post is under the lateral side of the forefoot. A forefoot valgus post should pronate a flexible foot and stabilize a rigid cavo varus foot.

Rearfoot Valgus Post

A rearfoot valgus post is an added wedge under the lateral rearfoot of the orthotic shell (Table 1). The thickness or apex of the post is under the lateral side of the rearfoot. This type of post is the least commonly used as it will increase subtalar joint pronation. Indications for the rearfoot valgus post include prevention of ankle sprains and to accommodate a rigid equinovarus deformity such as occurs in certain neuromuscular diseases.

Zero Degree Post

The zero degree post can be prescribed when no observable varus or valgus of the rearfoot is observed.

Bar Post

A bar post is a flat forefoot post that may effectively decrease pressure on the metatarsal heads by supporting the metatarsal necks. It is common to request a 2-5 bar post when treating symptomatology associated with a plantarflexed first ray.

Biplanar Grind

The biplanar grind is a grind down wedge on the distal medial portion of the extrinsic rearfoot post which *theoretically* maintains ideal osseous alignment through the unaltered rearfoot post, but allows the rearfoot to pronate the necessary 4° for shock absorption during the contact phase of gait.

Deep Heel Seat

The heel cup height is the vertical distance between the heel contact point of the positive cast and the circumscription line of the heel cup on the positive representation of the foot. Most FO labs have a default of 12 mm's for heel depth but an increased depth can be prescribed. A deep heel seat, especially a high medial heel cup is used to *Continued on page 111*

limit excessive subtalar joint pronation as manifested by eversion of the calcaneus.

Calcaneal Inclination Angle (Calcaneal Pitch)

The calcaneal pitch involves removing 1/4 inch to 1/2 inch of material from the plaster positive and then forming the shell to this contour. The calcaneal inclination angle (calcaneal pitch) is used to theoretically control sagittal plane motion at the midtarsal joint by supporting the anterior process of the calcaneus.

Lateral Flange

The lateral flange is an increase in the height of the orthosis on the lateral side of the rearfoot starting lateral to the heel and continuing distally at viable length usually not beyond the 5th metatarsal head. The height is variable but no higher than inferior to the lateral malleolus. Indications for a lateral flange are for prevention of ankle sprains, to prevent lateral slide off of the foot, and to control and support rigid rearfoot varus deformity such as in clubfoot. In general, when the rearfoot varus post; however, if the rearfoot varus deformity is rigid, such as in clubfoot or the long-standing equinovarus deformity of neuromuscular disease, a lateral flange might control the rigid varus deformity of the rearfoot.

Lateral Clip

The lateral clip is an increase in the height of the orthosis on the lateral aspect of the foot starting proximal and lateral to the center of the heel and ending distally at the proximal aspect of the 5th metatarsal base. The height is variable, but should be no higher than the inferior surface of the lateral malleolus. Indications are the same as for a lateral flange.

Medial Flange

The medial flange is an increase in the height of the orthosis on the medial side of the foot starting medial to the heel and extending distally with increasing height with the apex near or above the navicular and then decreasing in height to end along the first metatarsal shaft. Indications for the medial flange are for control of severe pronation, whether rigid or flexible, and to accommodate for such symptomatic conditions as os tibiale or hypertrophic navicular with a scalloping or other type of accommodation. To tolerate a medial rearfoot post, there must be some flexibility to the foot with a range of motion; however, a rigid rearfoot valgus deformity such as occurs in endstage flatfoot disorders with no range of motion may be controlled somewhat with a high medial flange.

Toe Crest

A toe crest may be used to treat hammer and claw toes. By supporting the central portions of the 2nd through 4th digits, toe crests function to reduce pressure beneath the metatarsal heads and distal toes by distributing pressure over a larger surface area. Also, because toe crests effectively stabilize the distal phalanges, their addition theoretically might improve the propulsive period function of the flexor digitorum longus, which does not function properly (flexor stabilization) when digital contractures are present.

First Metatarsal Head Cutout

This is complete removal of the orthotic shell under the first metatarsal head. Indications for the first *Continued on page 112*



metatarsal head cutout include: sesamoiditis, forefoot valgus deformity, and hallux limitus with dorsal osteophytic formation.

