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Foot Orthotic Therapy

• H. CROSS

"There is hope of saving the feet of leprosy patients only when it is widely recognised that the whole problem is really one of mechanics, not of medicine. The advice and help of the physiotherapist, the social worker and the shoe maker are likely to be of more significance than the medicine of the physician or the knife of the surgeon." (Brand, 1989)[4]

INTRODUCTION

Many of the principles underlying footwear design for anaesthetic feet have remained essentially unchanged since the early 1960s when pioneers such as Bauman, Brand, Price and Ross began to accentuate the importance of footwear provision.[1,4,22,24,27,28] With utmost respect to those who have contributed so much to our current understanding of foot pathology, this chapter is offered as a further contribution. The chapter does not, however, provide the definitive answers. The early pioneers used physics to explain why people affected by leprosy developed ulcers. It may be that in the twenty-first century, physics will not be enough. We will need to find psychosocial answers to explain why people affected by leprosy are still developing ulcers. Footwear affordability with client acceptability and compliance have perhaps become the most important factors to consider if the challenge of plantar ulceration is to be met. Any attempt to provide appropriate footwear and appliances will be confounded if these crucial issues are not respected.

PHYSICS AND FUNCTION

Price recommended that all feet compromised by scarring should be fitted with a rigid soled sandal with a soft insole.[24] He designed a wooden sandal with a soft insole to meet these criteria and suggested that:

"The rigid sole forestalls deep damage between soft tissues and the bony skeleton of the plantar region. The soft insole forestalls damage caused by friction between the skin surface and the immediate points of contact."

Price's assumption that soft material would forestall damage due to friction was at best only partially correct. The effect of cushioning is to reduce force by decreasing the acceleration quotient of the "mass x acceleration" equation describing force. The suggestion that the "rigid sole forestalls deep damage between soft tissues and the bony skeleton of the plantar region" finds some support because the rigid sole he designed incorporated a rocker effect beneath the metatarsal heads.

Translational friction is an essential component of grip and is proportional to the product of the normal force and a coefficient of friction dependent on the properties of two involved surfaces. It may be described as a force acting to prevent relative sliding between two contacting surfaces. Friction acts to stop the moving foot and as such it is essential if man is to walk. If the internal momentum between bone and soft tissue continues to excess however, shearing stress and tissue fatigue can be a result.[25]

Many have sought to address the problem of shearing stress by immobilising the foot using rigid soled footwear. Although the concept of immobilisation to prevent shearing stress appears sound, it can bear a high functional cost.

Dorsiflexion of the toes stabilises the forefoot and thereby facilitates effective ankle plantarflexion at propulsion. When the toes dorsiflex the skin is drawn distally to permit unimpaired motion. This action results in horizontal shear between skin and metatarsal heads which is greatly exacerbated by the posterior thrusting of the skeleton to achieve acceleration for locomotion. It was reasoned, therefore, that by preventing toe dorsiflexion shearing stress in the tissues between the metatarsal heads and the skin would be reduced.

The anatomy of the normal footpad, however, is structured to accommodate shear.[5] Further mechanisms permit an element of sliding between soft tissue structures and bones, these include bursae and synovium encapsulated joints. It is only if the integrity of these structures is challenged by excessive demand that they will demonstrate fatigue. Alternatively if the structures have been damaged and scarring has resulted in the adhesion of skin and fascia, the functional capacity of these features may be markedly reduced. By eliminating the requirement to dorsiflex the toes, therefore, there will be a reduction in stress in the tissues beneath the metatarsal heads. Although eliminating these sagittal movements may be advantageous, the potential problems associated with uncontrolled frontal and transverse plane movements should also be considered

FOOTWEAR

Rocker Shoes

Bauman et al. conducted a comprehensive study of rocker shoes for leprosy patients.[1] Their study focused on kinetic effects and assumed that changes in pressure distribution would alter a predisposition for the foot to ulcerate. On the basis of their findings they suggested that the angle of rocker, the anteroposterior position of the rocker axis and the orientation of the rocker axis with the shoe were key criteria. What arises from reviewing the literature however, is that there is no consensus relating to rocker shoes on these criteria.[21,30,31]

