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REVIEW

Foot orthoses and lower extremity pathology

C. S. Nicolopoulos,* J. Black,† E. G. Anderson,† P. V. Giannoudis‡

**Ortho-Foot Center, Department of Podiatry, Nicosia, Cyprus, †Western Infirmary, Department of Orthopaedics, Glasgow, UK, ‡St James Hospital, Department of Orthopaedics, Leeds, UK*

SUMMARY. Foot orthoses are used widely to treat the symptoms of hindfoot and forefoot malalignment. From the literature it appears that such interventions have been remarkably successful but quantitative studies have produced contradictory results. Many factors may be responsible for these conflicting results, especially inappropriate prescription of foot orthoses. Many overuse injuries of the lower limb can be relieved with the use of foot orthoses, but it is not clear how an orthosis can produce this effect. The main aim of this review paper is to offer an overview of the use of foot orthoses and their relationship with foot biomechanics. © 1999 Harcourt Publishers Ltd

INTRODUCTION

Foot orthoses have been used to treat numerous problems within the foot, including overuse syndromes and abnormal foot function.[1–9] The most commonly treated abnormality is excessive pronation.[5,6,8–13] Pronation and supination determine the extent to which the foot will behave as a flexible or rigid body during the gait cycle. When the foot meets the ground, pronation is produced by simultaneously everting the calcaneus, and adducting and plantarflexing the talus while supination occurs through the opposite movements of calcaneal inversion.[14,15] These two movements are responsible for the compensatory actions in gait. Compensation is a change of structure, position or function of one part of the body in any attempt to adjust to a deviation of structure, position or function of another part. Normal compensation is the motion of the foot (within the limits of the range of motion of the joints) which adjusts to any irregularities of the supporting surface or to deviations in the position of any part of the trunk or lower extremity. Abnormal compensation is the motion in which the foot moves to adjust for abnormal structure or function of the trunk or lower extremity. Structural or position abnormalities create a recurrent or persistent demand for compensation that may result in pathological change.[16] When structural deformities exist, normal and abnormal compensation is accomplished by the subtalar joint (STJ) and the midtarsal joint (MTJ) by their triplane axes of motion. The STJ compensation minimizes the disruption of human locomotion created by foot deformities.

Correspondence to **C. S. Nicolopoulos**, Ortho Foot Center, 19 Leoforos Staurou, 2035 Strovolos, Nicosia, Cyprus.
Tel: +3572 496684; Fax: +3572 496687; E-mail: dionysis@ucy.ac.cy

Normal hindfoot to forefoot relationship is produced when the vertical bisection of the hindfoot is perpendicular to the forefoot, using the prone position described by Root.[16,17] This happens only in a perfect foot and individual variation and triplanar movement of the tarsals may allow the forefoot to be in an inverted or everted position. If the forefoot is everted relative to the hindfoot, it is called forefoot valgus. If the plantar aspect of the foot is inverted relative to the hindfoot, it is called forefoot varus. If the inversion contracture of the forefoot upon the rearfoot occurs at the midtarsal joint, it produces forefoot supination, which is often referred to as forefoot varus. If the hindfoot is in an everted or inverted position when the rest of the foot is neutral, it is called rearfoot valgus or varus respectively. Excessive pronation or supination causes delay in external and internal rotation movements. A less efficient and less powerful gait is a consequence of these biomechanical deformities which produce overuse syndromes.[5,15,18,19]

Although many overuse injuries of the lower limb can be relieved by foot orthoses,[20–25] it is not clear how this is achieved. Many treatment strategies have an unclear outcome, as is evident from a paucity of effective audit.

TREATMENT OF LOWER LEG PROBLEMS, FOOT ORTHOSES AND FOOT BIOMECHANICS

Many lower leg problems are amenable to conservative treatment.[3,5,7,12,21,26] Conservative measures are usually advised first as they carry fewer potential problems than surgery.[19] A central tenet of conservative treatment is the use of foot orthoses.

In the UK, the annual National Health Service budget for orthoses is approximately £38 million, of which 30% is spent of foot orthoses and footwear. A foot orthosis is usually prescribed for overuse syndromes, to resist excessive pronation or supination of the foot and restore normal alignment to the entire lower limb.[3,5,7,12,13,25] Problems said to be associated with excessive pronation are plantar fasciitis, calcaneal heel spurs, Achilles tendonitis, interdigital neuritis, metatarsalgia, knee, hip, and back pain.[12,19,20,25,27]

CALCANEAL EXOSTOSIS

Calcaneal exostosis may be associated with bursitis overlying the posterior-lateral part of the calcaneus.[19,25,28,29] There may be abnormal rearfoot inversion during heel strike with excessive shearing forces between the heel counter of the shoe and the foot. Orthotic treatment of this deformity involves control of abnormal supination by the means of functional foot orthoses. If this fails, surgery may be indicated.

