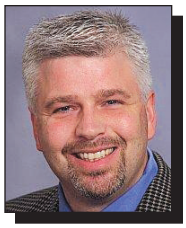
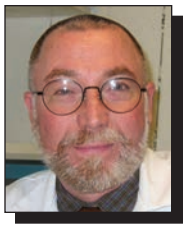
Michael Bozzaotra



Patrick DeHeer, DPM

Howard Dananberg, DPM



Robert Eckles, DPM

Larry Huppin, DPM

Kevin Kirby, DPM

Re-Examining Foot Orthotic Therapy

Our experts discuss some ongoing controversies in this cornerstone of conservative podiatric care.

BY MARC HASPEL, DPM

Without question, the discipline of foot orthotics is a common thread that impacts nearly all practices of podiatric medicine and surgery. As a treatment modality, it may very well be the cornerstone of conservative podiatric care, but at the same time a number of ongoing controversies at times require us to re-think concepts and re-examine therapy.

To start, given today's emphasis on evidence-based medicine and outcomes, the way that orthotic treatments are evaluated in medical literature needs to be appreciated by prescribing podiatric physicians in order to preserve this valuable service now and into the future.

Next, although the modality of orthotics may not be a new one, new technologies are ever emerging, such as modern impression-taking techniques that directly impact the process of casting, ordering and, ultimately, fabricating appropriate devices. There are, of course, a variety of opinions regarding the comparative efficacy of these technologies.

Other aspects of orthotic therapy continue to inspire continuing controversy, from rearfoot posting to functional vs accommodative devices, from plantar fasciitis treatment to chronic ankle pain in young athletes.

There are, of course, a variety of opinions regarding the comparative efficacy of these technologies.

Podiatry Management Magazine has invited several prominent practitioners of orthotics and biomechanics to weigh in on these and other issues pertaining to this area of podiatric practice. Joining this roundtable:

Michael Bozzaotra is the laboratory director and owner of Performance Labs, a custom orthotic laboratory in Northern New Jersey, since 1984. He is also a consultant to the School of Podiatric Medicine at Temple University.

Patrick DeHeer, DPM is a member of the APMA, and a fellow of ASPS and ACFAS, diplomate of the American Board of Foot & Ankle Surgery. He is in private practice in Central Indiana, and is the team podiatrist for the Indiana Pacers and Indiana Fever.

Howard Dananberg, DPM practiced podiatric biomechanics for almost 40 years in Bedford, New Hampshire. He is the 1994 recipient of the Outstanding Clinical Paper of the Year Award by the APMA and remains a contributing editor to *JAPMA*. He currently consults to Vasyli International (Vionic) and is the chief technology officer for Insolia, an innovative shoe

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component manufacturer with product sales worldwide.

Robert Eckles, DPM is dean of Clinical and Graduate Medical Education, associate professor of Orthopedic Sciences at the New York College of Podiatric Medicine, and is residency director at Metropolitan Hospital Center.

Larry Huppin, DPM is a graduate of the CCPM biomechanics fellowship. He currently is the medical director at ProLab orthotics and has a Seattle private practice where he specializes in biomechanics and orthotic therapy.

Kevin Kirby, DPM is adjunct associate professor in the department of applied biomechanics at the California School of Podiatric Medicine. He is in private practice in Sacramento, California.

PM: *Describe the impact of evidence-based medicine on the practice of orthotic treatment. Do you feel it's problematic if a DPM fails to keep abreast of current EBM literature?*

Kirby: Evidence-based medicine (EBM) is a double-edged sword when it comes to foot orthoses. Even though there are good prospective studies showing that foot orthoses can prevent injuries, and other lower level evidence studies demonstrating the therapeutic effectiveness of foot orthoses, these studies only represent a fraction of the pathologies that podiatrists successfully treat on a daily basis with foot orthoses. Therefore, EBM research can be used for the benefit of patients for the few foot and lower extremity pathologies where foot orthosis therapy has been studied.

Insurance companies, however, that are motivated by profit and governmental agencies that have finite healthcare budgets are more than willing to use the lack of higher level EBM research to deny prescription of foot orthosis therapy to our patients, especially since many of the pathologies treated effectively with foot orthoses have not been the subject of research in terms of the therapeutic efficacy of orthotics. With these facts in mind, podiatrists requesting prescription foot orthosis therapy for their patients will have a definite advantage in discussions regarding the research evidence for foot orthoses if they stay current on the latest research.

For those who are interested in reading more about foot orthosis research, my chapter in Paul Scherer's book may be a good overview (Kirby KA: *Introduction to Recent Advances in Orthotic Therapy*. In Scherer PR (ed), *Recent Advances in Orthotic Therapy: Improving Clinical*

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Outcomes with a Pathology Specific Approach, Lower Extremity Review, USA, 2011).