A reduction in pressure under the medial and central metatarsal heads (MTHs) with a rocker positioned behind the MTHs was a recurrent finding.[6,7,21,30,31] However, a comparable reduction in pressure on the lateral forefoot has not been reported. Some investigators have recorded an increase in pressure under the fifth MTH.[30] The elevated pressure, or insignificant reductions in pressure on the fifth MTH, were probably due to rockers being positioned nearer the fifth MTH which lies in a proximal position relative to other MTHs (author's opinion).

Pollard et al. were able to report that an effect of rocker bottom shoes is the reduction of shearing stress.[23] Significant reductions in longitudinal shear were demonstrated when a shoe, incorporating a "deep rocker" behind the MTHs was compared with other types of footwear. Increased heel loading and force impulse, the product of force and the duration of the application of force, are widely reported. Such findings suggest that rockers are contraindicated for individuals with a history of heel ulcers.

The height of the rocker is a critical factor. If the anterior edge of the rigid shoe makes ground contact at propulsion there will be considerable force applied to the forefoot. This effect is the result of an alteration in the order of leverage with the distal displacement of the axis of motion. However, a greater risk may prevail for the midfoot due to the loss of toe dorsiflexion. If the distal edge of the footwear does make ground contact, the lever arm that normally extends to dorsiflex the toes at the

MPJs is extended to demand dorsiflexion at the ankle which, during propulsion, is being used to apply a plantarflexion thrust. The effect of the opposing forces of dorsiflexion and plantarflexion is that propulsive plantarflexion is jammed. A large dorsiflexion moment is created around the ankle. As the ankle reaches the limit of its range of motion, force is translated forward into the subtalar and midtarsal joints. The talar navicular articulation will present the first occasion of least resistance and excessive opposing forces may cause the dorsal edges of the opposing bones to impinge on each other thereby potentiating trauma. This may be a significant consideration for neurologically impaired feet, vulnerable to neuropathic bone disorganisation.

Further rationale for the use of rocker shoes was that the rigidity and alternative geometry of the shoe would alter gait to the benefit of the injured foot. Schaff and Cavanagh demonstrated this effect by recording that all subjects wearing rocker shoes in their study took shorter steps (reduced by 8 cm) and increased rate of cadence by six steps a minute.[30] Zhu et al. reported findings that support Brand's hypothesis that a shuffling gait would reduce peak pressure.[33] They later presented evidence to indicate that an increased cadence was associated with increases in peak pressure.[34]

There can be little doubt that rocker shoes may significantly improve the prospects for foot salvage. The cost of producing and supplying effective rocker shoes, however, is prohibitive. Furthermore, in India distinctive footwear is a major stigmatising agent and patients are understandably unwilling to pay for footwear meeting such low patient acceptance.

SANDAL DESIGN

Enna presented a sandal designed for leprosy impaired patients in America.[10] He sought to produce a sandal incorporating a moulded polyethylene insole, supported by a mixture of sawdust and latex on a neoprene crepe sole. This approach could be useful for patients with an a-propulsive gait, but it may be contra-indicated for more normally functioning feet. The foot is a dynamic structure, it shortens and lengthens during the normal stance phase of the gait cycle. Unless the foot is immobilised with a rigid sole incorporating a rocker, a close fitting moulded innersole could be counterproductive. Enna's choice of expanded polyethylene is not appropriate unless resources permit frequent change because the material compresses within a relatively short period.

Patil et al. also based their recommendations on static studies.[22] However, their recommendations were that microcellular rubber, of varying degree shore, should be used as components to form a composite sandal insole. Their recommendations are based on findings relating to one atypical subject and whilst demonstrating the requirement to address individual needs their recommendations may not be applicable for the general population of leprosy sufferers.

