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BIOMECHANICS AND FOOT ORTHOSIS TREATMENT OF METATARSALGIA

The term "metatarsalgia" within the podiatry profession generally refers to a diffusely located painful plantar forefoot pathology, involving at least three of the plantar metatarsal heads. In general, the pain from metatarsalgia increases with increased duration of weightbearing activities, is made worse by walking and/or standing on hard surfaces and gets better when off-weightbearing. Clinically, patients with metatarsalgia have normal and pain-free range of motion of the digits and do not have significant edema in the plantar forefoot. In addition, a reduced amount of ankle joint dorsiflexion (i.e., equinus) is often seen in patients with metatarsalgia. Other common pathologies causing plantar forefoot pain, such as plantar plate tears that generally occur at a single metatarsophalangeal joint (MPJ), need to be clinically distinguished from the more broadly diffuse pain across the plantar metatarsal heads seen with metatarsalgia.

One of the important clinical findings in individuals with metatarsalgia is that they are often noted to have higher-than-normal medial longitudinal arch height (i.e., pes cavus deformity) on weightbearing examination. Because of this association of metatarsalgia with increased cavus foot structure, it seems biomechanically reasonable that higher plantar forefoot pressures may be a prime etiology of the plantar forefoot pain in patients with mild, moderate or severe pes cavus deformities. In fact, Burns et al, in their landmark paper on the treatment of metatarsalgia with custom foot orthoses, suspected that increased forefoot pressures seen in pes cavus were likely responsible for much of the pain within the plantar forefeet in these individuals. In their study of 154 pes cavus subjects, custom foot orthoses not only significantly reduced plantar forefoot pressures better than sham flat insoles, but were also significantly better at improving foot pain scores, function scores, and quality of life measures compared to the control sham insoles used in their study (Burns J et al: Effective orthotic therapy for the painful cavus foot. JAPMA, 96:205-211, 2006).

In order to better understand the biomechanics of the increase in plantar forefoot pressures that are seen in patients with pes cavus deformity and metatarsalgia, it is important to appreciate the difference between plantar force and plantar pressure. During weightbearing activities, gravitational acceleration will pull the mass of the individual toward the ground which will, in turn, cause a reaction force from the ground to act on the plantar foot. This reaction force from the ground is called *ground reaction force* (GRF).

Pressure is not the same thing as force. Rather, pressure is determined by the amount of force acting over a given surface area, or Pressure = Force/Area (P = F/A). For example, if two individuals of the same weight are asked to stand on both feet, but one is asked to stand flat on both their rearfoot and forefoot, while the other one is asked to raise up only on their forefoot, the plantar pressures on the forefoot of the "tiptoe" standing individual will be much higher than the other individual, even though they are of the same weight. Therefore, the formula for determining pressure, P = F/A, tells us that any time a force is concentrated over a smaller surface area than before, the pressure will be increased. This fact of physics is very important in understanding why individuals with pes cavus deformity often develop metatarsalgia.

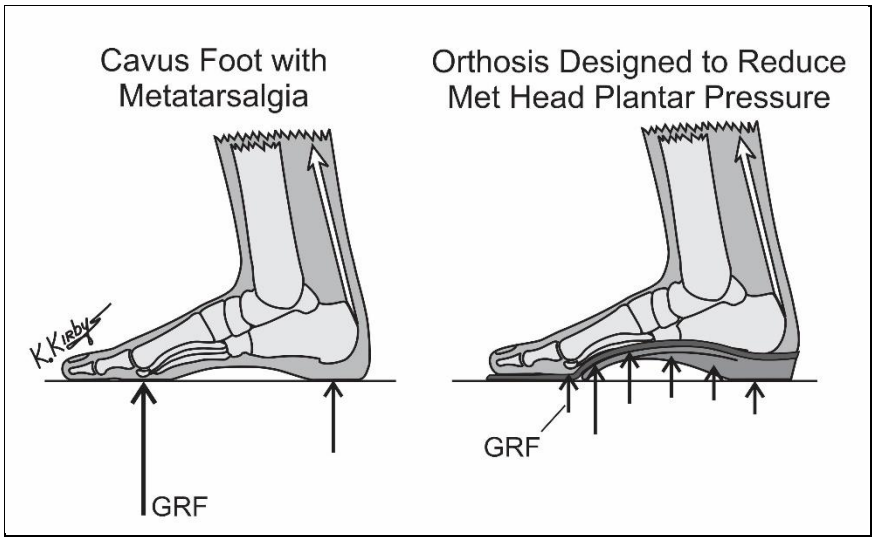

Figure 1. In the cavus foot with metatarsalgia, the increase in longitudinal arch height causes increased ground reaction force (GRF) on the plantar metatarsal heads (left). Effective custom foot orthoses made to treat metatarsalgia will transfer much of the GRF from the metatarsal heads to the longitudinal arch of the foot to decrease the metatarsal head plantar pressures which are the likely cause of metatarsalgia (right).