Dananberg: Orthotic management of podiatric pathologic biomechanical conditions is part art and part science. The literature is replete with numerous orthotic studies, but often, the specific prescription is either not discussed or a single type of orthotic design is used for all subjects. Individually prescribing orthotic devices for patients is unfortunately not well established in the evidence-based medicine literature. It is, therefore, highly unlikely that using previous study data to absolutely prescribe and/or dismiss this form of care currently exists.

Huppin: Evidence-based medicine affects all of our decisions when we prescribe orthotic devices in our clinic, and the recommendations that we make to clients of the orthotic lab for which I work as a consultant. The orthotic prescriptions we write for such common problems as plantar fasciitis, metatarsalgia, hallux limitus, and prevention of diabetic foot ulcerations are all affected by studies that have been published in the last 10 to 15 years. Not being aware of these studies and their effect on orthotic prescriptions puts orthotic practitioners and their patients at risk of achieving significantly less than optimum clinical outcomes.

DeHeer: Evidence-based medicine is the way medicine is evolving, and it is for the better, but like most things, the evidence must be examined critically because not all research is good research. Additionally, I recommend looking for multiple sources with similar results. Graduating from a residency program should not be the end of learning for a podiatric physician; continued growth and development through education is critical.

Eckles: Thankfully, we are in a golden age in terms of mechanics and clinical data. Access to literature is so simple, and there is so much good material coming out on the subject of non-operative orthopedics, it is truly exciting. Having said that, there are only so many ways one can write prescriptions for orthoses. Evidence based medicine has made it easier to make decisions about when to treat with orthoses (and it occasionally indicates when they don't work), about what other modalities should be employed concurrently or as an alternative, and has made it easier to understand our failures with devices. Accordingly, from that perspective, indeed it is a problem when practitioners don't read. What EBM has not done is drive really specific construction detail. If one sought, for example, really good "evidence" that forefoot posting makes orthoses more effective, one is sure not to find a longitudinal multi-center study proving it. The third aspect of EBM is always clinician experience (with literature being one, and patient expectation and context being the second), thus leaving, I think, especially in the case of prescribing orthoses, lots of room for the art of it.

PM: *What are your feelings about the effectiveness of the various available methods for prescribing orthotics (i.e., plaster, foam, digital, pressure technology, STS slipper sock)?*

Bozzaotra: I believe that any prescribing method that involves a non-weight-bearing foot and locked subtalar and midtarsal joints is effective at capturing the plantar surface of the foot for functional orthotics. Of all methods in use, plaster casting is the reference standard.

The STS slipper sock comes close, but the size must be carefully chosen. If the sock is too big or too small, contact with the foot can be compromised, causing distortion in the cast as it cures.

Digital formats differ from device to device, and their effectiveness at capturing plantar images varies. If a particular digital system lacks certain information, the laboratory is limited in its ability to read any deformity that may be present. True 3-D

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systems come close. Rearfoot neutrality, however, cannot always be confirmed via 3-D because of a lack of data about the back and sides of the heel. Because the scanner gets its image from the plantar aspect of the foot, it can only read up to the widest point. Beyond that, present plantar scanning technology has a limited range. In my view, the industry could build on current methods to provide additional views and angles that would capture the missing data.

Pressure technology is an effective tool for diagnostic use, but the information it supplies for orthotic fabrication is limited to two dimensions. It is little more than an outline of the foot. If the foot is in motion when the pressure scan is taken, it can act as a digital pedograph. Either way, there is not enough data to make a three-dimensional object from the information collected. Pressure technology is arguably the least accurate method of obtaining plantar surface data.

Casting foam also has limitations. Physicians like it for its speed and cleanliness, but its results are often not repeatable. This casting method also suffers from a lack of data past the widest point of the plantar aspect as well as from difficulty in truly neutralizing the foot. Its use is limited, in my estimation, to purely accommodative or neurological cases.

DeHeer: The literature is very interesting on this topic, and the conclusions vary. Laughton et al. in *JAPMA* 2002 found that foot measures are significantly affected by impression technique, methods differ in reliability, and plaster casting was the preferred method for capturing forefoot to rear foot relationships (i.e., functional devices). Guldemond, et al. (*JAPMA* 2006) found differences with respect to contact area and walking convenience, but only slight differences in peak pressures. The study also noted differences in gait lines between accommodative (more medial) and functional (more lateral), but casting method did not lead to any difference in gait line. They recommended foam impressions for functional devices due to convenience and expense.

