



Orthotic Prescription Writing for Patients with Diabetes

The goal is to reduce pressure and shear forces.

BY LAWRENCE HUPPIN, DPM

Preventing foot ulceration is a critical aspect of the overall treatment of diabetic patients. Ulcer prevention includes patient education, regular screening, use of proper shoes and socks, palliative care as needed and the use of orthotic devices specifically designed to reduce those forces that are likely to lead to ulceration. This article will take a closer look at the prescription and use of orthotic devices to prevent ulceration in the diabetic patient.

for the at-risk diabetic patient. This article will evaluate a number of criteria that may lead to ulcer formation and make specific orthotic recommendations based on each criterion.

Redistribution of Pressure

Pressure is the amount of force acting per unit area, for example, pounds per square inch. When prescribing orthoses that are designed to decrease pressure, it is critical to understand that the larger the surface area over which force can be dis-

In addition to close conformity to the arch of the foot, it should be noted that wider orthoses will distribute force over a larger surface area than more narrow orthoses. Rigidity of the device is also critical. Traditionally, softer orthoses have been prescribed for patients with diabetes and with a history of ulceration. In fact, however, softer “mushy” orthoses will simply deform under body weight and will not distribute pressure as effectively as more rigid orthoses.

Orthotic Prescription Recommendation:

To distribute pressure over the largest possible surface area, the orthosis should conform close to the arch of the foot, be at least as wide as the foot, and be rigid enough to resist deformation.

- **Cast:** For an orthosis to conform closely to the arch of the foot, it is recommended that the a non-weightbearing neutral suspension cast of the foot be taken with the sub-talar joint in neutral position, the midtarsal joint locked, and the first ray plantarflexed. Casting in a semi-weightbearing position often leads to ground reactive forces causing a flattening of the arch (dorsiflexion of the first ray) during casting. The resultant orthosis will have a lower arch height and will not conform as close to the arch of the foot.^{9,10}

- **Cast fill:** Prescribe a minimum cast fill. A minimum fill means that less fill is added to the medial arch of the positive cast, resulting in an orthosis that conforms closely to the arch of foot.

Continued on page 94

To most effectively reduce peak pressure on the plantar foot, an orthosis should act to distribute force over the largest possible surface area.

It's All About the Forces

The goal of the orthotic practitioner in prescribing orthoses for the at-risk diabetic patient is to provide an orthosis that decreases the forces that are likely to lead to foot ulceration. Traditionally, the primary goal when prescribing orthoses for this population has been to decrease pressure, or those forces that act horizontally on the plantar foot during ambulation. Although numerous studies have reported a relationship between increased pressure and ulceration,^{1,3} ulcer prevention is much more complicated. There is significant evidence that shear—or friction—forces play just as critical a role, and possibly a more critical one in ulcer etiology, and thus must be addressed when prescribing foot orthoses

tributed on the plantar foot, the less pressure will be applied to any one area of the foot. In addition, those pressures that would be considered normal and non-pathologic in the non-diabetic population may lead to ulcers in the diabetic patient.^{4,5}

To most effectively reduce peak pressure on the plantar foot, an orthosis should act to distribute force over the largest possible surface area. Such an orthosis would be one that conforms very closely to the arch of the foot and is rigid enough so as not to deform under body weight.^{6,8} Mueller and colleagues showed a reduction in peak plantar pressure of 16-24% using a total contact insert which acted to increase contact surface area by 27%.⁶



Orthotic Prescription (from page 93)

- **Width:** Prescribe orthoses to be wide or incorporate a medial flange in order to distribute force over as large of a surface area as is possible.

- **Material:** Use an orthosis shell material that is not prone to excessive deformation under body weight, for example, semi-rigid polypropylene.

Pronation in the Diabetic Patient

The diabetic patient with an excessively pronated foot may see increased plantar metatarsal head pressures compared to the non-diabetic patient. This is likely due to glycosylation of the midfoot ligaments causing limited joint mobility at the midtarsal joint (MTJ).¹¹ In a situation where there is normal mobility of the MTJ, heel eversion will result in inversion of the forefoot against the rearfoot. In the presence of limited joint mobility at the MTJ, the ability of the forefoot to invert is limited. In this situation, more pressure must be applied against the medial forefoot in order to invert the forefoot on the rearfoot. Several studies have confirmed this increase in submetatarsal pressure in the diabetic patient with limited joint mobility.¹¹⁻¹⁴

Orthotic Prescription Recommendation:

Diabetic patients are often prescribed softer accommodative types of orthoses with the idea that softer devices offer greater protection. While soft tissue supplement topcover materials should be included (discussed below), functional orthoses that act to control excessive pronation should be considered for the diabetic patient with excessive STJ pronation in order to reduce medial forefoot pressure.