Attempting to address the problem of stigmatising footwear, Antia designed an extruded plastic sandal which was similar in appearance to sandals obtainable in local markets throughout India. This sandal incorporated an upper to hide moderate deformities, a heel counter and a steel shank beneath an 8mm, 18 shore EVA sponge. These sandals were evaluated by Kulkarni et al. who used Harris mats to demonstrate reduced loading.[18] They also reported problems associated with the dorsum of the foot where the plastic had caused cuts. There were further problems with the fittings on the shoe (buckles snapped off).

The rationale for introducing a steel shank is to limit dorsiflexion at the metatarsophalangeal joints (MPJs). The potential for damaging effects on the midfoot if toe dorsiflexion is prevented is presented above (see Physics and Function).

THE FOOT ORTHOSIS AS AN APPROACH TO MECHANICAL MALFUNCTION AND ITS EFFECTS

The general aim of a foot orthosis is that it should intervene to attenuate the punishing consequences of abnormal foot structure or function. More specific aims will depend on the nature of the underlying problem. The action of some orthoses will be to perform as a substitute for anatomical inadequacy whilst others will aim to alter kinematic function or the effects thereof. More specific aims include:

1. The correction of phasic joint kinematics by controlling the extent of subtalar pronation.
2. The redirection and redistribution of force.
3. The accommodation of foot structure to facilitate optimum foot function.
4. The attenuation of effects of uncontrolled subtalar pronation.
5. The distribution of weight over an increased area of the foot.
6. The support and palliation of vulnerable areas of the foot
7. The deflection of pressure from a vulnerable area.
8. Cushioning to reduce impact.

Investigators have studied a variety of variables considered to be affected by foot orthoses. Landorf and Keenan have presented a comprehensive literature review of recent studies which the author recommends.[13]

The Functional Orthosis

The term "functional" when used in this context usually refers to an orthotic device that restricts subtalar pronation. The aim of a functional orthosis is to improve the prospects for the foot to achieve the desirable objective of reaching mid stance with the subtalar joint approximately neutral (i.e. neither pronated nor supinated). If this objective is reached it is reasoned that the foot will be ideally prepared, kinematically, for the demands of the propulsive phase of stance.[17]

An appropriately angled wedge beneath the heel effectively brings the supporting surface into contact with the inverted position of the calcaneus at heel strike. The angle of the wedge is calculated by measuring the angle between the supporting surface and the calcaneus when the subtalar joint is in its neutral position.[3] A response to this approach is that the subtalar joint will pronate but not to excess. The angle of the wedge may be increased to accommodate ligamentous laxity which would exacerbate the tendency of the subtalar joint to pronate.[26]

Orthoses that do restrict or attenuate the effects of subtalar pronation are likely to affect the subsequent function of the foot. Such devices are, therefore, "functional" in their action. A term commonly used for orthoses that are not prescribed principally to alter foot function is "accommodative". The term has passive connotations and does not project the potential for such devices which can infact initiate dynamic effects.

Individuality dictates that orthoses require consideration of peculiar specifications. Orthoses are prescribed on consideration of a combination of criteria. The prescription will be based primarily on a subject's foot structure and gait. Other physiological considerations will be arterial supply, venous return and neurological status. An assessment of intellect and psychosocial factors is also required There are basic components that can be incorporated in the manufacture of an orthosis. These are commonly used in combinations, however, each component is specific and may be applied in isolation, where appropriate. The efficacy of foot appliances as an adjunct to the treatment of plantar ulceration in leprosy has been investigated.[8,9]

Note: *All foot orthoses described in this chapter are ideally constructed using micro cellular rubber (MCR) but can be made using other materials including ethyl vinyl acetatate (EVA) or Poron.*

The Tarsal Platform

The tarsal platform is designed to extend from the anterior edge of the heel to a line immediately proximal to the metatarsal formula (the arc in which an individual's metatarsal heads lie in the transverse plane) where the full thickness of the material (4 to 5 mm) is bevelled to accommodate the metatarsal heads (Fig. 17-1).