Conversely, McPoil, et al. *(Physical Therapy 1989)* found forefoot to hind foot alignment was more reliable for supine or prone non-weight-bearing plaster casting compared to semi-weight-bearing foam impressions. They felt that although the semi-weight-bearing method allowed subtalar joint neutral position, the ability to lock the midtarsal joint was affected, thereby accounting for the differences. I happen to use semi-weight-bearing foam impressions with the STJ in neutral position for a functional device and have had good results.

Huppin: In 2009, I participated in a review of the various methods of capturing an image of the foot for production of custom orthotics. We evaluated plaster casts, STS socks, foam boxes, and five digital scanners. An extensive review of the literature determined the criteria for capturing an image of feet for effective functional orthoses.

What we found is that the most effective methods allowed completely non-weight-bearing foot capture, first ray plantarflexion, a true 3-D image of the foot, and adequate posterior heel capture so the forefoot can be balanced to the rear foot. The methods that meet these criteria were non-weight-bearing plaster casting, STS slipper sock, and certain digital scanners. Those methods that required pressure on the plantar aspect of the feet were not as effective for producing a functional orthosis. These included foam box, pressure mats, and digital scanners that required that the feet touch the scanner while the images were being taken.

Eckles: Practitioners who apply skill and care to their impressions can make a good negative out of almost anything. I'm traditionally biased against foam boxes because they fail, unless one is highly specific in technique, to capture the plantar foot in a "locked" and accurate (uncompensated) position, but I agree that some practitioners do it and create acceptable results. Moreover, we are seeing new generations of 3-D scanning devices that can now really deliver in terms of accuracy as well as permitting appropriate suspension positions—this just wasn't the case 10-15 years ago. Many 2-D devices came on the market, which were not valid in my view. That was, I think, a low point, but we've navigated past that to some extent.

Kirby: I have been using neutral position negative casting with plaster splints to achieve three-dimensional models of the plantar feet of my patients now for over 30 years. It takes only about 5-10 minutes for me to make both casts. I get an instant three-dimensional model of the foot which I can inspect both from the inside and outside of the cast for accuracy, and I can also show the casts to the patients so I can point out features regarding their foot morphology. Since my results have been so good with this casting technique for so many years, I may find it hard to change to another method of obtaining a three-dimensional foot model for orthosis manufacture. Foam boxes, optical scanners, contact scanners, and the STS slipper sock, however, may be used to obtain usable three-dimensional models of the plantar foot and they all have their pros and cons. Conversely, pressure mats, which only provide two-dimensional scans of the plantar forces acting on the foot, do not have the ability to deter-

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Practitioners who apply skill and care to their impressions can make a good negative out of almost anything.—Eckles

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mine the three-dimensional shape of the plantar foot and, for that reason, should not be used, in my opinion, to create custom orthoses.

In-shoe pressure analysis is an outstanding method of analyzing the effects of orthotic prescription on a patient's gait.—Dananberg

Dananberg: Actually, I believe, as far as in-shoe pressure analysis goes, this is an outstanding method of analyzing the effects of orthotic prescription on a patient's gait. It adds a layer of objectivity that heretofore did not exist. While some literature exists which suggests that the shape of the orthotic alters the ability to collect accurate data, current "masking" technology allows for pressure analysis to focus on areas which are not affected by orthotic shell shape: the heel and forefoot. Speed of motion, symmetry between feet, and weight-transfer between foot segments are all measurable and can contribute to a far more objective method of analysis. My personal experience also shows that very subtle adjustments in orthotic design (very thin heel lifts, either shock absorbing or firm, shape of 1st ray cutouts, and 1st ray shell grooves, posts) can have a profound effect on function. These would easily be missed without this technology.

PM: *How do you determine whether a patient is a candidate for accommodative orthotic devices versus functional ones?*

Eckles: I argue there is not much difference. The only questions I consider are to what extent I feel I need to create a high level of surface contact and where to put specific accommodation, if needed, but I tend to do this on the top devices most would classify as "functional." I think we do our diabetic and elderly patients a disservice when we fail to coincidentally treat their significant postural issues because we have somehow concluded they need soft, flexible, "accommodative" devices. In the case of the patient with diabetes, at a minimum, I see a highly volatile mix of neuropathy, limited range of motion, and high pressures related to BMI, etc. Prevent ulcers here, yes,

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but don't forget what else is happening to the foot. Charcot change is predictable and perhaps preventable.

