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Orthotic Management of the Arthritic Foot

by C. Michael Schuch, C.P.O.

With ever increasing public exposure, orthotists are being requested more frequently to confront new challenges caused by physical disability. In the spectrum of orthotic protocols, management of the arthritic foot and ankle is a relatively new challenge. During the past five years, the Department of Orthopaedics and Rehabilitation, the Division of Rheumatology, and the Division of Prosthetics and Orthotics, all of the University of Virginia Medical Center, have comprised an Arthritis Rehabilitation Research and Training Center, providing a regional referral center for arthritis patients. Orthotic services for these patients have concentrated on the foot and the ankle, and this population of patients has been substantial enough to permit the development of a consistently successful protocol of management. The intent of this paper is to review the skeletal anatomy of the ankle and foot, discuss the types of arthritis and their relative pathophysiology and clinical manifestations, and finally to present our protocol for management of the various problems presented by the arthritic foot and ankle.

Review of Ankle-Foot Anatomy

The skeleton of the foot consists of three groups of bones: tarsal bones, metatarsal bones, and phalanges. The tarsal bones are further divided into two groups, the first group consisting of the talus and the calcaneus, together forming the hindfoot. The talus, which is the only bone to articulate with the tibia and the fibula, acts as a rocker by which the foot as a unit can be dorsiflexed and plantarflexed at the hinge of the ankle joint. In stance, the talus receives the entire weight of the lower limb; half this weight is transmitted forward to the bones forming the arch of the foot, and half of the weight is transmitted downward to the heel or calcaneous. The calcaneus, or os calcis, is the bone of the heel. It supports the talus, withstands shock as the heel strikes the ground, and transfers forward the portion of body weight it receives from the talus.

The second group of tarsals consists of the five bones anterior to the talus and the calcaneus. The navicular, cuboid, and three cuneiforms increase flexibility of the foot, particularly in its twisting movements. These bones form the longitudinal arch of the foot, and are referred to collectively as the midfoot.

The five metatarsal bones lie anterior to and articulate with the second group of tarsal bones described above. Each metatarsal consists of a base, a shaft, and a head, in respective order from proximal to distal. The distal-most bones of the foot are the five phalanges, which extend from the five metatarsals and form the bones of the toes. The metatarsals and the phalanges form the forefoot.

The foot has three arches: the medial, lateral, and transverse. The normal medial arch rises through the calcaneous to the head of the talus, and from this high point it descends forward through the navicular, cuneiforms, and first three metatarsal heads. The lateral arch, which is lower than the medial, extends from the calcaneus to its high point at the cuboid, and down through the fourth and fifth metatarsals. The transverse arch rises across the width of the foot between the medial and lateral borders, primarily under the metatarsal shafts.

The junctions of these various groups of bones form the joints that allow the functional motions of the ankle and foot to occur. The talocrural (ankle) joint consists of the medial and lateral malleoli and the trochlear surface of the talus. This joint permits the motion of plantarflexion and dorsiflexion. The subtalar (talocalcaneal) joint is formed by the articulation of the talus and the calcaneus, and permits the heel to share in inversion and eversion. The transverse tarsal (midtarsal) joint is not an anatomic entity, but an important functional grouping of two joints which occur anterior to the talus. These two joints, the talocalcaneonavicular and the calcaneocuboid, permit much of the inversion-eversion of the foot. The other tarsal joints, tarsometatarsal joints, and distal joints aid in flexibility of the foot from heel strike through mid-stance, and help the foot form a rigid lever during toe-off, or the propulsion part of the gait cycle.

Each of the joints of the ankle and foot, including the joints between the sesamoids and the first metatarsal are lined with synovium so that when inflammatory conditions that affect the synovium are present, the foot and ankle may show dramatic changes clinically, radiographically, and pathologically.

Types and Pathophysiology of Arthritis

While there are a half dozen or more differing types of arthritis,[3] we will limit our discussion to the types that have a tendency to involve the foot and ankle. The most commonly seen and most debilitating form of arthritis is rheumatoid arthritis.

