A common misconception is that metatarsalgia is a symptom secondary to a more specific pathology. Metatarsalgia is frequently categorized as both a symptom and a diagnosis. Metatarsalgia is defined as pain from the area of five different metatarsal heads, five different metatarsophalangeal joints (MPJ), and a variety of soft tissue structures in between. It usually occurs plantarly. This often intractable pain is difficult to resolve even with repeated attempts.

by Cherri S. Choate, DPM, and Paul R. Scherer, DPM
Although many causes of metatarsalgia are possible, it seems that the mechanical origin component is common to both primary and secondary forms.

The exact location of the pain is frequently elusive and often seems to migrate to different areas in the forefoot. The source of the pain must first be established before successful orthotic intervention can be attempted.

Pain origins
Over the years, many attempts have been made to categorize metatarsalgia. It is generally divided into primary and secondary metatarsalgia (Table 1).1 Primary metatarsalgia is defined, for the purpose of this article, as pain related directly to foot structure or function that results in a chronic imbalance of pressure through the forefoot. Common diagnoses of primary metatarsalgia include second metatarsal stress syndrome, hallux valgus, brachymetatarsia, a plantar-flexed metatarsal, and iatrogenic symptoms secondary to a surgical procedure. Pain from primary metatarsalgia originates from a specific mechanical origin, and treatment should focus on accommodating or redirecting the specific mechanism.

Secondary metatarsalgia is pain related to a problem that does not originate within the metatarsal area. This outside force then produces problems or a mechanical imbalance affecting the MPJ area. Typical etiologies for secondary metatarsalgia include rheumatoid arthritis (RA), seronegative arthropathy, gout, infection, and equinus deformities. Treatment must be focused on both the systemic diagnosis as well as on the local forefoot pain in secondary metatarsalgia.

A comprehensive study published in 1980 evaluated 98 patients with forefoot pain.1 Study participants were divided into three groups: primary metatarsalgia, secondary metatarsalgia, and unrelated forefoot pain. The subjects underwent force plate analysis and received nerve blocks. The researchers found that 31 of the 98 patients had two or more mechanical etiologies for primary metatarsalgia. It was also documented that primary and secondary metatarsalgia commonly are found together in the same feet. The authors determined that force plate evaluation and certain local injections were helpful in determining a more precise location of the pressure redistribution, which led to a more accurate and successful treatment.

This became a landmark study because it revealed the complexity of metatarsalgia. Although many causes of metatarsalgia are possible, it seems that the mechanical origin component is common to both primary and secondary forms.

Biomechanical imbalance
Evaluation of patients with metatarsalgia, both primary and secondary, has been conducted in several studies2-4 that tried to determine the level and source of biomechanical imbalance, and whether it was from structure, gait pattern, disease process, or compensation.

A 2004 study focused on plantar pressure alterations in RA patients.5 The researchers used pedobarography to compare 50 RA patients who had several symptoms (including metatarsalgia) with 50 symptom-free non-RA patients. The researchers compared their findings with radiographic joint erosions in the RA patients.

Most dynamic pedobarographic parameters were significantly different between the two groups. Patients with RA had higher static pressure contact areas in the forefoot. Those with higher erosion scores also had higher static and dynamic peak pressure values. This study suggests that joint erosion may lead to gait changes (increased pressures during dynamic studies) due to pain and deformity. The findings also suggest that as RA progresses, load shifts from the medial foot to the lateral MPJ joints, and a new gait pattern and mechanics result in metatarsal pain.