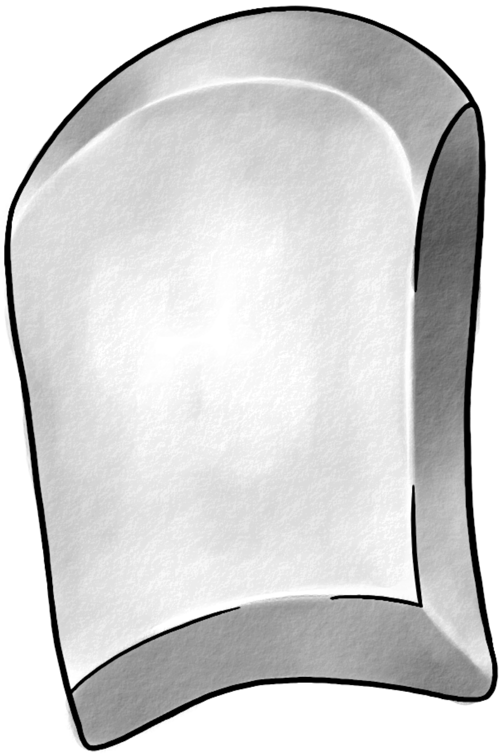

FIGURE 17-1 Tarsal Platform– **Action:** Reduce pressure and the duration of pressure applied to metatarsal heads; Loads metatarsal shafts; Counters STJ supinatory effects.
Indications: pressure lesions affecting a rigid functioning foot (as with STJ supination).

The posterior edge is shaped to the heel and bevelled to a width of approximately 1 cm. As a platform of firm material, it enlarges the weight bearing area of the foot and relieves the loading on the heel and metatarsal heads. Its primary function is to bring the lateral border of the foot into contact with the supporting surface. In so doing it imposes a slight evertory force on the foot. As a basic structure, it is indicated for pes cavus feet which exhibit excessive metatarsal loading and lateral instability but is contra indicated for feet with fixed varus abnormalities.[32] The author suggests that it should not be used where feet demonstrate grossly abnormal lateral loading (as in foot drop). The tarsal platform is the base for a number of modifications designed to meet individual requirements.

The Tarsal Cradle

This is an extension of the tarsal platform to include a medial arch support with a flanged extension (Fig. 17-2). The structure is modelled to fill the concavity of the medial longitudinal arch thereby maintaining the architecture of the arch as it resists the effects of abnormal (late or excessive) subtalar pronation.[29] The author recommends that it should extend medially, as a flange, to cover the sustentaculum tali, the talar head and the tuberosity of the navicular. From its highest point, at the tuberosity of the navicular, it should slope inferiorly to the base of the first metatarsal head.

Note: *Whether an arch support is used as a component of a tarsal cradle or independently, the structure of the support is crucial to its function and acceptability.*

A well-designed tarsal cradle will support both the medial and lateral borders and present resistance to hypermobility of the foot. When the calcaneus everts it causes an axial rotation