When comparing feet of the same

size, one foot with a planus deformity and the other foot with a cavus deformity, the planus deformity will always have a relatively larger surface area of contact with the ground compared to the cavus deformity simply due to the fact that the planus foot has a much lower medial longitudinal arch height making more contact with the ground, thereby increasing the overall ground contact surface area relative to the cavus foot. Therefore, given that two individuals, one with a planus deformity and the other with a cavus deformity, are standing on both feet and are of equal body weight, the plantar pressures experienced by the plantar soft tissue and osseous structures of the individual with a cavus deformity will be significantly larger than the plantar pressures of the planus individual. This increase in plantar pressure in the cavus foot, which may be especially increased in the forefoot if coexisting with an equinus deformity, is likely the main reason why so many feet with pes cavus and equinus ultimately develop metatarsalgia.

As a result, effective treatment of metatarsalgia in patients with pes cavus deformity should revolve around the goal of reducing the forefoot plantar pressures and reducing stress on the soft tissue structures and osseous structures of the plantar forefoot. Foot orthosis treatment may be initiated with over-the-counter (OTC) orthoses but, in general, for the patient with a significant pes cavus deformity, most of these one-size-fits-all types of orthoses are simply not high enough in the medial longitudinal arch to transfer significant plantar force from the plantar forefoot and into the medial arch. In my experience, patients with even a mild to moderate pes cavus deformity with metatarsalgia derive much more therapeutic benefit from custom foot orthoses than OTC orthoses, since custom orthoses have a far greatest ability to transfer more of the GRF into the medial longitudinal arch of the patient and away from the metatarsal heads than do OTC orthoses.

Custom foot orthosis modifications which are often used for treating metatarsalgia include using a thinner polypropylene shell than normal (e.g., 3 mm polypropylene for weights less than 160 pounds, and 4 mm polypropylene for weights over 160 pounds) and leaving the anterior edge of the orthosis full thickness (i.e. write “no grind anterior edges” on order form). Leaving a full-thickness “drop-off” at the anterior orthosis edge will create a type of “internal metatarsal bar” effect for the patient which will help to more effectively off-load the metatarsal heads. If there is significant fat pad atrophy also noted on clinical examination, a 1/4" (6 mm) thick full length topcover is used to provide more shock absorption for the metatarsal heads. However, it is not recommended to use the thicker topcover material only in the forefoot extension of the orthosis since only increasing the thickness of the topcover under the metatarsal heads may actually increase plantar pressures at the forefoot by causing the plantar metatarsal heads to bear more weight than otherwise (Fig. 1).

If an associated equinus deformity is also noted on clinical examination of the patient, the *heel contact point thickness* (HCP) of the orthotic may be increased to 3 mm to increase the weight born by the patient’s plantar rearfoot which will, in turn, decrease the plantar forefoot pressures accordingly. Writing on the order form, “make HCPs 3 mm thick”, is an effective way of indicating to the orthotic lab that you want a thicker heel on the orthosis to prevent compensation for the equinus deformity. Alternatively, adding a small heel lift to the orthosis can also be easily be ordered for the same purpose of redirecting body weight to the rearfoot.

Other than custom foot orthoses, conservative treatment for metatarsalgia should include stretching exercises for the gastrocnemius/soleus three times per day and avoidance of barefoot activities. I also recommend using Oofos or Hoka recovery sandals at home since their soft and thick foam construction seem to help reduce plantar forefoot pain for many patients with metatarsalgia. Recommended shoes include any of the “maximalist running shoes”, such as those commonly found in the Hoka shoe brand. My personal favorite Hoka shoes for metatarsalgia are currently the Bondi and Gaviota models, both of which have a very thick and cushioned forefoot midsole with a rocker sole. The combination of custom foot orthoses, regular calf stretching and maximalist shoes with thicker rocker forefoot designs invariably will produce excellent therapeutic results by helping to reduce the pain and disability of metatarsalgia in most patients.

Kevin

Kevin A. Kirby, D.P.M.
Biomechanics Director