Rheumatoid Arthritis

Rheumatoid arthritis is an inflammatory condition of unknown etiology that primarily affects the synovial lining of joints, tendons, and bursae. Secondarily, it may cause destruction to cartilage, bone, ligaments, and other soft tissue. Most people with rheumatoid arthritis have some degree of foot and/or ankle involvement.[3] The joints of the feet are initially involved more often than the joints of the hands.[4] Vaino showed that more than 88% of adults and 69% of children with rheumatoid arthritis have involvement of the feet during some phase of the disease.[6]

Guerra states that the earliest sign of rheumatoid arthritis is congestion of the synovial membranes with edema.[2] As the synovial inflammatory tissue and fluid within the joint ac-

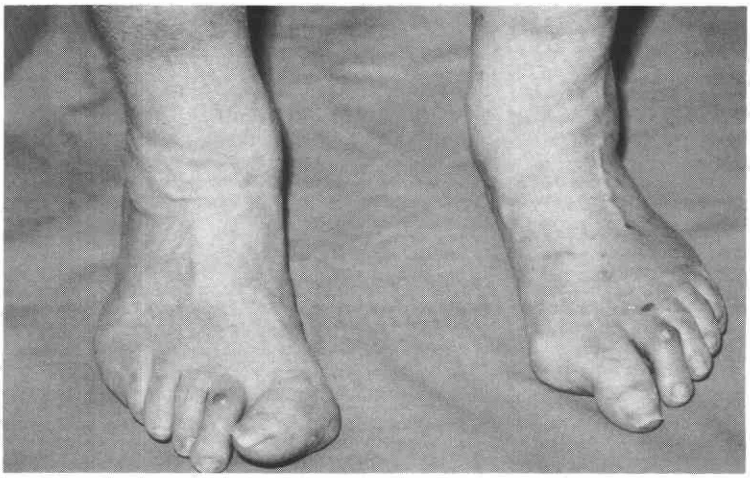

Figure 1. View of patient's feet afflicted with rheumatoid arthritis. Note, hallux valgus, claw toes, depressed longitudinal arch, and pronation or eversion at the subtalar joint.

cumulate, there is swelling of the soft tissue, and decreased range of motion of the joint. The inflamed synovium adjacent to the marginal bare areas causes destruction of bone, resulting in bony erosion at the margins. Because the inflamed synovium, known as the pannus, also proliferates, expansion occurs over the cartilage and destroys the cartilage through enzymatic action, producing symmetrical joint space narrowing. The pannus may also penetrate the unprotected bare bone and cause destruction of the cartilage from the marrow side. The reactive hyperemia, part of the inflammatory process, is implicated in the periarticular osteoporosis and the discontinuity of the subchondral bony plate.[2] Joint destruction and deformities occur and become fixed as the weakened support structure of the ankle and foot gives way to the normal mechanical stresses placed upon it; changes in alignment of joints allow muscles, tendons, and ligaments that cross the joints to exert different forces, and stiffness and pain in the joints prevent mobility.[3]

Clinical manifestations can include all joints of the ankle-foot, collectively or individually. Ankle involvement in rheumatoid arthritis is not as common as involvement of other joints of the foot.[5] The clinical picture of ankle involvement is less dramatic than with the other joints, with swelling, stiffness, decreased range of motion, and pain being the indicators. Unlike the ankle, the hindfoot is often affected early in rheumatoid arthritis. The most common deformity of the hindfoot is pes planovalgus, or more simply, valgus of the hindfoot and flattening of the longitudinal arches.[5] The midfoot-tarsal joints develop inflammatory changes that contribute to the pes planovalgus deformity of the hindfoot and midfoot.[5] In time, each of the tarsal bones seem to be equally involved, causing loss of pronation-supination and malleability of the foot in general. The forefoot shows marked abnormalities on clinical and radiologic examination. The altered forces created by hindfoot and midfoot deformities act with the inflammatory process, affecting the metatarsal-phalangeal (MTP) joints and proximal interphalangeal (PIP) joints to give the typical findings of hallux valgus, claw toes, subluxation and depression of the metatarsal-phalangeal joints, abduction of the forefoot, and splay foot. Involvement here as in other parts of the foot is symmetric and increases with disease duration.[5]