An even more gait-specific 2004 study addressed joint motion in patients with RA and metatarsalgia.6 Eleven subjects with RA and five

TABLE 1:

<table>
<thead>
<tr>
<th>CHARACTERISTICS OF PRIMARY AND SECONDARY METATARSALGIA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary</strong></td>
</tr>
<tr>
<td>➤ Congenital short/long metatarsal</td>
</tr>
<tr>
<td>➤ Planar-flexed/dorsiflexed metatarsal</td>
</tr>
<tr>
<td>➤ Long/short first ray</td>
</tr>
<tr>
<td>➤ Freiberg’s disease</td>
</tr>
<tr>
<td>➤ Second metatarsal stress syndrome due to hallux valgus</td>
</tr>
<tr>
<td><strong>Secondary</strong></td>
</tr>
<tr>
<td>➤ Rheumatoid arthritis</td>
</tr>
<tr>
<td>➤ Infection</td>
</tr>
<tr>
<td>➤ Psoriatic arthritis</td>
</tr>
<tr>
<td>➤ Stroke</td>
</tr>
<tr>
<td>➤ Neurologic disorders with excessive forefoot pressure</td>
</tr>
</tbody>
</table>

40 BIOMECHANICS • JULY 2008 www.biomech.com
Foot Care

without were evaluated using a six-camera video-based motion analysis system. Ten of the 11 RA subjects had MPJ pain. The RA patients had reduced range of motion compared with the healthy subjects across all segments and in all planes of motion. During gait, the RA patients, on average, had more eversion motion of the rearfoot and reduced forefoot motion in all planes. This multisegment study hypothesized that the painful, deformed forefoot led to shorter strides, slower walking, and limited propulsion, which produced the metatarsalgia.

Another study, conducted by a French research group, measured the loss of MPJ range of motion of patients with metatarsalgia through an evaluation of gait kinematics. By using a video-based system, the researchers found that walking velocity was slower and stride length shorter in patients with RA. The data also showed a strong negative relationship between maximum flexion of the knees and hips during walking and the underlying dorsiflexion range of motion of the MPJ. This may suggest that an impact on the kinematics of the proximal joints produce the metatarsalgia when there is deformity in the forefoot.

These studies of metatarsalgia in RA patients suggest that focused evaluation with pressure plates, motion analysis, and injection therapy may help to differentiate the source of the pain. This kind of evaluation may also aid in more directed and effective treatment with orthoses. Although not every case is complicated, it is useful to map out a grid to determine areas most in need of treatment for the patient (Table 2).

Because patients present with pain and the compensatory signs of metatarsalgia, the importance of recognizing the cause cannot be overstated. Multilevel treatment of the originating cause, as well as the compensatory processes, must be considered. The success of the orthotic therapy depends on a thorough patient evaluation based on the research studies that focus on the metatarsal region of the foot.

Pressure reduction

Many studies have been published about biomechanical evaluation and intervention with the use of orthoses. Some focus on peak pressures, while others concentrate on pain relief and increased quality of life.

Reducing metatarsal head pressure has been the goal of treatment in some of these studies. The use of metatarsal pads in many shapes and sizes has been the most common method of in-shoe adjustment. A metatarsal pad placed behind the forefoot contact area supports the metatarsal shafts and relieves pressure from one or all of the metatarsal heads. As more ground reaction force is shifted to the metatarsal necks, less is placed on the metatarsal heads.

In 1990, a research group reviewed 10 asymptomatic patients to determine the effect of metatarsal pads on pressure under the metatarsal heads. Barefoot plantar foot pressures were first measured using a Biokinetics Pedobarograph. Each subject wore a small foam metatarsal pad and was measured as he or she walked. The effect on the first metatarsal was insignificant, although the pressure was reduced at the second metatarsal head for all subjects. The pressure reduction was less significant for each subsequent metatarsal.

Another study of metatarsal pads, published in 1994, expanded on this idea by measuring peak pressures on eight discrete plantar foot locations on the hindfoot, midfoot, and forefoot. While there were no statistically significant changes in peak plantar pressures at the hindfoot or midfoot, a mild decrease in pressure was shown at the first and second metatarsal heads, and slight increases were exhibited laterally. Although peak pressure changes were minimal, the results showed decreased contact durations at all metatarsal head locations and decreased pressure-time integrals at the first, second, third, and fourth metatarsals. Both these studies were conducted on asymptomatic populations, but even in those patients, metatarsal pads were effective at decreasing peak plantar pressures in the forefoot.