CLAWTOE DEFORMITY

This deformity affects the proximal and distal interphalangeal joints of the second to fifth toes. Hammer toe deformity is another form of this deformity, usually affecting the proximal interphalangeal joint of one or two digits rather than all digits of the claw deformity. Claw deformity occurs in pes cavus and other neuromuscular diseases. Orthotic treatment involves a foot orthosis with a metatarsal 'dome' with interdigital silicone splintage.

RELATIVELY ELONGATED SECOND METATARSAL

In this condition the second metatarsal is longer than usual. Because of this elongation, the metatarsal head is subjected to increased force during the propulsive period of gait where the foot changes from a low gear (lateral forefoot loading) to high gear (medial forefoot loading) mechanism.[19,29] The resulting high force produces plantar callus beneath the second metatarsal head. Mallet toe due to a tight shoe box is a secondary effect of this deformity. Orthotic treatment involves accommodative foot orthoses placed under or proximal to the metatarsal heads.

HALLUX LIMITUS AND HALLUX RIGIDUS

In the condition of hallux limitus there is a restriction of dorsiflexion (<65°) of the first metatarsophalangeal joint. Hallux limitus is associated with a first ray, which may hypermobile, longer than normal and dorsiflexed. Hallux rigidus is a late stage of this deformity. Orthotic treatment involves control of the motion of the foot and hallux by a stiff metal or carbon fibre extension at the toe box (Morton's plate). This also can be inserted between layers of the sole.

HINDFOOT AND/OR FOREFOOT ALIGNMENTS SYNDROME

This condition is associated with excessive forefoot varus or valgus and rearfoot varus or valgus or a combination of both. Forefoot varus may be associated with a plantarflexed fourth or fifth metatarsal. In order to treat a forefoot varus deformity properly, a negative impression or cast of the foot must be taken to capture the hindfoot to forefoot relationship when the subtalar joint is in the neutral position. Appropriate modifications on the positive cast allow soft tissue displacements, a shell or plate is moulded along the plantar contour. An angled medial wedge is then placed under the distal medial part of the shell. The biomechanical role of this device is to put the subtalar joint in a more favourable position during midstance to bring the medial part of the forefoot to the ground. A forefoot varus deformity may be associated with a flexible plantarflexed first ray, and the major concern of the functional foot orthosis is to dorsiflex the plantarflexed ray to the same level as the other metatarsals. Forefoot varus or valgus with a rigid plantarflexed first ray requires the use of an appropriate post with a first ray cut to accommodate the plantarflexed first ray.

Forefoot valgus may be associated with a congenital plantarflexed first ray in which the lesser metatarsal heads describe a common plane, perpendicular to the sagittal bisection line, but the first metatarsal head lies more plantar than the other metatarsal heads. Furthermore, forefoot valgus may be associated with a plantarflexed second metatarsal head, in which the plane described by the other metatarsal heads is perpendicular to the sagittal calcaneal bisection line, but the second metatarsal head is plantar to the common plane described by the other metatarsal heads. After the fabrication of the positive model and the construction of the shell, an angled lateral wedge or post is then added to the plantar anterolateral shell bringing the bisection of the hindfoot in vertical position. In flexible forefoot valgus, the orthosis will limit excessive subtalar pronation and prevent lateral hindfoot instability. In rigid forefoot valgus, the biomechanical function of the post in the orthosis is to limit the abnormal supinatory compensation of the subtalar joint as the medial forefoot touches the ground and to assist the foot in the propulsive period of gait using the high-gear push off, rather than the low gear one used in an uncompensated rigid forefoot valgus deformity.

In rearfoot varus, the hindfoot is in an inverted position when the forefoot is neutral. Because of the

excessive inversion of the rearfoot, initial heel strike occurs along the postero-lateral edge of the calcaneus. Since rearfoot varus is an osseous deformity, orthotic treatment is based on the accommodative type of foot orthosis (or sometimes functional foot orthosis) with a rearfoot varus post to control and decrease the need for compensatory subtalar pronation during the gait cycle. The post works by bringing the weightbearing surface to the medial rearfoot, rather than forcing the patient to pronate in order to bring the medial forefoot to the floor. The combination of rearfoot varus with forefoot valgus is the most commonly observed. The basic principle of orthotic treatment is to put the talo-navicular joint as closely as possible to its neutral position. In a rearfoot-forefoot varus combination deformity, orthotic treatment uses a medial forefoot post to bring the rearfoot to vertical and then adds a separate rearfoot post to tilt the entire device laterally. In a rearfoot varus combined with forefoot valgus, foot orthoses are dependent on the size of the deformity and the relative compensation. If there is large rearfoot varus deformity compensated by subtalar joint pronation, then primary consideration in orthotic treatment is given to the control of rearfoot motion. An equal rearfoot and forefoot deformity requires forefoot valgus posting to bring the rearfoot to a vertical position. When the forefoot valgus deformity is greater than the rearfoot varus, a forefoot post should be used with an angle determined by subtracting the rearfoot angle from the forefoot angle, measured in a non-neutral casting position. In a rearfoot varus deformity, combined with a flexible plantarflexed ray deformity, an orthosis with a rearfoot varus post and a 2–5 bar forefoot post should be used to control excessive pronation of the subtalar joint during the contact period. In the same condition, if the plantarflexed first ray is rigid, an accommodative orthosis should be used with a first ray cut out.