Kinetic Wedge[™]

The Kinetic Wedge, created by Dr. Howard Dananberg, is a cutout under the first metatarsal head replaced with lower durometer material. The shape of the cutout with a wide medially shaped wedge is angled to the 1st ray axis. The kinetic wedge[™] is indicated to promote plantarflexion and eversion of the first ray for functional hallux limitus.

Morton's Extension

Material is added under the orthotic shell extending through the first ray and crossing the first metatarsophalangeal joint to immobilize the joint. Indications for a Morton's Extension modification are for a painful hallux limitus/rigidus for splinting and immobilization. See Table 1 for summary of foot orthoses modifications.

Cuboid Pad

A cuboid pad is a small pad placed directly beneath the cuboid, used with prefabricated orthotics to accommodate plantarflexed 4th or 5th rays. Some orthotic companies put a cuboid pad on all orthotics claiming that it supports the "lateral arch."

Metatarsal pad

This pad is placed proximal to the 2nd, 3rd, and 4th metatarsal heads in order to reduce pressure from these structures.

Neuroma Pad

This small heart-shaped pad is placed either under the 4th or 3rd metatarsal head or within the third interspace to theoretically reduce the compression on the common and/or proper digital nerves affected.

Orthotic Materials³¹

Acrylics (Polydor^m) are polymerized from methylmethacrylate polymers. These are stiff, dense, tough materials. Acrylic shells are commonly 3-5 mm thick.

Carbon graphite orthotic devices

are fabricated by laminating very thin sheets of carbon graphite fiber cloths using a liquid resin. The number of laminations varies depending on the strength desired, but for most podiatric applications, the shell is approximately 2 mm in thickness. This produces a thin rigid shell that is appreciably thinner than other thermoplastic orthoses. Carbon graphite has been used in combination with other materials such as fiberglass since the 1970's.

Composites are combinations of different plastics into one form. A composite of carbon fiber and acrylic, called Carboplast,^M is a popular combination used in foot orthosis shells. Combining acrylic plastic with carbon fibers creates a plastic sheet as rigid as acrylic and polypropylene, but with only half the thickness. TL-61^M is a composite

All of Root's original devices were modifications of the Levy mold.

material consisting of two carbon graphite layers with an acrylic core, with the core being 1 mm thick and lending the material a thermoplastic property. This composite was improved with the production of TL- 2100^{M} and TL Blue^M.

Thermoplastics

Thermoplastics are heat-moldable and soften as they are heated and harden each time they are cooled. Polypropylene thermoplastic is the most common materials composing the shell of the rigid foot orthosis. Polypropylene is a thermoplastic polymer with low specific gravity and good resistance to chemicals and fatigue. The polymer structure gives polypropylene high stiffness and good tensile strength.

Polyethylene thermoplastic is also a common material used for the shell of a semi-rigid to rigid foot orthosis. Polyethylene thermoplastics possess the properties of toughness and flexibility with good dimensional stability, are heat moldable and lightweight, and possess favorable weight/strength ratios. They are generally classified as being of low, medium, high, or ultra-high density.

The high density polyethylene thermoplastics (Ortholen[™], Vitrathene[™]), are generally used where a rigid weightbearing support system is required; however, they may fatigue when subjected to repeated stresses. A tendency to crack may increase when they are repeatedly exposed to active compounds such as alcohol, strong soaps, or hydrocarbons, and should not be placed in environments where temperatures reach 100° Celsius or more.

Leather

Leather is animal skin used in the fabrication of foot orthoses. Leather foot orthoses can be functional or accommodative depending on material combinations and casting techniques. The shell of a leather orthosis consists of adding layers of leather to one another to form a lamination that can be shaped to a positive cast of the patient's foot or molded to the foot directly. The advantages of leather devices include the fact that leather conforms to foot contours and prominences and is well tolerated by most patients. Disadvantages include breakdown by very active patients or patients that have hyperhidrotic feet.