A number of important studies have assessed patients with complaints of metatarsalgia and their response to various treatments. One such study examined the difference between prefabricated orthoses and custom orthoses, both with and without rocker bars. Forty-two symptomatic patients were evaluated for peak pressure changes and pain score changes at the metatarsal heads. The prefabricated orthoses with rocker bars decreased pressure in the digital forefoot as did the custom ones, with and without the rocker bar. Most important, pain scores were significantly lower for the custom orthoses, both with and without the rocker bar.

Another intervention study, conducted on 33 subjects who complained of metatarsal pain, used two different prefabricated soft insoles for a period of eight weeks. To determine pain relief, plantar pressures were measured using the Musgrave Footprint System and a visual analog scale. In all subjects, plantar foot pressure was decreased and more than half the patients reported pain relief.

A Taiwanese research group evaluated the metatarsal pad to determine whether its placement and location had an effect on peak plantar pressure. A group of 10 patients with a history of primary metatarsalgia had a rubber metatarsal pad placed at a variety of locations under their feet. The peak pressures were evaluated for all metatarsal heads using a floor mounted pressure mat. The metatarsal pad measured 55 mm in length, 36 mm in width, and 10 mm in height, and was uniformly used in all subjects. Greatest pressure reduction was achieved when the metatarsal pad was placed just proximal to the peak pressure point of the metatarsal head. Application of this finding in a clinical setting without pressure measurement equipment may be difficult. The study
Because one of the most important outcomes of treatment is pain relief, a study published in 2006 assessed the correlation between use of a metatarsal pad and subjective symptoms. A group of 13 symptomatic patients were evaluated for peak plantar pressures and VAS scores, before and after a two-week period. The maximum peak pressures, pressure-time integrals, and VAS scores overall were reduced significantly in all subjects who used the metatarsal pads.

A number of studies on secondary metatarsalgia focused primarily on pain relief with the use of orthoses and metatarsal pads. Investigators found that the pads decreased peak plantar pressures and pressure-time integrals as well as relieved pain and increased quality of life. In addition, the use of custom fabricated orthoses, without the pad, provided a frequent lowering of peak pressures and decreased metatarsal pain.

These investigations have shown that use of a metatarsal pad is helpful in reducing peak plantar pressure and subjective metatarsalgia pain, especially if it is applied in the appropriate location.

The next step in treating a patient with metatarsalgia is to determine how to apply these study data and information to writing an orthotic prescription.

Orthotic prescriptions
Before writing a prescription, the practitioner should determine the etiology. Any systemic issues and subsequent changes due to compensation must be established, along with the mechanical origin of pain.

A prescription can be developed by creating a list of issues that are common for patients with primary or secondary metatarsalgia and by studying the literature.
Imbalance of weight-bearing in the metatarsophalangeal area. Most of the studies regarding clinical intervention for metatarsalgia have involved the use of off-loading metatarsal pads.\textsuperscript{1,2,4-12} The best placement, according to the data, seems to be just proximal to the metatarsal head. The size and shape of the pad should vary depending on the foot's size, shape, and the metatarsals involved.

The use of metatarsal bars on the device or shoe can assist in relieving symptoms. One study found that a metatarsal pad placed just proximal to the point of peak metatarsal head pressure and just distal to the orthosis edge was superior to the metatarsal bar in relieving pain and pressure (Figure 1).\textsuperscript{12}

The device must have minimal fill or a high arch. This results in better contact of the orthotic plate against the plantar foot and increases the intrinsic off-loading within the orthotic plate itself. For every Newton of additional pressure on the arch, an equal Newton of pressure is taken away from the metatarsal heads. A semirigid or rigid device offers intrinsic off-loading because the loading of the foot is fully supported by the plate. A flexible plate is not appropriate because it compresses on loading and shifts weight to the metatarsal heads.