- **Material:** Use an orthosis shell material that is not prone to excessive deformation under body weight, for example, semi-rigid polypropylene.

- **Pronation Control Features:** Deep heel cups, medial heel skives, wide orthoses and minimum cast fill will help control excessive STJ pronation.

Cushion and Pressure

In most people, the heel and forefoot fat pads provide adequate cushioning that acts to reduce pressure by compressing and splaying,

resulting in a redistribution of force. In the presence of diabetes, the fat pad under the heel and forefoot can become thinner and less effective in reducing pressure. Effects of diabetes on the fat pad include:

- 1) Atrophy of the fat pad due to peripheral vascular disease.

- 2) Glycosylation in poorly controlled diabetics that can lead to decreased integrity of the fat pad.^{15,16}

- 3) Anterior displacement of the forefoot fat pad secondary to digital contraction.¹⁷

found Poron® to have a significantly longer effective life when compared to other soft tissue supplement materials such as soft Plastazote® and Sorbothane®.²⁰ Tong and Ng investigated the amount of pressure reduction for different padding and insole materials. They found significant reduction in minimum and mean pressure with a combination of Poron® and firm Plastazote® when compared to barefoot and better pressure reduction when compared to Slow Recovery Poron® and Poron® + soft Plastazote®.²¹

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Abouaasha and colleagues looked at the relationship between the thickness of the fat pads and plantar foot pressure, and found a strong inverse relationship between thickness of the plantar fat pad and pressure under the metatarsal heads in diabetic patients.¹⁸

Cushioning Materials

Given the propensity for decreased natural cushioning in diabetics and the strong relationship between decreased fat pad and increased pressure, it is beneficial to include soft-tissue supplements in the form of cushioning materials when prescribing orthoses for diabetic patients. These soft tissue supplements should be included as part of a topcover on an orthotic device. There are many materials available and these include foams, rubbers, and viscoelastic materials. Although there is limited data indicating which of the cushioning materials are the best replacement for the natural cushioning provided by the fat pads, there is some evidence to help us determine the materials that are likely to be most effective.

Paton, et al. investigated the physical properties of materials used to fabricate orthoses designed for the prevention of neuropathic diabetic foot ulcers. They found that the most clinically desirable dampening material was Poron®.¹⁹ Campbell, et al.

Orthotic Prescription Recommendation:

- **Topcover:** A topcover with soft tissue supplement should be included on all orthoses for diabetic patients. Although the study by Tong and Ng showed the greatest reduction in plantar pressure with the use of Poron® and firm Plastazote®, firm Plastazote® is a difficult material to conform to an orthosis when producing a topcover, so for the time being, this author would recommend using Poron® alone for cushioning. Poron®, however, has a tendency to tear in response to shear forces, so it must be glued to a top layer of a material that is not prone to tearing. The current topcover recommendation is for 3mm or 4.5mm Poron® glued to a top layer of leather or 1.5mm soft EVA, either of which will prevent tearing of the Poron®.

- **Forefoot Extension:** For patients with significant forefoot fat pad atrophy, it is also recommended that a forefoot extension consisting of another 1.5mm—3mm thickness of Poron® be prescribed. This should extend from the distal edge of the orthosis to the sulcus. It is recommended that the extension not extend full length to the toes so as not to crowd the toe box of the shoe. Finally, we recommend that the cover be prescribed to be glued only on the posterior half of the orthosis. This allows addition or modification

Continued on page 96



Orthotic Prescription (from page 94)

of metatarsal pads as will be discussed later in this article.