Rubber

Rubber is a natural elastic substance produced from the milky sap (latex) of rubber trees. Rubber is tough, resilient, and a high shock absorber. Natural rubber is chemically described as 1,3 cis-butadiene. In 1835, Charles Goodyear developed a process known as vulcanization in which sulfur was added to the natural latex under pressure and heat, thus producing the cross-linking of monomers via sulfur bridging. Vulcanized rubber is resistant to oil and has a different density and consistency as compared with natural rubber. Rubber was eventually made synthetically. The three classes of rubbers are expanded, sponge, and latex. Elastometrics are synthetic rubber-like materials, and among Continued on page 114



them ethylvinyl acetate (EVA) is commonly used for foot orthoses. EVA is a hollow material which creates an internal network of air cells used to construct insoles of low to high durometer. Toprelle^M is a hybrid of rubber and thermoplastic which makes a lightweight, relatively flexible orthotic shell.

Both the natural and synthetic rubbers can be made into rubber foams by either the use of chemical additives or the injection of air. These rubber foams can be of either the closed-cell or open-cell variety with the closed-cell being more durable and costly. Open-cell foams have air chambers that communicate both with each other and the material's surface, thus allowing for evaporation and heat dissipation. Closed-cell foams are made with air chambers that do not communicate with each other or the material's surface, thus acting as an insulator, retaining heat and moisture.

Closed-Cell Expanded Rubber (Spenco[™])

Closed-cell expanded rubber, or Spenco,^m is manufactured by the introduction of nitrogen gas under pressure to the rubber mix. External pressure is lowered, allowing absorbed gas to expand and form thousands of individual closed cells. Spenco^m has a nylon top cover and is a very common flexible insole material.

Open-Cell Sponge Rubber (Lynco[™])

Open-cell sponge rubber $(Lynco^{\mathbb{M}})$ is formed by mixing a blowing agent into a rubber compound. Gas is liberated during the vulcanization process, forming open cellular structures. It is clinically used as Spenco^{\mathbb{M}} would be.

Rubber Butter

This is a generic substance formulated by mixing liquid latex with either cork, wood, or leather shavings, each producing a slightly different material. The concentrations of each component can be altered to yield various consistencies. Rubber butter, composed of latex and leather grindings, has more shock attenuation than the latex and cork mixtures; however, because of the leather content, this rubber butter is susceptible to breakdown over time.

Pre-made materials in sheet form being similar to rubber butter are manufactured by several companies, and are available under various trade names.

Cushion Cork[™] is a latex and cork combination available in sheets that are supplied in thicknesses measuring 1/8, 1/4, and 1/2 inch, and commonly used by the podiatric profession for wedges and lifts. This rubberized cork makes the cork more flexible, reducing cracking and adding additional shock absorption.

Korex[™] is a cork latex mixture manufactured by Armstrong. Orthocork[™] consists of a cork and latex mixture that has a very high cork content, making this a very lightweight product that does not

Leather foot orthoses can be functional or accommodative.

compress easily.

Thermocork[™] is the only heat moldable product in this group. Thermocork[™] original and the newer Thermocork Lite[™] are very popular in the foot orthotics laboratories for fabrication and adjustments.

Polyethylene Foams

Polyethylene thermoplastic foams (plastazote[™]) are heat moldable closed cell foams, making them good insulators. Orthotic shells may be fabricated using polyethylene foams, either singularly or in combination, by lamination of different densities. Due to the variety of materials in this category, orthoses manufactured with PE foams can be constructed as extremely rigid devices, semi-rigid, or very flexible. After heating briefly, the foams may be laminated onto a positive cast or molded directly to the patient's foot.

Adding layers may be accomplished by heating and applying contact cement between the layers. PE foam orthoses may be modified by the addition of other materials, posting, and/or covering, and although these devices are quite versatile, they are not as durable (with the exception of Plastazote[™] firm 69 durometer) as some of the other categories of orthotic materials. PE foams are manufactured under different trade names and each product is supplied by its own company's system of naming or numbering the various durometers available.