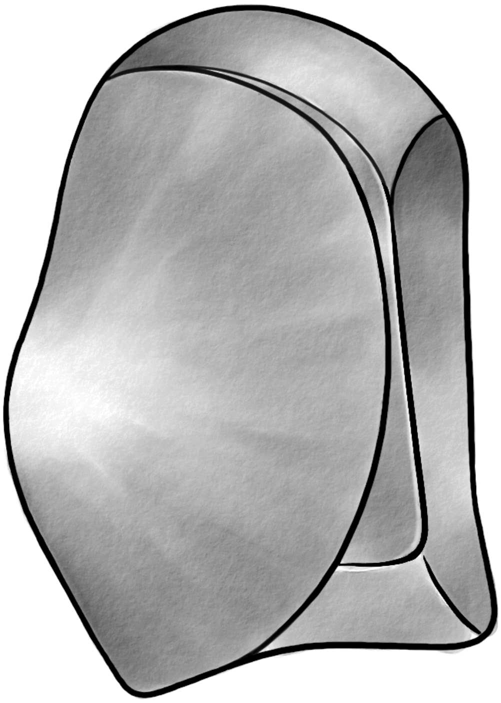

FIGURE 17-2 Tarsal cradle– **Action:** Redistributes forces; Stabilises the foot against the affects of STJ pronation; Augments first ray function.
Indications: Feet at risk of the affects of aphasic STJ pronation.

of the cuboid which destabilises the lateral column and consequently causes hypermobility of the fourth and fifth metatarsals.[12] The tarsal platform component supports the medial, plantar and posterior process of the cuboid which underlaps the calcaneus. This support adds resistance to calcaneal eversion and in so doing enhances the stability of the lateral column.[20] In a similar fashion, support beneath the tuberosity of the navicular and sustentaculum tali should resist the adduction and plantarflexion of the talus and the eversion of the calcaneus respectively. These effects should contribute to the stability of the medial column and the foot in general.

The salient objective of the tarsal cradle is to facilitate efficient functioning of the first ray. Assuming normal phasic activity, as the STJ starts to supinate (after heel strike), the tarsus inverts and the second metatarsal follows to assume an inversion tilt. Responding to ground reaction force the lateral metatarsals will dorsiflex to the extent allowed by individual tarsometatarsal connections. This is usually sufficient to allow the metatarsal heads to lie in a common transverse plane.[12]

As the lateral metatarsals dorsiflex in response to ground reaction, the medial side of the foot remains tilted in inversion. To attain a plantigrade attitude and stabilise the foot for propulsion the first ray must plantarflex. The first ray has a triplane axis. As the first ray plantarflexes therefore, it also everts. The torsional twist around the second metatarsal head contributes to a tightening of the support structures of the medial arch.[19] The medial arch is simultaneously heightened by the plantarflexion of the first ray and extension of the digits.[15] Whereas the dorsiflexion of the lateral rays is principally a passive response to ground reaction, the plantarflexion of the first ray is dynamic. Efficient first ray function is dependent on a number of structural and functional variables.[26]

If the STJ is supinated the first cuneiform and the base of the first metatarsal are elevated relative to the cuboid. Using the stabilised cuboid as a pulley, the plantar direction force of peroneus longus is enhanced by the increased angle of approach to its insertion. This mechanical advantage allows peroneus longus to stabilise the first ray at its base. Its function is also to synergise with the actions of abductor hallucis and flexor hallucis to bring the ray into plantarflexion. In so doing maximal benefit is achieved from compressional forces to stabilise the medial kinematic chain in preparation for propulsion.[12,26]

If the medial column is destabilised due to subtalar pronation the first ray will dorsiflex in response to ground reaction. As a consequence the angle of approach of peroneus longus will be reduced. Having lost mechanical advantage peroneus longus will be unable to effect adequate plantarflexion of the ray and the integrity of this crucial mechanism is compromised. The second or third metatarsal heads are exposed to excessive compressional and shearing stress.[26]

Facilitating first ray function is a fundamental aim if forefoot integrity is to be maintained.[15] By supporting the structures that maintain the optimal height of the arch it is reasoned that the dynamic features of first ray function will be augmented. This may be the most important function of the tarsal cradle.

The author suggests that if the tarsal cradle is extended medially and posteriorly to include a partial heel meniscus this will benefit the objective of subtalar pronation control. By including a medial wedge a supinatory moment will oppose the pronatory moment around the subtalar axis (Fig. 17-4). This effect will inhibit, if not prevent, the eversion of the calcaneus.[11,17] Other modifications can be made to address individual specifications.