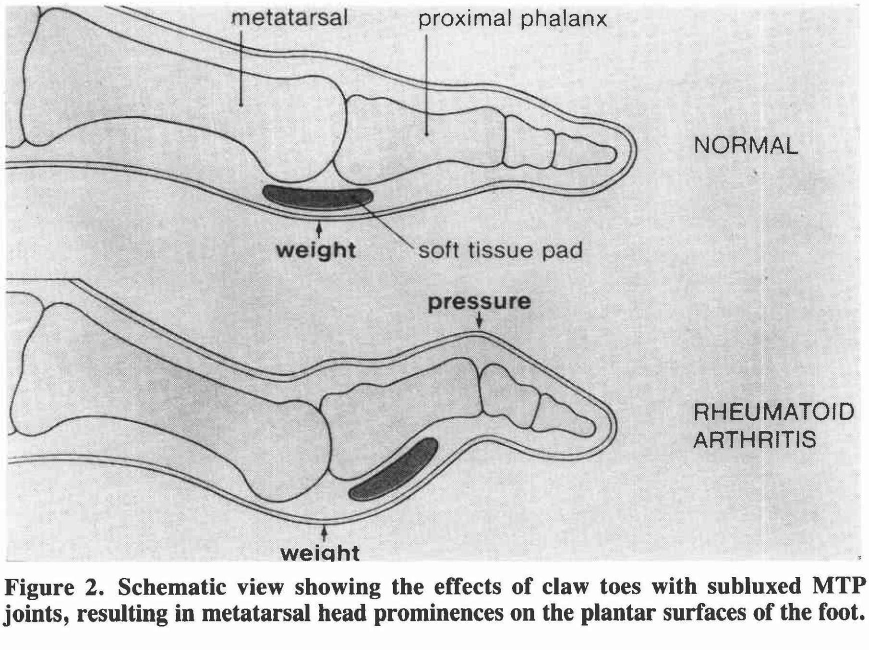

Figure 2. Schematic view showing the effects of claw toes with subluxed MTP joints, resulting in metatarsal head prominences on the plantar surfaces of the foot.

Osteoarthritis

The next most commonly seen type of arthritis to cause foot problems is osteoarthritis, or degenerative joint disease. This form of arthritis is not a systemic inflammatory disease; rather it is a disease that is secondary to the wear and tear phenomena on joints. Disruption of the cartilagenous matrix occurs as a result of enzymatic action. Large weight-bearing joints of the body are particularly prone to dysfunction. The ankle joint and the first MTP joint seem most susceptible, with weight bearing, trauma, and footwear having all been implicated as causative agents. Radiologic examination reveals asymmetric narrowing of the joint space, the areas of stress demonstrating less interosseous space.[2]

Other Arthritis Types

The arthritis patient population requiring foot orthotic management primarily falls into one of the above two categories of diagnosis. However, occasions will arise necessitating foot and or ankle management for patients with other arthritic diagnoses. The seronegative arthridities are ankylosing spondylitis, Reiter's syndrome and its variants, and psoriatic arthritis. Two additional types of arthritis that may affect the foot and/or ankle are gout and systemic lupus erythematosis. While differing in pathophysiology from rheumatoid arthritis and osteoarthritis enough to warrant separate diagnostic classification, the clinical manifestations of the ankle and foot are similar.

Orthotic Designs and Indications

As in all orthotic management, the scope of the problem dictates the complexity of the orthosis. We have been pleased with the simplicity of the decision making process that has been developed at the University of Virginia. Sophisticated evaluation processes are not necessary; patient communication concerning location of pain and routine physical examination of ankle-foot abnormalities are sufficient. Observation of gait irregularities usually reinforce communication/physical examination findings. Orthotic management conveniently falls into two levels of complexity: foot orthoses (FO's) and ankle-foot orthoses (AFO's).