Plastazote[™] was first used by American podiatrists in 1969, after Dr. Paul Brand found it to be successful for limb preservation in leprosy patients. Plastazote[™] is heat moldable at 140° Fahrenheit, and is self-accommodating to lesions and bony prominences as well as being very light weight. Plastazote[™] is typically available in thicknesses measuring 1/8, 1/4, and 1/2 inch. Plasta $zote^{M}$ is available in three densities. The medium (pink) and firm (white) durometers of Plastazote[™] are commonly used for accommodative and dynamic inlays, while the rigid (black) durometer is used for a semifunctional orthotic device. A disadvantage of Plastazote[™] is that it is a poor shock absorber.

Evazote is a polyethylene foam manufactured by Bakalite Xylonite LTD (BXL) available in one density only, which is very self-accommodating and lightweight.

Pelite is another PE foam manufactured by BXL and is commonly used as a liner for prosthetics; it is available in four durometers.

Aliplast is a PE foam comparable to Plastazote, but manufactured by the Alimed Corporation and supplied in four durometers. While comparable to Plastazote[™], the rigid density of Aliplast[™], namely the XPE, is heavier than the rigid durometer of Plastazote.

Felt (Orthofelt^{\times}, Hapads^{\times}, Platform felt) is a fabric made of wool fibers matted together by steam and pressure. Adhesive-backed, pre-cut felt can be used as heel, arch, metatarsal, and callus pads which can be placed directly on the foot or into the shoe or directly onto the foot orthosis.

Viscoelastic polymers made from polyurethane elastomers create *Continued on page 116*

rubber-like insoles, heel pads, and foot orthoses. They are rather heavy in general and difficult to grind. The SofSpot Viscoheel[™] (Bauerfeind USA, Inc, Atlanta, GA) is a silicone polymer heel cushion which has a builtin area of softer durometer specially designed to disperse weight around the plantar medial tubercle of the calcaneus, the site of inflammation in plantar fasciitis. Viscoelastic heel pads have been reported to reduce the impact of heel strike on the leg and low back by as much as 40% percent. The Tuli[™] heel cup (Tuli International Comfort Products, San Marcos, CA) is a soft rubber heel cushion with trademark waffling. Sorbothane, which has been used extensively for over two decades, is another well-known shock-absorbing material used in foot orthoses.

Polyurethane foam (Poron[®] and PPT[™]) are open-cell polyurethane foams which are not heat moldable. Both are commonly used as soft shock-absorbing insoles and as a soft cover over the rigid shell of the functional foot orthosis. The Rogers Company of Connecticut developed a special polyurethane foam through its Poron[™] Division, and thus named the foam Poron[™], which is distributed by Rogers as medical grade Poron[™]. Poron[™] is a combination of polyether and polyester resins. PPT[™] is available in one durometer only, with thicknesses available measuring 1/16, 1/8, and 1/4 inches. The 1/8 inch thickness is also available with a nylon top cover. Being an open-cell foam, PPT[™] dissipates heat well, and because of its retention of memory, it is a good shock attenuator, as well as being durable and easy to skive on a grinding wheel. Due to the recent purchase of Benefoot by Langer the usage of PPT[™] vs. medical grade Poron[™] will most probably swing to PPT[™] since Langer[™] owns the trademark and has it produced by a company other than Rogers.

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1) The foot orthosis made of steel from an off weight bearing supinated plaster cast with a high medial flange and a lateral clip just proximal to the fifth metatarsal head is the:

A) Shaffer plate

- B) Root functional foot orthosis
- C) Whitman brace D) Levy mold

2) The accommodative latex sulcus length orthosis which incorporates a toe crest and is casted semiweight or full bearing is known as the:

- A) Shaffer plate
- B) Root functional foot orthosis
- C) Whitman brace
- D) Levy mold

3) Which of the following is not necessary when fabricating a **Root Functional Foot Orthosis?**

A) The foot must be offweight bearing B) The subtalar joint must be held in its neutral position C) The forefoot is pronated and locked on the rearfoot D) There must be a deep heel seat

4) Biomechanical theory has been directed at the rearfoot, the forefoot, and the midfoot as the primary deformities leading to pathologic function.