DeHeer: In my opinion, the accommodative versus functional orthoses decision is based on foot biomechanics, pathology, footgear, and activity level. A rigid, maximally pronated flatfoot will not tolerate a functional device and would be more receptive to an accommodative device. It has been my experience in working with professional basketball players over the past 20 years that most of them do not like a rigid, functional device. They prefer semi-flexible to semi-rigid devices with significant padding for shock absorption. At a certain point, the shell stiffness takes the device from functional to accommodative for the elite athlete who plays a high impact sport and is a typically larger person than others in the general population. I am not sure what that point is, but I do believe there is balance in the equation of control, comfort, and shock absorption.

Kirby: I agree that regarding the terms functional and accommodative to describe foot orthoses, the notions that cork and leather orthoses cannot be made to be functional or that polypropylene or graphite foot orthoses cannot be made to be accommodative for our patients are false and not consistent with our current knowledge of the biomechanics of foot orthoses. In theory, this is because it is not the orthosis material that determines whether the orthosis is functional or accommodative. Rather, it is a) the three dimensional shape of the orthosis, and b) the resistance of the orthosis to deformation (i.e., its stiffness) that determines the ability of a foot orthosis to alter the kinetics and kinematics of gait (i.e., its function), and the ability of the orthosis to reduce pressures in specific areas of the plantar foot (i.e., to accommodate).

Podiatric physicians who are experienced in foot orthosis therapy will use their knowledge of foot biomechanics and the physical characteristics of orthosis materials to design the best orthoses that not only improve the gait function of their patient, but also reduce plantar pressures in symptomatic areas of their plantar feet in order to maximize patient comfort and better decrease their risk of developing new pathologies.

Dananberg: During my practice years, I have rarely used accommodative devices, preferring functional devices with accommodation when necessary. My reasoning has been that the majority of those with the need for accommodation have underlying gait issues which require care greater than would be managed by a purely accommodative device. For instance, some of the most rewarding patients to treat are geriatrics who exhibit mild to severe unsteadiness when walking. Neurologic issues must of course be ruled out, but if they are otherwise idiopathic, then orthotic intervention can be considered. If treatment were simply related to age alone, then accommodative care would fail to address these patients' issues. Carefully evaluating these subjects, however, and prescribing a fully functional device made tremendous changes in gait style. This is enough at times to remove canes and/or walkers from their lifestyle. Speed of gait and steadiness are inseparable.

Balance while walking can be likened to riding a bicycle. Riding too slowly fails to develop the resonant pace required to maintain stability. The slower one walks, the more unsteady they become. The body responds to this instability with prolonged double support phase and shortened single support. Humans, however, slow during double support phase and speed up during single support. The less single support phase, the slower the overall pace. Providing the correct device changes lives, and provides an independence which at some advanced ages was not thought possible.

Bozzaotra: I do believe that there are distinctions. An accommodative orthotic maintains part or all of the deformity inherent in the foot's structure and, thus, must be casted in a semi-weight-bearing position for the deformity to be captured. A functional orthosis supports the foot's structure to correct deforming forces. Because of its rigidity, a functional device provides rear foot-to-forefoot correction as the foot moves through the gait cycle. Functional devices must be casted in a non-weight-bearing position to reveal any forefoot deformity.

A rigid, maximally pronated flatfoot will not tolerate a functional device and would be more receptive to an accommodative device.—DeHeer

If the patient benefits from holding the foot in a semi- or non-corrected state such as a fixed, rigid foot structure, an accommodative orthotic can provide a shock-absorbing guard against ground reaction forces.

When selecting a functional orthotic, I feel the "reverse-of-deformity" theory works well as a general rule. Rigid feet benefit most from more flexible orthotics and flexible feet benefit from more rigid orthotics. There are a few exceptions. A rigid flatfoot, for example, may require a functional device using a forefoot extrinsic post if the flatfoot is non-reducible.

A viable alternative to the "reverse-of-deformity" theory is using a functional, semi-rigid device. This can be successful with most foot types, but the arch fill must be chosen accordingly: maximum fill for the highest arches to allow for any available pronation, if needed, or to make the device tolerable in older patients; minimum fill on the lowest arches to limit pronation, while using an extrinsic forefoot post on non-reduc-

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ible, limited foot structures. Padding a semi-rigid device, in many cases, will also aid in comfort and compliance.

PM: *What are your thoughts on using rear foot posting?*

Kirby: Rear foot posting is important in a foot orthosis if increased frontal plane stability of the orthosis and foot is desired.

Rear foot posting is absolutely necessary for optimal treatment of conditions such as posterior tibial tendon dysfunction, peroneal tendinopathy, chronic ankle instability, sinus tarsi syndrome, medial tibial stress syndrome, and patellofemoral syndrome, to name a few. Where the foot is relatively stable, however, but just needs midtarsal midfoot or forefoot support to decrease the load on the injured structures, then rear foot posts may not be necessary to achieve treatment success. I often may not use rear foot posting in patients with stable feet but who also have, for example, plantar fasciitis, metatarsalgia, and intermetatarsal neuromas.