Foot Orthoses

The objectives of foot orthoses for arthritic patients include, (1) maintainence and support of existing arches of the foot; (2) re-establishment of fallen arches when flexibility permits; (3) provision of inversion-eversion balance or stability; (4) distribution of weight bearing pressures; and (5) provision of soft tissue supplement.

The clinical picture requiring this level of orthotic management can range from mild longitudinal arch depression with callous formation under the metatarsal heads to severe loss of the longitudinal arches, medial drift of the talocalcaneonavicular joint complex, subluxation of MTP joints with depressed and protruding metatarsal heads, hallux valgus, and claw deformities of the phalanges. Traditional foot orthoses for this type of clinical picture have been Plastizote® inserts, molded directly to the patient's foot. However, Plastizote® is not durable; it packs down quickly with wear. The more severe the deformity, the quicker the material loses its integrity and ability to meet the objectives of foot orthoses as described above. Occasionally, arthritic patients have presented or reported being fit with rigid foot orthoses, fabricated of Nyloplex (Rohadur), usually provided by podiatrists. While this material selection and orthotic design are ideal for many cases, we have found it to be highly unsuccessful with arthritic patients to the point that we consider rigid foot orthotics contraindicated for this patient population. Our experience has shown that this type of orthosis lacks the flexibility and soft tissue supplement necessary to promote acceptance by patients with arthritis. The choice of materials and design for arthritic foot orthoses at the University of Virginia has been PVC-Pelite™ foot orthoses, molded over positive models of the patient's foot or feet.

Description of Technique

Negative impressions of the patient's feet are obtained using any of the commercially available foam impression blocks. This impression is taken with the patient seated, to capture the shape of the existing arches at their maximum height, free of weight-bearing loads. Care should be taken to balance inversion-eversion as the foot is pressed into the foam. Positive models are obtained in the conventional manner

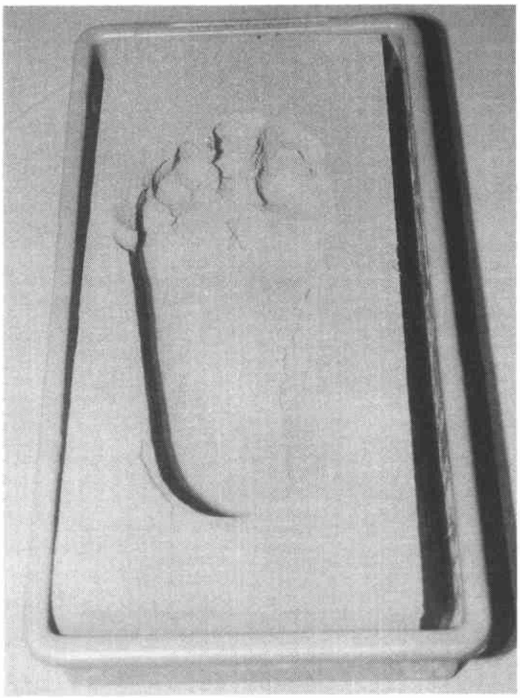

Figure 3. View showing left foot impression taken in foam foot impression block. Note "X" identifying metatarsal head prominence.

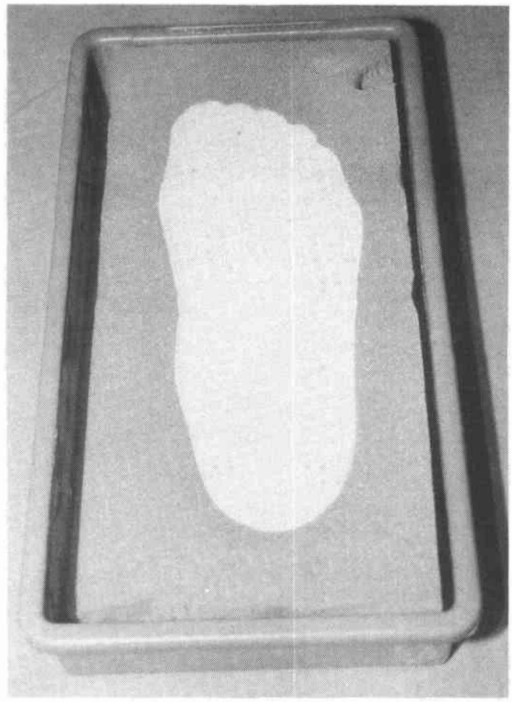

Figure 4. Foot impression filled with molding plaster forming a positive model of the patient's foot.

