Orthotics & Biomechanics

Incorporating Friction Management into Orthotic Therapy

Here's how to treat and prevent ulcers, calluses, and blisters.

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__Disclosure:__ Dr. Huppin serves as Medical Director for ProLab Orthotics, manufacturer of foot orthoses and distributor of the PTFE Patch™ discussed in this article.

Traditionally, prevention and treatment of calluses and ulcers has focused on reducing pressure (or vertical forces). Significant literature, however, points to friction (horizontal forces) as an important contributor to the formation of calluses and ulcers.[3,4,7,8] In addition, friction is likely the primary force leading to blister formation.[9]

How Does Friction Contribute to Skin Damage, Blisters or Callus?

Callus or skin inflammation usually precedes ulceration. These signs can be perceived as early warning signs but should really be more importantly considered increased horizontal load and the first signs of irreversible skin failure.

Skin can fail either because of:

- too much vertical load (pressure)
- too much horizontal load (friction)
- too many cycles (steps)
- or all of the above

Essentially, the loads are introducing more energy than the skin tissue can tolerate or recover from. Our intervention, until now, primarily addressed the vertical load by attempting to off-load an at-risk area. This article will focus on a practical method to decrease horizontal load (friction).

What Is Friction?

Simply put, friction is rubbing. To be a little more sophisticated, there are perpendicular loads we call pressure and there are parallel or horizontal loads we call friction. PF Naylor found that the higher the perpendicular load, combined with the higher the friction load, the quicker the damage to the skin.[12] Even at the same perpendicular load but with a higher friction load, the quicker skin damage occurred. Friction may be the missing link in producing the variable distribution we see in ulcer formation. Increased friction can make a small vertical load very destructive to skin.

How Can We Reduce Friction?

Traditional methods of reducing friction inside a shoe have been very limited. These have included the use of custom or prefabricated orthoses to limit excessive motion of the foot that lead to friction. Socks of new materials often have a lower coefficient of friction than do traditional cotton socks. Finally, moisture (which in-

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New Concepts and Studies

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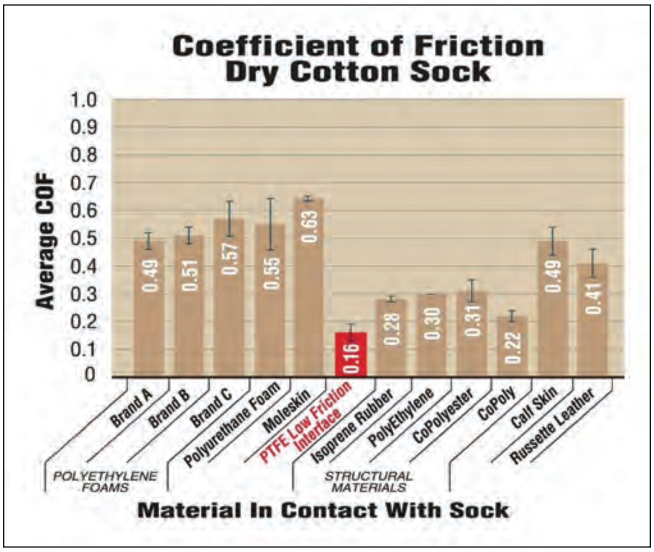

Figure 1: Coefficients of Friction of common orthotic materials compared to PTFE in the presence of a dry cotton sock