Bozzaotra: I believe, actually, that to promote pronation, in cases such as a forefoot valgus with a vertical heel that does not pronate on weight-bearing, a post is not necessary. In limiting pronation of the rear foot, however, a post will stabilize the plate. Dr. Merton Root was the first to add a rear foot post to stabilize the orthotic within the shoe.

If the goal is to limit the pronatory motion of the subtalar joint or excessive motion at heel strike, then rear foot posting is beneficial.—Bozzaotra

An orthotic device without a rear foot post contacts the shoe floor at the parabola and heel. It resembles a three-point structure, such as a three-legged table, and if excess force presents to any one side, it becomes unstable. The orthotic plate itself does not have the stability of an extrinsically posted orthotic, which more resembles a four-point structure or four-legged table. In an extrinsically posted orthotic, the medial and lateral sides of the rear foot post act as two legs, and the medial and lateral aspects of the parabola act as two more contact points, producing superior stability. Intrinsic grinds are the least effective corrective method but utilize a greater contact area than an unposted rear foot. A medial skive without a post can help provide some correction of rear foot deformity, but requires a deeper heel seat. For best results with a medial skive, I suggest using a zero-degree rear foot post and a deep heel seat.

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DeHeer: Rearfoot varus posting essentially does two things: first, it stabilizes the orthoses against the ground and, second, it limits frontal plane pronation motion. If the goal is to limit the pronatory motion of the subtalar joint or excessive motion at heel strike, then rear foot posting is beneficial. I typically use a 4-degrees inverted rearfoot post position and 4-degrees post motion.

Huppin: There is a fairly limited amount of research that we found on rear foot posting. A 2006 study by Paton and Spooner noted that the addition of a rear foot post had an effect on lateral to medial center-of-pressure position. A 1994 study showed that when maximal control of rear foot frontal plane pronation is desired, an orthotic device with a rear foot post is more effective than one without or one with forefoot posting alone.

I use rear foot posts on a majority of the devices that I make that are to go into an athletic or other full-sized shoe. They help to stabilize the orthosis in the shoe, and they also provide a platform to add additional wedging should I want to add that later.

PM: *Under what circumstances would you order orthoses for the treatment of plantar fasciitis and why? What are your thoughts about the statement that some have made that orthotics are the best treatment for this condition?*

Kirby: What we now call plantar fasciitis is probably a number of different pathological entities that may respond differently to the same treatments. Plantar heel pain, commonly called proximal plantar fasciitis, generally responds very well to foot orthoses if the plantar heel tenderness is not too severe, in which case a walking boot brace or cast works better to first calm down the plantar calcaneal pain. Likewise, plantar fascial arch pain, commonly called distal plantar fasciitis, responds well to foot orthoses, but responds even better to plantar arch taping (i.e., low-Dye strapping).

Mechanically-caused pathologies, such as proximal and distal plantar fasciitis, respond well to mechanically-based treatments, such as foot orthoses, that off-load the plantar heel and plantar fascia even though there are many other treatments such as calf stretching, NSAIDs, and cortisone injections that also may be therapeutic for these conditions. In my practice, however, some form of foot orthosis therapy, whether via premade or custom orthoses, is always used as part of my treatment regimen for patients with plantar fasciitis.

When prescribing orthotic devices for plantar fasciitis, my primary goal is to reduce excess tension on the plantar fascia.—Huppin

Dananberg: I agree that not all heel pain is plantar fasciitis. I have seen many patients who presented with a previous diagnosis of plantar fasciitis. Of course, my process always would begin with a detailed history and then careful examination. The three most common heel problems I encountered were actually plantar tuberosity pain, actual plantar fasciitis, and a third entity related to muscle spasm of the abductor hallucis muscle. On exam, the muscle spasm is detected by carefully palpating above the actual plantar fascia directly into the muscle. This is then compared to pain from the plantar heel. Should the muscle be the site of maximum pain, then treatment involves manipulation of the cuboid.

In these cases, the pain will then spontaneously resolve. When pain is related to the tuberosity, then accommodation within a custom foot orthosis via a heel cut-out filled flush with cushioning material would be my treatment of choice. On rare occasions, a cortisone injection could be used, but fat pad atrophy must be avoided as this site can become chronically painful. In the case of plantar fasciitis, my orthotic Rx typically included a 1st ray-cutout to improve 1st ray plantarflexion/hallux dorsiflexion and, thus, proper windlass action. Leg length difference (LLD) was also carefully evaluated as short sided function often caused overuse to the heel area, because of early heel lift, and would not resolve until the appropriate amount of heel lift was added.