Aperture

Tong and Ng also tested subjects with a 1st metatarsophalangeal joint aperture cut-out, bilaterally made of semi-compressed felt padding. They found that an aperture for the first metatarsal head decreased peak pressure more effectively than did the cushioning materials.²¹ These types of apertures can be a very effective method for decreasing localized pressure under a metatarsal head. The potential problem with these apertures is that they will transfer pressure to adjacent areas of the foot and could increase risk of ulceration under an adjacent metatarsal head.²²

Orthotic Prescription Recommendation:

Korex® and firm EVA are common materials used to add apertures to orthoses. To ensure proper placement of the aperture, it is recommended that the patient first be allowed to wear

ing forefoot pressure in patients with diabetes. Hastings, et al. evaluated total contact inserts and metatarsal pads in the reduction of peak plantar pressure. The purpose of the study was to determine the effect of metatarsal pad location on peak plantar pressure in subjects with diabetes

Leaving the anterior portion of the topcover unglued makes this process easy.

Shear

While pressure is an important contributor to ulcerations of the diabetic foot, shear forces also play a significant role. Hsi noted that patients with

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mellitus and peripheral neuropathy. Compared to the total contact insert alone, researchers found consistent plantar pressure reduction when the metatarsal pad in this study was located between 6 to 11 mm proximal to the metatarsal head line. Pressure reduction lessened as the metatarsal pad moved outside of this range and actually increased if the pad was located too distal of this range.²³ Hsi, et al. found that metatarsal pad application decreased maximal peak pressure

areas of normal plantar pressure values may still ulcerate, and patients with elevated plantar pressure may not.²⁶ Lavery, et al. said that foot pressure is a “poor tool” in predicting ulcers.²⁷ He and others note that foot ulcers do not necessarily occur at sites of peak pressure but may occur at sites of normal pressure magnitudes.²⁸⁻²⁹

The techniques discussed thus far to control pressure (vertical forces) do not necessarily control shear (horizontal forces or forces parallel to the skin). To reduce shear (friction), a primary goal is to reduce the coefficient of friction (COF). The lower the COF, the less friction and the less load there will be on skin. New materials which act to lower the COF at localized areas prone to ulceration may be beneficial in reducing ulcer formation.

Orthotic Prescription Recommendation:

Consider the application of Polytetrafluoroethylene (PTFE) pads in areas at risk for ulceration. A study by Lavery compared rate of ulcer formation in patients using orthoses without PTFE and those using orthoses with PTFE and found orthoses with PTFE to be 3.5 times more effective at preventing ulcers.³⁰

Summary

Foot orthoses designed to prevent ulceration in the diabetic patient should act to reduce those forces that lead to ulceration, namely pressure and shear.

The following orthosis prescription would fit the criteria described above as effective in reducing patho-

Continued on page 97

Compared to the total contact insert alone, researchers found consistent plantar pressure reduction when the metatarsal pad in this study was located between 6 to 11 mm proximal to the metatarsal head line.

the orthosis for approximately two weeks. During that time, indentations will appear in the topcover indicating the location of higher pressures. Using these indentations as a template, apertures can then be added. For example, if an indentation is seen under the 3rd metatarsal head, 3mm Korex® can be applied to the bottom of the topcover under metatarsal heads 1,2,4 and 5, creating a slot aperture for the 3rd metatarsal head. Always provide patient education and regular evaluation of adjacent metatarsal heads when an aperture is used.

Metatarsal Pads

Several studies have evaluated the use of metatarsal pads in reduc-

and pressure time integral under the second metatarsal head. In this study, teardrop shaped metatarsal pads made of polyurethane foam were used, and optimum pressure reduction was found when the pads were placed just proximal to the metatarsal head.^{24,25}

Orthotic Prescription Recommendation:

- **Topcover:** *In order to ensure easy access to add, remove, or adjust a metatarsal pad, it is recommended that the topcover, when first applied to the orthosis, not be glued on the anterior half of the orthosis.*

- **Metatarsal Pad:** *Metatarsal pads can be added to orthoses at the lab or added by the practitioner in the clinic.*



Orthotic Prescription (from page 96)

logic force on the plantar diabetic foot. It should be noted that this is not the only prescription that would fit the criteria. For example, although Polypropylene is the recommended material in the prescription below, any orthosis material that does not deform excessively under body weight could be used.