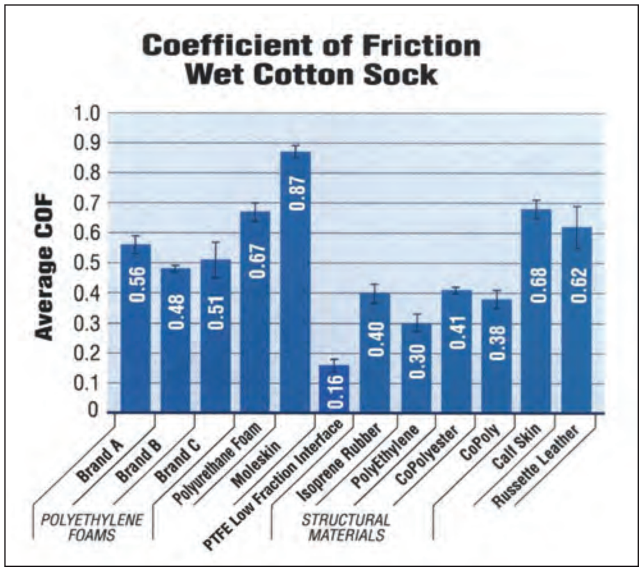

Figure 3: Coefficients of Friction of common orthotic materials compared to PTFE in the presence of a wet cotton sock

creases the coefficient of friction of almost all materials) can be managed with the use of antiperspirants and socks that wick moisture away from the foot.

In addition, some materials cause less friction than others (these materials have a lower "coefficient of friction" (COF). To prevent skin damage caused by friction, we need to use materials in shoes and next to the foot that have lower COFs.

What Orthotic and Shoe Materials Have the Lowest COFs?

The bar graph (Figure 1) shows the different materials we use in shoes and orthoses.

Typical foams and orthotic top covers are in the COF 0.5 to 0.6 ranges. A material called PTFE (polytetrafluoroethylene) has a COF of about 0.16. That is incredibly low for any material. Ironically we normally use the higher COF materials mainly because they are soft and we think they are better for the foot.

What Is PTFE?

PTFE is a new material with an extremely low coefficient of friction that is also used for vascular and nerve sutures (as well as for artery grafts.) It allows the suture material or blood components to move through the vessel with little friction, therefore limiting the trauma of the suture or blood flow.

PTFE's Friction Reduction Abilities Not Affected by Moisture

In trying to reduce skin trauma in-

To prevent skin damage caused by friction, we need to use materials in shoes and next to the foot that have lower COFs.

Figure 2: PTFE suture

side a shoe, moisture is an enemy, but very common. Moisture may occur due to sweat, puddles or rain; regardless, almost every material in a shoe will have a higher COF when it is moist. Friction between a sock and every common orthotic topcover material increases when the foot sweats. This directly increases friction on the skin.

PTFE is unique in that it is the only material that is used inside a shoe or on top of an orthosis which does not have an increased coefficient of friction when it gets wet. The "Wet Sock" bar graph (Figure 3), when compared to the "Dry Sock" graph (Figure 1) , demonstrates the effect of moisture on common topcover materials. Note that the only material that does not show an increase in the COF in the presence of moisture is PTFE.

PTFE Patch™ for Orthoses and Shoes

PTFE appears to be a logical solution to reducing horizontal loads that produce shear and ultimately plantar skin failure. Research by PF Naylor in the fifties confirms that skin shear is directly related to skin failure.[12] Recent research seems to demonstrate that shear-reducing materials prevent skin failure.[3,8,23]

For use on orthoses and shoes, PTFE is available as self-adhesive patches to be applied in areas of increased friction.

PTFE patches™ come in three configurations; small ovals, large ovals and 1st ray (Figure 4). The 1st ray configuration is shaped to go under the hallux and the first and second metatarsal heads. They are designed to be trimmed to fit (Figure 5) and should be trimmed to extend beyond the callus or ulcer by no more than 1cm.

PTFE Patches™ can be applied to orthoses or to shoes. They should never be applied to the skin.