INTERDIGITAL NEURITIS (MORTON'S NEUROMA)

This condition is characterized by metatarsal pain combined with a radiating pain (burning paresthesia-numbness) in the third and fourth toes.[20] The next most common locations are between the second and third and then the fourth–fifth metatarsals. Pain in the forefoot during standing or walking is a typical symptom. Relief of pain can sometimes be achieved by removing the shoe and massaging the forefoot. These symptoms suggest a mechanical problem of the foot due to rotational movements of the forefoot. Orthotic treatment is based on the control of the rotational movements of the forefoot using functional foot orthoses. Transverse movements are very difficult to control by means of functional foot orthoses. A metatarsal pad is another option and can also help by causing increased dorsiflexion of the metatarsals and therefore proximal phalanx plantar flexion, which decreases the angulation of the digital nerves as the course underneath the distal edge of the inter-metatarsal ligament.

FIRST RAY DEFORMITIES

Plantarflexion first ray deformity

A plantarflexed ray deformity may occur either as a structural deformity, i.e. congenitally plantarflexed as in pes cavus or positional deformity, and compensated plantarflexed as in a supinated foot. Pain under the first metatarsal due to pressure is very common. When the plantarflexed ray deformity is congenital, the initial goal of orthotic therapy is to accommodate the plantar position of the first metatarsal head. Because this deformity behaves almost identically to the forefoot valgus, an accommodative orthosis can be used with a first ray cut out. The biomechanical role of the foot orthoses is to allow the forefoot to load smoothly from the lateral to the medial metatarsal heads as untreated, the first metatarsal is loaded first rather than the fifth, with normal subtalar joint pronation during the contact period.

Shortened first metatarsal

In some individuals, the first metatarsal may be so shortened that the first ray is unable to plantarflex through the range necessary for the midstance phase of the gait cycle. Thus the first ray is unable to participate in the normal distribution of the high ground reaction forces at this stage in the gait cycle and the neighbouring metatarsals are subjected to higher forces than normal. Orthotic treatment requires an extension of the functional foot orthoses (Morton's extension) placed beneath the first metatarsal head to participate in the distribution of high ground reaction forces and control the hyperpronation.

Dorsiflexion first ray

Dorsiflexed first ray due to overactivity of tibialis anterior or caused by weakness of peroneus longus is also called a metatarsus primus elevatus. This deformity does not evert or invert the forefoot relative to the perpendicular to the sagittal calcaneal bisection line. Using functional foot orthoses with a 2–5 bar post or a varus post under the lesser metatarsals, an attempt is made to control the everted rearfoot motion which improves the function of peroneus longus and thus the plantarflexion of the first ray. Orthotic treatment using a small metatarsal pad proximal to the dorsiflexed metatarsal, shifts the ground reaction forces away from the neighbouring metatarsal heads.

PLANTAR FASCIITIS AND CALCANEAL SPUR

In this condition, there is pain beneath the anterior part of the calcaneus due to an overstress of the plantar fascia.[29,30] Symptoms may or may not be associated with a radiologically demonstrable calcaneal spur. Morning heel pain is a common symptom. Treatment of this condition involves steroid injection, foot orthoses,[19,21,30] physical therapy-wall stretching,[30] cryotherapy, ultrasound and laser therapy.[19] Orthotic treatment is based on the control of rotational movements of the forefoot using soft functional foot orthoses or taping rather than controlling the tension of the plantar fascia.[14,21,30] Accommodative foot orthoses may be considered for relief of the tender area.

CONCLUSION

The pathological conditions presented in this paper are related to abnormal function of the foot. They are capable of being treated effectively using a mechanical treatment via functional or accommodative foot orthoses. In cases where the pathological conditions do not respond to the use of foot orthosis, surgical intervention may be necessary. Postoperative use of foot orthoses should be considered to avoid recurrence of the pathology or restore the normal function of the foot.

Review of the literature concerning foot orthoses reveals that, despite the widespread use of orthoses, objective evidence to support their prescription is at best limited. There have been many reports of successful treatment outcomes, but quantitative studies have produced contradictory results. Reasons for failure may include inappropriate prescription and/or inadequate fitting of foot orthoses, the determination of the subtalar joint neutral position and lack of knowledge regarding the relationship among foot pathology, foot orthotic treatment and foot biomechanics. We believe that in deformities related to excessive pronation, foot orthoses can produce excellent results.

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COMMENTARY

While this fine paper discusses many aetiologies for which prescription functional custom orthoses can be helpful, it should be noted that this list is not complete. Many additional conditions not discussed by the article may also benefit from the use of these devices. While randomized controlled studies are not currently available on this subject, there are many 'expert opinion' papers and presentations extolling the virtue of orthoses for a variety of conditions as well as countless patients who have benefited from them. It should also be noted that specific modifications and control will differ in each case and modifications are frequently needed during the course of treatment.

Bret Ribotsky DPM, FACFAOM