Huppin: One aspect of plantar fasciitis/plantar fasciosis that is generally accepted is that excessive tension on plantar fascia contributes to the pathology. Therefore, when prescribing orthotic devices for plantar fasciitis, my primary goal is to reduce excess tension on the plantar fascia. The tissue stress theory described by Dr. Tom McPoil attributes excess tissue stress to patient symptoms. In all plantar fasciitis cases, I incorporate some tool, usually a prefabricated or custom foot orthosis, to reduce tension on the fascia as an important component of the overall treatment plan.

Two key studies by Kogler should be incorporated in all podiatrists' decisions for addressing the underlying tissue stress causing symptoms in plantar fasciitis. These studies indicate that the orthotics should conform very closely to the arch of the foot and incorporate valgus forefoot wedging in order to best reduce tension on the plantar fascia.

There are prefabricated orthoses that incorporate valgus forefoot correction and a relatively high arch, and for many patients, that is effective at reducing plantar fascia tension adequately to reduce symptoms. Other patients will require custom orthoses which will usually be more effective at reducing plantar fascia tension as they can conform closer to the arch and we can incorporate the amount of valgus correction based on

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the patients' biomechanical findings and pedal structure.

Bozzaotra: I routinely work with physicians on cases of plantar fasciitis and get results using neutral, non-weight-bearing casts and orthotics that address the deformity accurately.

Strain on the fascia from deforming forces of the rear foot and forefoot are corrected with an accurately-casted, deep-seated, fully- posted device.

I, too, have seen many physicians start with a pre-fabricated device or strapping to determine the results a prescription orthotic may provide. A functional pre-fab may be enough to correct deforming forces without moving to a functional prescription device. If, however, the pre-fab device proves insufficient, the information collected from it as to what the patient can tolerate in a corrective device as well as the ways in which the pre-fab or strapping were or were not effective, is still useful in designing the functional prescription device.

DeHeer: My perspective on this is a bit different. I have long thought the treatment of plantar fasciitis is a two-step process. The first step is to fully resolve the acute condition by treating the symptoms of inflammation and the etiologies simultaneously until resolution. How this is done requires a much longer discussion. The second step is long-term treatment for prevention. I believe this step consists of two components: stretching the gastroc-soleal complex until it is fully corrected and use of orthoses. The orthoses I typically employ for this are functional devices.

PM: *What orthotic recommendations do you have for cyclists? What is your opinion about using wedges instead of orthoses for cycling shoes?*

Huppin: My orthotic recommendation for cyclists depends on their symptoms and our treatment goals. For example, one of the more common problems I treat in cyclists is paresthesias affecting the digits during and after long rides. We have been very successful in eliminating or reducing these symptoms by using orthotic devices that transfer pressure from the metatarsal heads onto the arch of the foot. In this situation, we use carbon fiber or direct milled polypropylene orthoses, which are both very thin materials, with a very minimum cast fill. In some cases, we incorporate a thin layer of cushioning under the metatarsal heads and the metatarsal pad on the orthoses.

In general, I use foot orthoses more than I do wedging for bicyclists as I feel that orthoses are more effective at stabilizing the foot since they stabilize both the midtarsal joint and the subtalar joint where heel wedging is likely to affect only the subtalar joint.

Strain on the fascia from deforming forces of the rear foot and forefoot are corrected with an accurately casted, deep-seated, fully posted device.—Bozzaotra

Shoe fit is a critical aspect of achieving optimum benefit from cycling orthoses, and I recommend always sending the shoes to the orthotic lab to ensure a proper fit.

Dananberg: Positioning the foot within a cycle shoe poses a unique set of challenges. This type of footgear is quite snug, and has no flexibility. Depending on the nature of the cyclist's problem, wedging can be effective is some instances, such as high degrees of tibial varum. Otherwise, at least a three-quarter length device is required to properly position the foot so that the forefoot can exert even pressure while pedaling. In some cases, having the patient bring the bicycle and stationary stand to review body position from a variety of angles can often prove helpful.

Eckles: I believe it all depends on what one is treating. If it is knee pain, and that is the dominant concern of most cyclists, I think there is relatively little use for traditional fully-formed foot orthoses in cycling shoes. Trying to work with shoes that are extremely low volume which may be causative with regard to forefoot symptoms in the first place is an enormous challenge. Interior modifications may be useful or necessary when there are areas that require accommodation or pressure redistribution. Intermetatarsal symptoms might force this decision, for example.