Orthotics and Friction Management

Foot orthoses have traditionally been used to alter abnormal motion and redistribute pressure. Rarely are

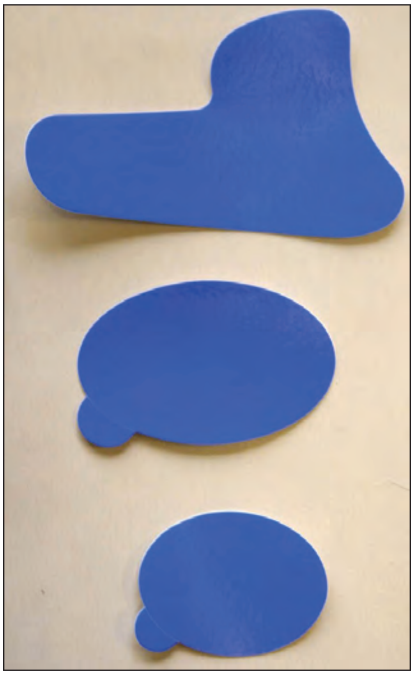

Figure 4: PTFE Patches™: First ray, large oval and small oval

orthoses prescribed in such a manner as to include the management of the deleterious effects of friction. Foot orthotic practitioners do, however, see many friction-related issues that could benefit from friction management. The PTFE Patch™ can help improve clinical outcomes with foot orthoses by adding the friction-reducing component to the orthosis role of altering pressures and motion.

Standard orthotic cover materials have relatively high coefficients of friction, and friction increases when they get moist. Adding localized friction-reducing materials, such as the PTFE Patches™, to orthoses and orthotic covers will significantly reduce localized friction due to their extremely low coefficient of friction and the fact that PTFE maintains all of its friction-reducing ability when wet.

Common uses of PTFE in conjunction with orthotic devices include:

- To extend wear of orthotic topcovers
- To enhance orthotic treatment

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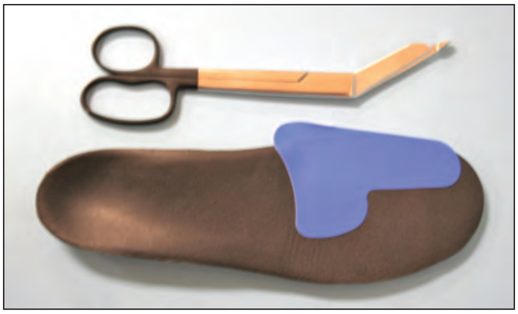

Figure 5: First ray PTFE Patch™ on right orthosis. Patch extends beyond medial aspect of cover and can be trimmed with scissors

of sub-metatarsal ulcers and calluses

- To enhance treatment of hallux pinch callus and hallux ulcers
- To decrease navicular irritation in patients with adult acquired flatfoot and patients with accessory navicular
- To reduce posterior heel irritation and shoe wear

Extending the Life of Orthotic Topcovers by Managing Friction

PTFE placed locally can be used to decrease wear and extend the life of orthotic topcovers. In most cases, topcovers must be replaced when localized areas, such as under a metatarsal head or under the hallux, become excessively worn. Because much of this wear is due to friction, by using a small piece of PTFE at the site of excessive wear, local friction is reduced and the topcover life will be extended

How to Use PTFE to Extend Topcover Life

1) After dispensing orthoses, have the patient wear them for several weeks. When the patient returns for follow-up, note any areas that are starting to wear on the cover. Point these out to the patient and educate your patient about PTFE. A PTFE Patch™ can then be applied directly to the topcover.

2) If a patient comes in with older orthoses for topcover replacement, take this opportunity to demonstrate areas of excessive wear and explain to the patient that they can extend the life of their new topcovers by adding a PTFE Patch™ to the new topcover.

3) The most common areas to place a PTFE patch to extend topcover life are in those areas that are most likely to show excessive wear. These include under the hallux and under the metatarsal heads.

Using Friction Management with Foot Orthoses to Prevent Sub-Metatarsal Ulcerations and Callus Formation.

The goal in prescribing orthoses for populations at-risk for sub-metatarsal calluses and ulcerations is to provide an orthosis that decreases the forces that are likely to lead to foot ulceration. This is true in all patients at risk for these conditions but is particularly critical for the diabetic population.

Standard orthotic cover materials have relatively high coefficients of friction, and friction increases when they get moist.