Casting Position: Neutral suspension cast with the foot held in subtalar joint neutral, midtarsal joint maximally pronated and the first ray dorsiflexed

Shell Material: Semi-rigid Polypropylene

Heel Cup Depth: Minimum of 18mm to control heel eversion associated with excessive pronation

Width: The orthosis shell should support the entire width of the foot. For most patients, this would be a “wide” or “medial flange” width orthosis.

Cast Fill: Minimum fill on the medial arch of the positive cast so

that the orthosis conforms close to the arch of the foot.

Rearfoot Post: A rearfoot post will stabilize the orthosis in the shoe and help prevent excessive STJ pronation.

Topcover: The most important aspect of the topcover is the cushioning materials, and the recommended cushioning material is Poron®. 3mm—4.5mm Poron® glued to leather or soft 1.5mm EVA is a recommended cover. The cover should be glued only on the posterior half of the orthosis so as to allow access to the anterior portion of the orthosis. This allows for easy application or modification of metatarsal pads and other additions.

Forefoot Extension: If there is significant forefoot fat pad atrophy, include a sulcus length extension of 3mm Poron®.

Special Additions: Special additions may include apertures to reduce localized metatarsal head pressures or the addition of PTFE pads to reduce the coefficient of friction at sites which are at most risk of ulceration. **PM**

References

¹ Armstrong DG, Peters EJ, Athanasiou KA, Lavery LA. “Is there a critical level of plantar foot pressure to identify patients at risk for neuropathic foot ulceration?” *Journal of Foot and Ankle Surgery* 37: 303-7 (July-August 1998).

² Veves A, Murray HJ, Young MJ, and Boulton AJM. “The risk of foot ulceration in diabetic patients with high foot pressure: a prospective study.” *Diabetologia* 35: 660-663. (July 1992).

³ Cavanagh PR, Bus SA. “Off-loading the diabetic foot for ulcer prevention and healing.” *J Am Podiatr Med Assoc.* 2010 Sep-Oct;100(5):360-8.

⁴ Lobmann R, Kasten G, Kasten U, Lehnert H. “Association of increased plantar pressures with peripheral sensorimotor and peripheral autonomic neuropathy in Type 2 diabetic patients. *Diabetes, Nutrition & Metabolism* 15: 165-168 (June 2002). 9

⁵ Maluf KS, Morley RE Jr, Richter EJ, Klaesner JW, Mueller MJ. “Monitoring in-shoe plantar pressures, temperature, and humidity: reliability and validity of measures from a portable device”

Continued on page 98



Orthotic Prescription (from page 97)

Archives of Physical Medicine and Rehabilitation 82: 1119-1127 (Aug 2001).10

⁶ Mueller MJ, Lott DJ, Hastings MK, Commean PK, Smith KE, Pilgram TK “Efficacy and mechanism of orthotic devices to unload metatarsal heads in people with diabetes and a history of plantar ulcers.” *Phys Ther.* 2006 Jun;86(6):833-42.

⁷ Tsung BY, Zhang M, Mak AFT, Wong MWN, “Effectiveness of insoles on plantar pressure redistribution.” *Journal of Rehabilitation Research & Development* 41: 767-774 (Nov-Dec 2004). 21

⁸ Chen WP, Ju CW, Tang FT. “Effects of total contact insoles on the plantar stress redistribution: a finite element analysis.” *Clinical Biomechanics* 18:S17-24 (July 2003). 22

⁹ McPoil, TG, et al; Comparison of three methods used to obtain a neutral plaster foot impression. *Phys Ther.* 1989

¹⁰ Davis I, et al; A comparison of 4 methods of obtaining a negative impression of the foot. *JAPMA.* 2002

¹¹ Zimny S, Schatz H, Pfohl M. The role of limited joint mobility in diabetic patients with an at-risk foot. *Diabetes Care.* 2004 Apr;27(4):942-6.

¹² Viswanathan V, Snehalatha C, Sivagami M, Seena R, Ramachandran A. “Association of limited joint mobility and high plantar pressure in diabetic foot ulceration in Asian Indians.” *Diabetes Research and Clinical Practice* 60:57-61 (Apr 2003).

¹³ Sauseng S, Kastenbauer T. “Effect of limited joint mobility on plantar pressure in patients with type 1 diabetes mellitus.” *Acta Medica Austriaca* 26:178181 (#5, 1999).