When the issues are related to knee pain, a bulky orthosis (especially with forefoot posting or extension), may add far too much bulk to a shoe to be practical. We know that wedging works in most instances by reducing medial knee/tibial translation towards the bike frame or by reducing the tendency for the tibia to internally rotate. One has to question the advantages of a full-length device in this case.

Considering the absence of real ground reactive force against the device, it shouldn't be expected to function as a normal walking/running orthosis. Also, because the design of most rigid cycling shoes as well as proper seat height put the foot in equinus during loading, traditional casting methods may have to give way to in-shoe casting with the foot in equinus. This position may partially activate the windlass mechanism and offer some intrinsic stability.

There will be riders for whom wedging is insufficient, however. Extreme foot or leg alignments such as excessive degrees of tibial varum, high degrees of forefoot varus or valgus, or a highly unstable medial column, for example, may require the use of an in-shoe device along with appropriate forefoot wedging in ad-

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dition to what is done to and around the cleat interface. Importantly, I recommend making sure that the cleat position, seat height, bar height, etc., are all optimized.

Kirby: During cycling, even though the metatarsophalangeal joints are the part of the foot that transfers the power from the lower extremity to the pedal, the rest of the foot must be stable so that the power from the lower extremity can be transferred with optimum efficiency, minimizing wasted motion within the lower extremity during the power stroke. If the cyclist has a foot with a medially deviated subtalar joint axis, the power stroke will cause excessive STJ motion which will, in turn, result in increased adduction of the knee toward the top tube of the bicycle, which lessens the efficiency of the power stroke. Thin polypropylene foot orthoses with good medial arch support along with a varus cleat wedge will make these cyclists more efficient. Otherwise, I prefer to use cleat wedges or cleat lifts (for limb length discrepancies) versus foot orthoses for cyclists since they are lighter in weight and cause no shoe fit problems for the cyclist.

Manipulation of the ankle and 1st met-cuneiform joint are invaluable methods of care for turf toe.—Dananberg

Bozzaotra: As power transmits to the forefoot via the rear foot during cycling, any uncorrected deformity in the rear foot will compensate within the shoe.

In a cycling shoe, the rear foot is the conduit for power transmission and should not be viewed as a separate structure from the forefoot. A functional orthotic device dynamically connects the rear, mid- and forefoot. Therefore, if the mid- and rear foot structure is not supported, it will invariably affect the forefoot.

I have made many devices with an extrinsic forefoot post that extends to the sulcus. This provides a platform for the forefoot, which is more effective in controlling deformities when the forefoot is engaged on the pedal. Cyclists say this is more comfortable compared to traditionally-posted devices. I also suggest a carbon fiber plate with a non-posted, deeper heel

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cup and a medial or lateral skive, if indicated, which should fit inside the typical cyclist's shoe. This is an efficient way to keep the heel neutralized as it transmits force to the forefoot.

***PM:** What is your orthotic treatment of choice in athletes diagnosed with turf toe?*

Dananberg: Turf toe is hallux limitus in athletes. I understand turf toe as a joint which cannot move when demand of motion is greatest. While orthotic management is essential, other factors are equally if not more important in management. Manipulation of the ankle and 1st met-cuneiform joint are invaluable methods of care for turf toe. The most common finding is peroneus longus inhibition. This spontaneously resolves with ankle manipulation, and is often the crux of care. Since the peroneus longus maintains the 1st ray in a plantarflexed position capable of permitting dorsiflexion, failure of it to stabilize the 1st metatarsal results in jamming of the MTPJ. (Testing for peroneus longus strength can be viewed at the following link, https://www.youtube.com/watch?v = AEe7SaSeCX8).

I find that 1st ray cut-outs on an orthotic to enhance range of motion is also of significant value. In addition, I would grind off the cleat directly under the 1st met head. What I would avoid is solid plates to prevent motion, as this will only serve to exacerbate the condition. By using mobilizing rather than restricting concepts to care, positive changes could be spontaneous, and care limited to a single visit.

Eckles: I find that patients do well with the rigidity provided by a Morton's extension. The selection of carbon/composite seems a good idea here. I would even consider the use of a traditional orthosis over a carbon plate in the shoe since the therapeutic goal is to prevent any recurrence of the hyperextension.

Kirby: I recommend strapping the hallux to prevent excessive hallux dorsiflexion in addition to using an orthosis with a Morton's extension or an orthosis combined with a medial forefoot stiffener inside the shoe to prevent painful hallux dorsiflexion. This often works well in the treatment of turf toe.

Huppin: My initial goal during the initial healing process of turf toe is to eliminate or limit dorsiflexion at the first metatarsal phalangeal joint. My long-term goal is to use an orthosis to decompress the joint.