Traditionally, the primary goal when prescribing orthoses or insoles for this population has been to decrease only vertical forces (pressure). Although many studies have reported a relationship between increased pressure and ulceration,[1,10,14] callus and ulcer prevention is much more complicated. There is significant evidence that horizontal forces (also known as shear or friction) play just as critical a role, and possibly more critical, in callus ulcer etiology and thus must be addressed when prescribing foot orthoses to treat these conditions.

Figure 6: Oval PTFE Patch™ placed sub-metatarsal on a prefabricated Plastizote insole

Pressure Redistribution

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 distributed 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.[15-16]

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]

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 a more rigid orthosis.

Other methods to decrease vertical forces (pressure) include:

- Wider orthoses
- Metatarsal pads
- Apertures
- Cushioning materials

Friction Reduction

While pressure is an important contributor to sub-metatarsal callus

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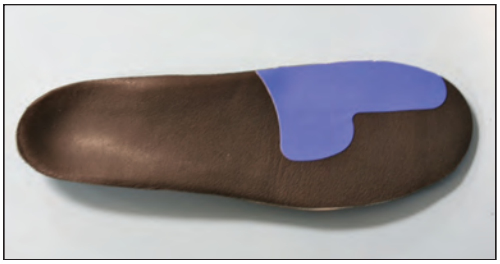

Figure 7: First ray PTFE Patch™ applied to right orthosis

formation and ulcerations of the diabetic foot, shear forces also play a significant role. Hsi noted that patients with areas of normal plantar pressure values may still ulcerate and patients with elevated plantar pressure may not.[20] Lavery, et al. said that foot pressure is a "poor tool" in predicting ulcers.[21] 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.[20,22]

Traditional orthotic modifications that are used to reduce pressure (vertical forces) do not necessarily control friction (horizontal forces). To reduce friction a primary goal is to reduce the coefficient of friction. The lower the COF, the less friction and the less load there will be on skin. New materials such as PTFE which act to lower the COF at localized areas prone to ulceration may be beneficial in reducing ulcer and callus formation.

Orthotic Prescription Recommendation

Along with traditional orthotic modifications which reduce pressure, consider the localized application of local PTFE under the metatarsal heads in areas at risk for ulceration and callus formation. 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.[23]

PTFE Patches™ are an easy method to provide localized friction reduction and should be applied to the cover of the orthosis (Figure 6) directly under the metatarsal head at risk for callus or ulceration. For easiest application, let the patient wear their orthoses for a week or two. After a week or so of use, the cover will start to show wear under the metatarsal heads that are most at risk of callus formation or ulceration. An oval PTFE Patch™ should be applied directly to the topcover at this site.

For a callus or ulcer under a single metatarsal head use a small oval PTFE Patch™. For a patient with more generalized callus formation under multiple metatarsal heads, use a large oval patch.

Using Friction Management to Treat and Prevent Hallux Pinch Callus and Hallux Ulceration

Medial hallux pinch callus is another common callus of the feet. Although callus is the most common evidence of skin damage in this area, ulcers and blisters are not uncommon. Effective friction management can enhance clinical outcomes when treating this common complaint.

Medial hallux pinch callus etiology almost always includes a lack of motion at the first metatarsophalangeal joint (functional hallux limitus). If the hallux is not able to dorsiflex during gait, then the foot is forced to externally rotate in order to propel forward. This leads to friction and pressure at the medial hallux.

The orthosis designed to treat medial hallux pinch callus and ulceration must play two roles. First, it must act to reduce the effects of functional hallux limitus by enhancing first MPJ dorsiflexion during gait. To accomplish this, the orthosis should be prescribed to include a minimum cast fill and modifications designed to prevent eversion of the heel including a deep heel cup and medial skive. It is also critical that the first ray be plantarflexed during the casting process.