by pouring molding plaster into the impression forms. Modification of the positive model is necessary to meet the objectives of foot orthoses for arthritic patients as discussed above. The longitudinal arch is increased mildly, especially posteriorly, as proposed by Carlson, et al., in their technique for modification of the UCB foot orthosis.[1] This modification meets the objectives of maintenance and support of existing arches, provision of eversion or valgus stability, and distribution of weight bearing forces. The metatarsal or transverse arch modification is perhaps most important, and the degree of this modification in terms of size and depth parallels the severity of MTP subluxation and metatarsal head depression. It is frequently greater than ½″ in depth. The shape of this modification should simulate that of prefabricated rubber metatarsal pads, which are commercially available in varying sizes and depths. Proper placement of this modification is critical; when an existing transverse arch can be identified, it should be exaggerated. If there is no identifiable transverse arch, the modification for this arch in the positive model falls under the metatarsal shafts, with the dome or apex of the plaster removal just posterior to the metatarsal heads, and the proximal edges blending gradually into the longitudinal arches. This modification provides support to uplift the depressed metatarsal heads and reduce trauma at the push-off phase of the gait cycle. It also meets the objectives of maintenance and support of existing arches in some cases, re-establishment of fallen arches in other cases, and better distribution of weight-bearing loads. The final modification to the positive model includes adding plaster to the plantar aspect of the PIP joints of the phalanges, which aids in providing a smooth transition from the MTP to the phalangeal area of the foot orthosis.

The positive model is now complete and ready for molding of the base material, PVC Pelite™, which is available in 4′ square sheets,

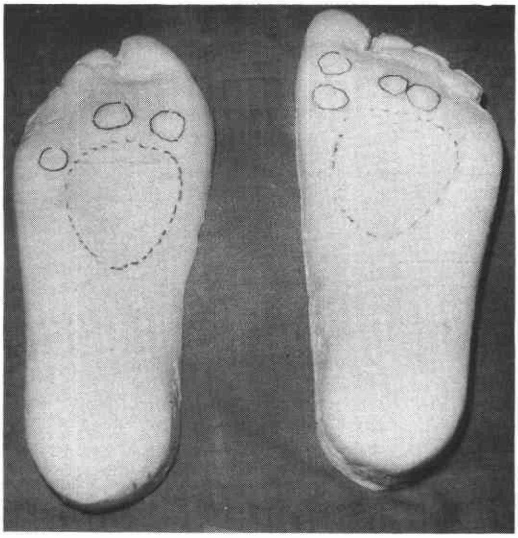

Figure 5. Positive models of patient's feet, plantar surface facing up. Note identification of transverse (metatarsal) arch and prominent metatarsal heads.

⅛″ thick. PVC Pelite™ is ideal for foot orthoses because: (1) the PVC laminate (vinyl covering) assists the Pelite™ in maintaining its desired shape after heat molding; (2) the PVC laminate provides strength and durability, decreasing and even eliminating incidences of the Pelite™ packing down, and (3) the PVC laminate consists of closed cells and is waterproof, which makes it easy to clean and discourages the growth of bacteria and fungus. The size of the PVC Pelite™ sheet to be molded over the positive model is determined by closely tracing the positive model onto the PVC Pelite™ and allowing extra material to cover the longitudinal arch and extra material beyond the phalanges. Care should be taken to closely trace the lateral and posterior aspects of the positive model, because excess material here makes molding or vacuum forming more difficult, frequently resulting in bunching or folding of the material and, thus, an unacceptable orthosis. Heating the PVC Pelite™ sheet can take place in an oven, an electric skillet, or with a heat gun. The vinyl covering of PVC Pelite™ should not be subjected to high heat or heated directly since it can delaminate under these conditions and develop bubbles or blisters. When sufficiently pliable and moldable from the heat, the PVC Pelite™ sheet is molded in place over the plantar surface of the positive model using any of the following techniques:

1. Wrapping the PVC Pelite™ in place around the positive model with an elastic bandage.
2. Vacuum formed in place using a vacuum hose placed inside a small airtight plastic bag.
3. Vacuum formed in place using a commercially available foot orthosis vacuum-forming machine.