Excessive weight-bearing during gait cycle. The most common component in overloading of the metatarsal heads is early heeloff. If the heel comes off the ground too quickly during the stance phase of gait, the metatarsals bear more weight for a longer period of time than normal. To compensate for this, a heel lift should be added to the orthotic post to bring the ground up to the foot. This forces the heel to maintain longer contact with the ground before propulsion phase of gait begins. This shifting of weight posteriorly reduces and delays pressure onto the forefoot.

Gait instability leading to tendinitis. Disruption of the normal anatomy and function of the MPJ produces lateral instability that overloads the more lateral metatarsal heads. Adding a reverse Morton's extension motion.\textsuperscript{10} A wide orthosis plate made from a cast with the first ray plantar-flexed will also maintain contact with the more medial aspect of the foot and allow for greater motion of the big toe.

Poor shock absorption. Body tissues lose their elasticity with age. This process may also occur following surgery, after multiple injections, or with chronic excessive pressure under the metatarsal head area. A topcover and a forefoot extension can add cushioning. Studies have shown that softer topcover materials not only provide more comfort, but they also increase the patient's tolerance of orthotic devices.\textsuperscript{17} Materials such as closed-cell neolone, plastazote, and Poron add shock absorption to the forefoot. Topcovers require replacement because eventual compression of soft materials negates the benefits of shock absorption, which can lead to noncompliance. Poron extensions under the metatarsal heads also attenuate pressure by delaying compression.

Using the information from the data in the literature, the ideal functional orthosis for most metatarsalgia patients is a semirigid device made from a neutral suspension cast with the first ray plantar-flexed. Cast correction should include a standard 14-mm heel cup, wide trim, and minimum fill.

<table>
<thead>
<tr>
<th>Origin</th>
<th>Local</th>
<th>Systemic</th>
<th>Compensatory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Second metatarsal stress syndrome</td>
<td>Off-loading metatarsal heads</td>
<td>None</td>
<td>Tendinitis due to gait changes to avoid pain</td>
</tr>
<tr>
<td>Equinus</td>
<td>Off-loading metatarsal area by increasing flexibility of gastrocnemius/hamstring muscles</td>
<td>None</td>
<td>Gait changes; a shortened stride</td>
</tr>
<tr>
<td>Pes cavus</td>
<td>Off-loading metatarsal heads</td>
<td>None</td>
<td>Lateral instability Gait changes; a shortened stride Tendinitis of the abductor hallucis Hip/back pain due to instability</td>
</tr>
<tr>
<td>Gout</td>
<td>Off-loading individual metatarsal</td>
<td>Uric acid elevation; dietary control</td>
<td>Gait changes; limping Edema Chronic pain resulting in inactivity, weight gain, and decreased flexibility</td>
</tr>
</tbody>
</table>

TABLE 2: LEVELS OF METATARSALGIA INTERVENTION

Additions should include a rearfoot post with a 3-mm elevator, metatarsal bar or pad, and a soft durable topcover with a soft poron extension (Figure 2).

Metatarsalgia is a common foot complaint. The onset is often slow, but the symptoms can be unrelenting and last a lifetime. Systemic disease and deformity contribute to severity. By using the variety of options and additions available on a custom orthosis in conjunction with correct shoes, orthotic intervention can be an important component in improving the quality of life and reducing pain in individuals with metatarsalgia.

Cherri S. Choate, DPM, is an adjunct professor of applied biomechanics at Samuel Merritt College in Oakland, CA. She also is a physician at Kaiser Permanente.
Foot Care

Medical Center in Fremont, CA, and a medical consultant for ProLab Orthotics in Napa, CA. Paul R. Scherer, DPM, is a professor of applied biomechanics at Samuel Merritt College and is the CEO of ProLab Orthotics.

References