I normally would not consider a custom orthosis as a primary treatment for the acute injury of turf toe. In this case, I usually use a prefabricated orthosis with modifications such as a reverse Morton's extension to decrease pressure on the first metatarsal head in combination with something to limit motion at the first MPJ. Initially, this is generally achieved with a walking boot, and, later in the treatment, either a shoe with a rigid rocker sole or a turf toe plate in the shoe under the orthosis is used to limit 1st MPJ motion.

In patients with more chronic pain in the first MPJ following the turf toe injury, I consider a custom orthosis designed to decompress the first MPJ. This device requires a negative cast, where the first ray was plantarflexed and the orthosis is prescribed to allow the first ray to plantarflex. I generally prescribe minimum cast fill, a couple degrees of inversion, and, if the heel is everted in stance, a deep heel cup and medial heel skive. Again, this device is designed to decompress the first MPJ. A Morton's extension could be added if it is still necessary to limit first MPJ dorsiflexion, but I still find it is much more effective to limit motion with the shoe or a turf toe plate in the shoe rather than with the orthosis itself.

My initial goal during the initial healing process of turf toe is to eliminate or limit dorsiflexion at the first metatarsal phalangeal joint.—Huppin

***PM:** What orthotic recommendations would you make to address chronic ankle pain in young athletes?*

Bozzaotra: I have consulted many physicians in designing a wide variety of appliances for podo-pediatric applications such as this. In my experience, controlling the rear foot utilizing an 18 mm heel cup, a medial flange, a zero-degree rearfoot post with the forefoot posted to cast, and a semi-rigid polypropylene shell, selected by weight, effectively addresses ankle pain.

Only treating physicians have first-hand knowledge of results in these cases, but collaborative efforts treating lateral ankle instability with an 18 mm heel cup, a lateral flange, a zero-degree rear foot no-skive lateral post, a forefoot valgus post with a first-met cut-out, a modification I refer to as a " Zotch Notch" and a semi-flexible polypropylene shell, selected by weight, should together stabilize the lateral aspect of the foot and load the medial column.

Huppin: This, of course, depends on the ankle condition and the specific biomechanical findings. For example, the most common cause of chronic ankle pain that I see in young athletes is chronic lateral ankle instability. This condition has two sub groups: those patients with an excessively pronated foot type and those with an excessively supinated foot type. Munn noted that those who are excessively pronated are going to be more likely to sprain their ankle because they have less ability and less range of motion to counteract the effects of a rapid inversion force at the ankle. In those patients, I want to use an orthosis that works to limit pronation to the end of the range of motion.

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Depending on the foot, this might include deep heel cup, medial skive, and medial flange. On the other hand, other patients who have chronic ankle instability are those who are excessively supinated. These are patients with a laterally deviated subtalar joint axis and for this group of patients, I would be looking to apply pronatory force lateral to the subtalar joint axis with the use of modifications such as a lateral forefoot extension and a lateral heel skive.

Kirby: It is true that ankle pain can be caused by many types of pathologies in young athletes. Medial ankle pain is often caused by posterior tibial tendinitis which responds very well to a foot orthosis with a medial heel skive and well-formed medial longitudinal arch. Lateral ankle pain is often caused by the many sequelae of inversion ankle sprains, many of which can be treated effectively by foot orthoses with lateral heel skives and valgus forefoot extensions to help prevent recurrence of inversion sprains and to help off-load the injured structures. The key to making effective foot orthoses for young athletes is to design the foot orthosis so that the orthosis has the same function as the injured structure within the athlete's ankle, and in turn, that the injured tendon or ligament will be off-loaded during their sports activities.

Dananberg: One of the most common findings in those who have prior history of ankle sprain and then present with chronic pain is to discern both their osseous biomechanics as well as eccentric muscle function. Just as in turf toe, peroneal inhibition is often involved. The peroneals are opposing to the posterior tibial muscle. When the peroneals are inhibited, they are unable to resist the inversion effect of the posterior tibial muscle. The foot then tends to assume a chronically inverted foot posture. It is important to note that testing peroneal strength in the presence of chronic ankle pain should be undertaken with great care. Pain and re-injury can occur if the practitioner does not gauge the level of pain and over-exerts during the testing process. It is also important to recognize that this is the result and not the cause of the morphology, often visible as a flexible forefoot valgus foot type. Simply making a highly posted valgus foot orthotic is not going to have a positive effect on muscle apposition. For this, manipulation of the ankle, and specifically the fibula, is required. The peroneals originate from the fibula head. The inhibitory effect is reversible once the fibula is manipulated. Proper adjustment technique can be viewed at https://www.youtube.com/watch?v=mr-SQiQrAb5E. **PM**

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