Once the PVC Pelite™ is molded in place and cooled sufficiently for the molded shape to be maintained, a sheet of ½″ thick medium density Pelite™ is cut to fill the transverse and longitudinal arch areas as a single piece. (To save time we have these precut in large numbers to a single large size that can be trimmed to fit a given positive mold.) This piece of ½″ medium density Pelite™ is heated to a moldable state using oven, skillet, or heat gun, and is then molded or vacuum formed in place as was the

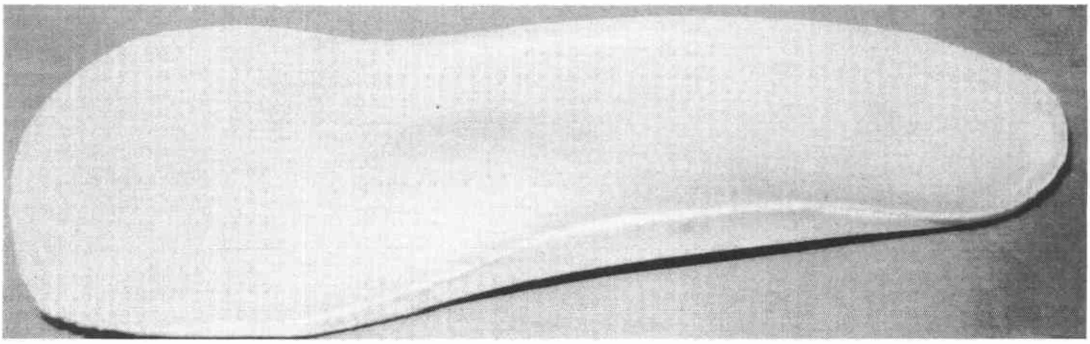

Figure 6. Molded PVC-Pelite™ foot orthosis, with longitudinal and metatarsal arch support.

PVC Pelite™. When sufficiently cooled, it is glued in place using Polyadhesive and sanded to a feather edge so that it will blend with the PVC Pelite™. Additional modifications to this PVC Pelite™ foot orthosis design may include either of the following:

1. For increased soft tissue supplement and shock absorption, ⅛" PPT can be glued to the bottom surface of the PVC Pelite™ foot orthosis.
2. For maximum soft tissue supplement in cases of severe metatarsal head protrusion, nylon lined ⅛" PPT may be glued on top of PVC Pelite™ foot orthosis.

Either modification will require greater depth within the patient's shoes. With or without the above modifications, final shaping and fitting are done to the patient and his shoes.

An additional point worthy of mention: soft tissue supplement, weight bearing pressure distribution, metatarsal head pain relief, and other plantar surface objectives can be attained with this foot orthosis system regardless of shoe integrity. However, when the objective is control of the inversion-eversion (varus-valgus) balance in the foot, or maintenance, support, or re-establishment of the longitudinal arch, the shoes become an adjunct to the foot orthosis and thus must have a firm heel counter with good integrity along the medial aspect of the longitudinal arch.