In addition, application of a material with an extremely low coefficient of friction placed directly under the hallux will decrease friction directly at the site of the callus or ulcer. The first ray PTFE Patch™ is designed specifically for the hallux. They come in left and right and are shaped to extend under the hallux itself and under the first and second metatarsal heads as shown in Figure 7. The PTFE Patch™ should be placed only under those areas at-risk for formation of a callus or ulcer. If there is no callus formation under either the first or second metatarsal heads, then those portions of the patch should be trimmed away.

Using Friction Management to Reduce Navicular Irritation

One of the most common painful prominences of the foot is the enlarged or prominent navicular. This condition is often seen in conjunction with adult acquired flatfoot (posterior tibial tendon dysfunction) and accessory navicular. In both of these situations the navicular is excessively prominent and is prone to irritation by the shoe or orthosis. This leads to pain and skin damage including callus formation, blistering and ulceration.

Orthotic devices are often used to reduce damaging forces on the navicular. These orthoses, however, have traditionally focused only on reducing pressure and rarely on managing friction. Better clinical outcomes can be achieved by reducing both types of damaging forces.

The two goals when prescribing orthoses designed to prevent skin damage from a prominent navicular are to:

1) Reduce pressure on the navicular with the use of an orthotic's sweet spots and/or accommodations surrounding the prominence (such as a Poron™ horseshoe pad). Cushioned topcovers can then be applied over the accommodations.

2) Reduce friction at the navicular with the use of friction-reducing materials such as a PTFE Patch™.

Using PTFE to Reduce Navicular Irritation

Proper placement of the PTFE Patch™ can be achieved by marking the painful portion of the navicular with lipstick and then holding the orthosis to the foot. The lipstick will transfer to the topcover of the orthosis. Circle this area with a pen and then wipe off the lipstick. An oval PTFE Patch™ can then be applied directly to the topcover.

If the irritation is from a shoe, there will usually be a worn area on the shoe where it rubs against the navicular prominence. You can place an oval PTFE Patch™ directly on the shoe.

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Using Friction Management to Reduce Posterior Heel Irritation

Patients with Haglund's deformity and retrocalcaneal exostoses will often experience excessive pressure and friction as the prominent portion of the heel rubs against the shoe. This excessive force can lead to trauma to both the foot and the shoe. Erythema, blisters and callus formation can occur on the posterior heel and excessive shoe wear is common on the the interior heel of the shoe.

Using Friction Management to Protect the Posterior Heel

Friction can be reduced on the posterior heel by limiting excessive motion of the calcaneus in gait and by applying a friction-reducing material to the interior posterior shoe. To reduce motion, prescribe prefabricated or custom orthoses to limit arch collapse and heel eversion.

In addition, PTFE in the form of the large oval PTFE Patch™ can be placed within the heel counter of a shoe to reduce friction on the posterior heel. By placing PTFE in the heel counter, friction between the foot and the shoe are reduced, protecting the skin and extending the life of the shoe.

Summary

Friction plays a significant role in the formation of ulcers, calluses and blisters, yet there has been very limited ability to alter friction in a therapeutically effective manner. Traditional methods of friction reduction have included the use of orthoses to limit excessive motion that leads to friction and moisture-reducing techniques such as socks that wick moisture away from the foot. These methods do not, however, address reduction of damaging shear forces at the localized area of potential skin trauma.

Common orthotic cover materials tend to have relatively high coefficients of friction and do little to reduce localized shear forces that damage skin.

A new material, polytetrafluoroethylene (PTFE) has unique properties that include an extremely low coefficient of friction relative to other materials commonly used on orthotic devices and the ability to maintain this low coefficient of friction when wet—a critical feature when used in a shoe.

PTFE is available as a self-adherent patch that can be applied to either orthoses or shoes in order to decrease shear forces in localized areas that are at risk for skin trauma. In combination with off-loading techniques to reduce vertical forces, PTFE should be considered a primary tool to reduce the risk of plantar ulcers, blisters and calluses. **PM**

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