- A) True
- B) False

5) What are the findings of studies on the effectiveness of foot orthoses reducing excessive pronation?

A) Excessive pronation is reduced wearing foot orthoses when walking, but not when running.

B) Excessive pronation is reduced wearing foot orthoses See answer sheet on page 119.

when running, but not when walking.

C) Excessive pronation is not reduced by foot orthoses. D) Some studies show that excessive pronation is reduced when walking and running and some studies show that excessive pronation is not reduced.

6) Which best describes the findings of studies on the effectiveness of posting foot orthoses?

A) Rearfoot varus posting has consistently demonstrated increased effectiveness in reducing excessive pronation as compared to non-posted foot orthoses.

B) Rearfoot varus posting has been shown to be ineffective in controlling pronation C) Results of rearfoot posting are inconclusive since they are

so variable

D) Rearfoot posting increases pronation

7) The advantages of composites of acrylic plastic with carbon fibers are:

A) Rigid but thin shell

- B) Soft lightweight shell
- C) Porous firm shell
- D) Stiff but flexible shell

8) A hybrid of rubber and thermoplastic is known as:

- A) Polydor[™]
- B) Carboplast[™]
- C) Toprelle[™]
- D) EVA

The popular product Spenco[™] used as a top cover in both custom and prefabricated foot orthoses, consists of:

A) Closed-cell polyurethane foam

B) Closed-cell rubber made by the introduction of nitrogen gas

C) Polyethylene foam D) Open-cell polyurethane foam

10) Poron[™] and PPT[™], which are extensively used in foot orthoses, are actually:

A) Closed-cell polyurethane foam

B) Closed-cell rubber made by the introduction of nitrogen gas

C) Polyethylene foam D) Open-cell polyurethane foam

11) As compared to an extrinsic post, intrinsic posting is made by:

A) Modifying the positive cast B) Modifying the negative cast C) Placing the post directly on the orthotic shell D) None of these

12) Your patient has metatarsalgia and you want to add a post that may effectively decrease pressure on the metatarsal heads by supporting the metatarsal necks. You should order:

- A) Metatarsal pad
- B) Flat post
- C) Bar post
- D) Forefoot valgus post

13) An orthotic modification used to control sagittal plane motion at the midtarsal joint by supporting the head of the calcaneus is the:

- A) Lateral flange
- B) Plantar fascial groove
- C) Calcaneal pitch
- D) Bar post

14) Your patient has a limb length discrepancy and wants to wear a stylish shoe. What is the maximum lift that can go into the shoe?

- A) 1/6 inch
- B) 1/8 inch
- C) 1/4 inch
- D) 1/2 inch

Continued on page 118



15) Your patient with the limb-length discrepancy decides to be more realistic and wear a large athletic shoe. Approximately how much of a lift can now be placed in this shoe?

- A) 1/6 inch
- B) 1/8 inch
- C) 1/4 inch
- D) 1/2 inch

16) When writing a prescription for custom foot orthoses the LEAST important information to include would be:

- A) Patient's name
- B) Patient's weight
- C) Type of shoe in which the orthoses will be worn
- D) MRI's

17) Plastazote^{\mathbb{M}}, pelite^{\mathbb{M}}, evazote^{\mathbb{M}}, and aliplast^{\mathbb{M}}, used for soft accommodative insoles and foot orthoses, are all examples of:

- A) Polyethylene foams
- B) Polyethylene thermoplastics
- C) Polyurethane foams
- D) Synthetic rubber compounds

18) An orthotic adjustment used to create a "lateral arch" is a:

- A) Plantar fascial groove
- B) Lateral clip
- C) Lateral flange
- D) Cuboid pad

19) Which would be false pertaining to leather foot orthoses?

A) A leather foot orthosis is usually laminated B) A leather foot orthosis can be functional or accommodative

C) Leather is difficult to make adjustments on D) Leather breaks down easily in very obese individuals

- 20) Spenco[™], Lynco[™], EVA, are all forms of:
 - A) thermoplastics
 - B) rubber
 - C) polyurethane foams
 - D) composites

See answer sheet on page 119.

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