Ankle Foot Orthoses

Although somewhat rare compared to the numbers of patients we have encountered requiring foot orthotic management, there are those arthritics with severe enough involvement to warrant a higher level orthosis. The typical picture requiring AFO management is pain, swelling, and decreased range of motion located in the ankle (talocrural) joint, with frequent moderate to severe pes planus and subtalar (talocalcaneal) erosion. Although rheumatoid arthritis patients dominate this type of patient population, it is not unusual for patients with osteoarthritis to present at this level. Again, severity of involvement dictates the complexity of the orthosis. We have used two types or designs of AFO's in our management of these kinds of problems: rigid, molded plastic AFO's and bivalved, weight bearing, rigid, molded plastic AFO's (also known as PTB AFO's or axial load resist AFO's.) The distinction between the two is quite simple. When pain in the ankle or subtalar joint is due to the forces of walking or movement, i.e. if the normal movements of the ankle-subtalar complex in the course of walking causes or increases pain, yet standing stationary is comfortable and pain-free, the only need is elimination of motion which can be provided by a rigid, molded AFO. When pain is experienced in both standing and ambulation, the goals are to redistribute weight-bearing loads by reducing the amount of weight to be borne through the diseased ankle-foot complex and to eliminate range of motion. These objectives can be met with a bivalved, weight-bearing, rigid, molded AFO.

Figure 7. Rheumatoid arthritis patient wearing right molded, rigid copolymer AFO and left molded, weight-bearing, bivalve, rigid AFO.

As standard AFO's are commonplace items in any orthotic practice, detailed discussion in this context serves no purpose. However, the need for rigidity should be emphasized. The lower vertical trimlines need to be anterior to the malleoli, and carbon composite inserts can be used if necessary.

Our chosen design for bivalved, weight bearing, rigid, molded AFO's is that described by Wilson, Stills, and Pritham[7] with the addition of a higher posterior trimline in the popliteal area, similar to that in a below-knee prosthesis. The reduction in the range of knee flexion as a result of this higher posterior trim is a minor sacrifice for a major gain in reduction in pain. We purposely try to avoid the use of the term PTB orthosis because of its erroneous weight-bearing implications. The patella tendon is identified by mild modification of the positive model in this anatomical region, similar to but much less aggressive than in a so called "PTB" prothesis. However, there is little concentrated weight-bearing in this area; the goal of weight-bearing is equal distribution throughout the entire part of the lower leg contained within the orthosis. Perhaps the most accurate prosthetic acronym describing the weight-bearing goals of the bivalved, weight-bearing, rigid, molded AFO, is the "total surface bearing" concept. In the case of an intact lower limb as is encountered in orthotics, modification of the term "to maximum surface bearing" seems appropriate.

None of our patients requiring rigid AFO's has required SACH (solid-ankle cushion-heel) and rocker sole shoe modifications. We do recommend the use of shoes with soft soles constructed of Vibram® or crepe.

Shoes for Arthritic Patients

Proper shoes are a vital component of orthotic management of the arthritic foot. As was stated earlier, some foot orthotic objectives can be attained with shoes of poor quality or integrity. However, properly designed and fitted shoes can only enhance the best designed and fabricated foot or ankle-foot orthoses.

Our large arthritic patient population at the University of Virginia has allowed us to recommend and fit a wide variety of accommodative shoes. As we gained experience, it became apparent that we could rely on a minimum inventory of shoe types or designs. I refrain from the use of the descriptor "style" because there may be several "styles" available within a shoe design category. The categories of "design" that I refer to could be listed and described as follows:

1. Thermo adjustable shoes
2. Extra depth shoes
3. Running shoes.

Thermo Adjustable Shoes

This shoe type or design is made primarily of Dermaplast®, which is a heat shrinkable Plastizote®. Known as Apex Ambulators®, there are two styles available: #1201, the simplest and most accommodative, and #1273, a more cosmetic version of the first style.

Style #1201 is of black Dermaplast™ with a thin outer fabric covering, crepe wedge soles, Velcro® lap closure (eases donning for those

Figure 8. View of various shoes useful in the management of patients with arthritis affecting the feet and ankles.

arthritics with hand involvement), and removable Plastizote® insole. There is no heel counter reinforcement. The indications for this type of shoe is last resort, severe deformities, especially in the dorsal aspect of the foot, that are difficult or impossible to accommodate in shoes of firmer and less adjustable materials. Examples of such deformities are severe hammer toes, severe hallux valgus, and/or nodules on the dorsum of the feet or toes. This shoe is fitted slightly large and then heated while on the patient's foot (with protection by socks, of course). The application of heat causes the Dermaplast® to shrink and mold to the patient's foot shape, thus accommodating the severe deformity. The shoe upper material of Plastizote® and fabric is very soft and forgiving to such deformities. In all cases, we replace the removable Plastizote® insoles with molded PVC-Pelite™ foot orthoses.