¹⁴ Fernando DJ, Masson EA, Veves A, Boulton AJ. Relationship of limited joint mobility to abnormal foot pressures and diabetic foot ulceration. *Diabetes Care.* 1991 Jan;14(1):8-11.

¹⁵ Klaesner JW, Hastings MK, Zou D, Lewis C, Mueller MJ. “Plantar tissue stiffness in patients with diabetes mellitus and peripheral neuropathy.” *Archives of Physical Medicine and Rehabilitation* 83: 1796-1801 (Dec 2002).

¹⁶ Gefen A, Megido-Ravid M, Azariah M, Itzchak Y, Arcan M. “Integration of plantar soft tissue stiffness measurements in routine MRI of the diabetic foot.” *Clinical Biomechanics* 16: 921-925 (Dec 2001).

¹⁷ Bus SA, Maas M, de Lange A, Michels RP, Levi M. “Elevated plantar pressures in neuropathic diabetic patients with claw/hammer toe deformity.” *Journal of Biomechanics* 38:19181925 (Sept 2005).

¹⁸ Abouaisha F, van Schie CH, Griffiths GD, Young RJ, Boulton AJ. “Plantar tissue thickness is related to peak plantar pressure in the high-risk diabetic foot.” *Diabetes Care.* 2001 Jul;24(7):1270-4.

¹⁹ Paton J, Jones RB, Stenhouse E, Bruce G. “The physical characteristics of materials used in the manufacture of orthoses for patients with diabetes.” *Foot Ankle Int.* 2007 Oct;28(10):1057-63.

²⁰ Campbell, GJ. “Compressive behaviour after simulated service conditions of some foamed materials intended as orthotic shoe insoles”./1984. *Rehabil. Res. Dev.*, 21, 57-65

²¹ Tong JW, Ng EY “Preliminary investigation on the reduction of plantar loading pressure with different insole materials (SRP—Slow Recovery Poron, P—Poron, PPF—Poron + Plastazote, firm and PPS—Poron + Plastazote, soft)”. *Foot (Edinb).* 2010 Mar;20(1):1-6. Epub 2010 Jan 18.

²² Armstrong DG, Liswood PJ, Todd WF. “Potential risks of accommodative padding in the treatment of neuropathic ulcerations.” *Ostomy Wound Manage.* 14: 44-46,48-49 (Aug 1995).

²³ Hastings MK, Mueller MJ, Pilgram TK, Lott DJ, Commean PK, Johnson JE. “Effect of metatarsal pad placement on plantar pressure in people with diabetes mellitus and peripheral neuropathy”. *Foot Ankle Int.* 2007 Jan;28(1):84-8.

²⁴ Kang JH, Chen MD, Chen SC, Hsi WL. “Correlations between subjective treatment responses and plantar pressure parameters of metatarsal pad treatment in metatarsalgia patients: a prospective study.” *BMC Musculoskelet Disord.* 2006 Dec 5;7:95.

²⁵ Hsi WL, Kang JH, Lee XX. Optimum position of metatarsal pad in metatarsalgia for pressure relief. *Am J Phys Med Rehabil.* 2005 Jul;84(7):514-20.

²⁶ Hsi WL, Ulbrecht JS, Perry JE, et al. Plantar pressure threshold for ulceration risk using the EMEDSF platform [abstract]. *Diabetes* 1993;42(S1):103a.

²⁷ Lavery LA, Armstrong DG, Wunderlich RP, et al. Predictive value of foot pressure assessment as part of a population-based diabetes disease management program. *Diabetes Care* 2003; 26(4):1069-73.

²⁸ Hsi WL, Ulbrecht JS, Perry JE, et al. Plantar pressure threshold for ulceration risk using the EMEDSF platform [abstract]. *Diabetes* 1993; 42(S1):103a.

²⁹ Murray HJ, Young MJ, Hollis S, et al. The association between callus formation, high pressures and neuropathy in diabetic foot ulceration. *Diabet Med.* 1996 Nov;13(11):979-82.

³⁰ Lavery L, et al. “Wear and Bio-

mechanical Characteristics of a Novel Shear-Reducing Insole with Implications for High-Risk Persons with Diabetes” *Diabetes Technology & Therapeutics* 2005.



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