Plantar Fascia Grooves in Foot Orthoses

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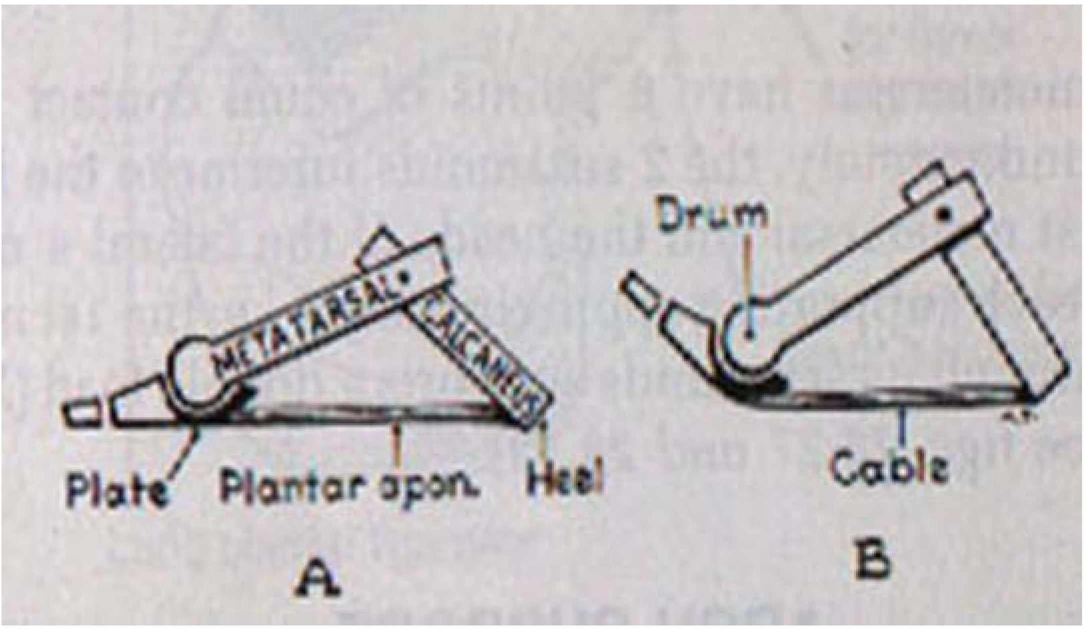
It is widely acknowledged that the foot should be a supportive structure to resist the forces that are applied to it during the propulsive or push of phase of gait. To do this the arch of the foot should be become elevated and the foot becomes more supinated. There are a number of ways in which the foot can do this, but the most efficient and widely recognized is the windlass mechanism, first described by Hicks (1954):



The windlass mechanism comes about as the plantar aponeurosis or plantar fascia, which primarily attaches to the heel (calcaneus) and the base of the proximal phalanx of all the toes, with the base of the first toe (hallux) being the strongest. When the hallux is dorsiflexed at the first metatarsophalangeal joint, it acts as a lever that winds the plantar fascia around the 'drum' of the first metatarsal head (the "windlass effect"). This has the effect of shortening the distance between the hallux and the heel (it raises the arch). During walking, this windlass effect only starts when the heel comes off the ground (the hallux essentially dorsiflexes, by remaining flat on the ground as the foot moves). This has the effect of making the foot a rigid and stable structure when the propulsive forces from above are applied. As the medial (inside) part of the windlass mechanism (the part attached to the hallux) is more powerful the medial side of the arch raises higher, which has the effect of supinating the foot and externally rotating the leg. As this occurs when the opposite leg is in the swing phase and the pelvis is rotating forward on this swing limb, there is an external rotation force in the leg that is still on the ground. This coincides with the foot supinating from the windlass effect.

As a result of this windlass effect more attention has been given to this mechanism (Aqunio & Payne, 1999) as it is important to more foot function. The clinical significance of the mechanism was first recognized by Dannenberg (1993) who described the clinical entity of functional hallux limitus. In this condition, there is a full range of motion at the first metatarsophalangeal joint during non-weightbearing, but for some reason during weightbearing, the joint does not want to dorsiflex, so the windlass mechanism cannot get established. The result of the windlass not getting established is that the mid foot collapses during propulsion and coordination between the pelvic and limb rotating externally during the opposite leg swing is not in coordination with the foot that should be supinating. There compensation can result in a number of problems that are commonly seen in the foot. As well as functional hallux limitus, a number of other things can interfere with the establishment of the windlass mechanism, such as foot orthoses that are too high in the anterior part of the arch (these inhibit the first metatarsal from plantarflexing, and this the first metatarsophalangeal joint from dorsiflexing). Roukis et al (1996) show that the first metatarsal must be able to plantarflex so that the first metatarsophalangeal joint can dorsiflex. Hillstrom et al (2002), have shown that the foot pronates more when the anterior part of the arch is too high on a foot support. The lack of the windlass working can cause the foot to pronate (flatten) excessively, but the pronated foot (form other causes) is not related to whether the windlass mechanism works or not (Aqunio & Payne, 2001).

Our recent work, as yet unpublished, as identified several characteristics of the windlass mechanism that have implications for foot function. The range of motion at the first metatarsophalangeal joint appears to vary from 4 to 22 degrees between individuals before the windlass starts working. The consequences of a larger range of motion before the windlass starts working is that the heel will already be off the ground and the midfoot is prone to collapse during walking as the windlass has not initiated. This is illustrated in the following two pictures. The picture on the left is a foot in which the windlass has started immediately on heel lift (and the arch rises) and the picture on the right is when there is a greater range of motion before the windlass initiates and the midfoot collapse:

Karpel-Bargess et al (1998) showed that when the onset of the windlass was delayed, there was more pronation of the rearfoot. The second characteristic that our work has identified is that the force needed to establish the windlass varies widely between people. In some people, the force needed is low and in others it is very high.

In reality it is speculated that what was previously considered as a functional hallux limitus is probably a combination of the timing of windlass initiation and the force needed to get it established. These exist on a continuum with, at one extreme there being a delay in windlass initiation and a high force needed to establish it, which is probably what functional hallux limitus is. At the other extreme there is an immediate onset of the windlass with heel lift and a low force to establish it.

As this windlass mechanism is important for normal function and can increase the risk for tissue damage if it is not functioning properly, it is important that foot orthoses or supports do not inhibit this mechanism and, preferably, enhance it. Our preliminary unpublished work has shown that in general foot orthoses do reduce the force needed to establish the windlass, but not all foot orthoses do this. It has been possible to identify the design features of foot orthoses that do result in a reduction in the force needed to establish the windlass mechanism and assist in earlier initiation of the windlass mechanism. This work is ongoing and will be published soon.

One design feature that has been used in foot orthoses is a groove (or ‘channel’) to accommodate the plantar fascia. In the past this has been mostly used as a comfort measure in those who have a very prominent plantar fascia in the arch area. Our work has shown the groove, that is traditionally placed in the midfoot area can lower the force needed to establish the windlass mechanism. However, this did not occur in all subjects. Some subjects responded to the groove in the midfoot and some when the groove was located further forward. Further work will try to identify why some responded and some did not.

As it is pretty clear that windlass function is very important to foot function and a plantar fascia groove should be incorporated into a foot orthoses, it would make sense that the groove should both be in the midfoot as well as further forward to achieve optimum function of the windlass mechanism.

Current research into this includes the ongoing work mentioned above, as well as a clinical trial comparing outcomes between patients using an orthoses with a full length plantar fascial groove and an orthoses with no groove.

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Prepared by Craig Payne, Department of Podiatry, LaTrobe University, Melbourne, Australia