The other style of Apex Ambulators® thermo adjustable shoes, #1273, is very similar to that described above. The major difference is the outer covering of the uppers, which in this second style is thin, pliable leather. This shoe is more cosmetically appealing to most patients because the leather uppers allow the choice of four colors, (the catalogue number varies with color variations). It has slightly more integrity than the #1201 style, including a moderately reinforced heel counter. It also has a removable tongue, which is secured in place with Velcro®, a feature that enhances its adjustability. It is available with either lace or Velcro® loop back closure. Accommodation of deformities can be accomplished either by heating and shrinking a loose fit as with the #1201's above or by fitting the shoes to the proper size and then stretching the uppers with shoe stretching tools over areas of deformity.

Extra Depth Shoes

Extra Depth® shoes are offered by several manufacturers and provide greater depth throughout the entire shoe. This depth is ideal for accommodating molded foot or ankle foot orthoses designed for arthritic foot deformities. Extra depth shoes, like molded AFO's, are a familiar item in any orthotic practice, and therefore do not necessitate detailed discussion. However, there are two important considerations regarding their application to arthritic patients: (1) the shoe style selected should be made of very soft leather, preferably calfskin or deerskin, as these leathers are most easily spot stretched to accommodate deformities, and are the most forgiving to areas of inflammation; (2) adequate width in the forefoot or toebox of the shoe cannot be overemphasized.

The extra depth shoes that we recommend for our arthritic patients are manufactured and distributed by Alden Shoe Company and P.W. Minor. The designs and styles vary in leather utilized, closure (lace or Velcro®), and amount of heel counter reinforcement. All have soft crepe soles and uppers that can be modified for deformities with relative ease using shoe stretching tools and equipment.

Running Shoes

Running or jogging shoes should be familiar to orthotists and patients alike. Their application to patients with arthritic foot problems stem from three of their characteristics: (1) they are acceptable to many patients who do not accept the "lack of style" of other appropriate shoes; (2) most utilize separate, removable insoles, which when removed, allow adequate room for use of molded foot or ankle foot orthoses; and (3) most are very light in weight. Problems we have encountered with running shoes include seams in the dorsal aspect of the toe box, making spot stretching difficult or impossible, and construction of vinyl or other synthetic materials which also make stretching difficult or less successful.

Conclusion and Results

An experience based protocol for orthotic management of the arthritic foot has been described. This experience is based on over 300 arthritic patients who required orthotic management by our service since 1985. Seven patients have been fit with eight bivalve, weight-bearing rigid, molded AFO's (one bilateral). One of these seven patients benefitted from a rigid, molded AFO on his lesser involved lower extremity. The remaining patients have been managed with custom molded PVC Pelite™ foot orthoses. Many of the patients fit with PVC Pelite™ foot orthoses were successfully converted from direct molded Plastizote® shoe inserts. Through routine follow up and chart reviews, we have found less than a three percent rejection rate; more important, we have found more active patients who enjoy a better quality of life.

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[7] Wilson, A. Bennett, Jr., David Condie, Charles Pritham, and Melvin Stills, *Lower-Limb Orthotics, A Manual,* First Edition, Rehabilitation Engineering Center, Moss Rehabilitation Hospital, Temple University, Drexel University.

Appendix

Alden Shoe Company, Taunton Street, P.O. Box 617, Middleborough, Massachusetts 02346.

Apex Ambulators, Apex Foot Products, 330 Phillips Avenue, S. Hackensack, New Jersey 07606.

PPT, The Langer Biomechanics Group, 21 East Industry Court, Deer Park, New York 11729.

PVC Pelite™, Durr-Fillauer Medical, Inc., Orthopedic Division, P.O. Box 5189, Chattanooga, Tennessee 37406.

P.W. Minor Extra Depth Shoe Co., 3 Treadeasy Avenue, Batavia, New York 14020.

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