Anti Pronatory Orthosis

Whereas the tarsal cradle can be useful as a therapeutic appliance (i.e. used where there is frank ulceration or other trauma) an anti pronatory orthosis can be prescribed as a prophylactic appliance. The appliance described here is known by various different names some of the more colourful of which reflect its shape (eg. Cobra pad, Hathi pad). The appliance comprises a combination of a medial arch sup-

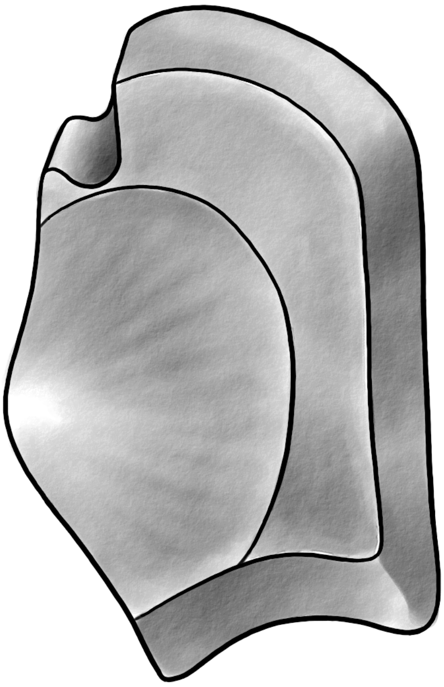

FIGURE 17-3 Combination Tarsal cradle with PMP– **Action:** Stabilises the foot against the affects of STJ pronation; Deflects pressure from an injured metatarsal head; Loads metatarsal shafts and unaffected metatarsal heads.
Indications: Lesions affecting a hypermobile foot (as with STJ pronation)

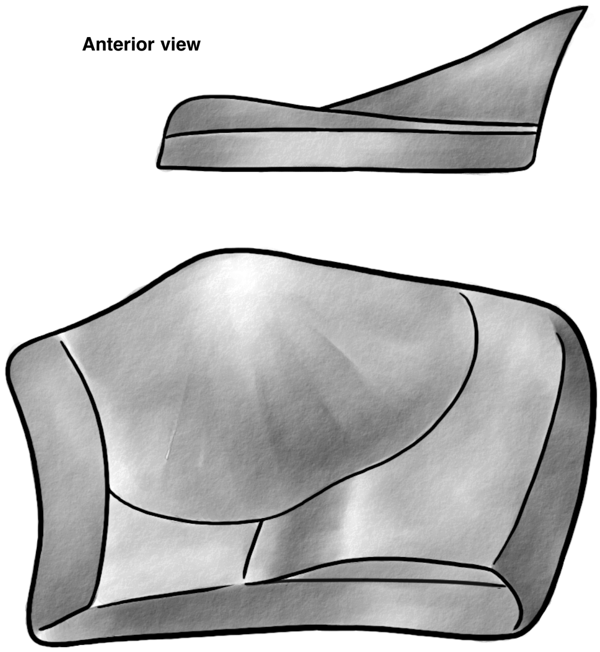

FIGURE 17-4 Combination Tarsal Cradle and Medial Wedge– **Action:** Accommodates forefoot valgus deformity; Stabilises the foot against the affects of STJ pronation.
Indications: Forefoot Valgus.

port with a heel meniscus (Fig. 17-5). The heel meniscus is designed such that the medial aspect has a wedge effect to limit the extent of calcaneal eversion. The lateral aspect (which extends to the styloid process of the fifth metatarsal) increases the weight bearing area of the heel and contributes to the stability of the foot.

As a general principle, where it is found that patients present with aphasic pronation an anti pronatory appliance should be offered to promote optimal foot function and thereby reduce the risk of insidious trauma. It should also be considered as a post Tibialis Posterior Transfer intervention. Electromyographic studies have demonstrated that tibialis posterior fires at heel strike.[26] The timing of activity and insertions of the tendon suggest that principle actions of the muscle are to prevent excessive STJ pronation and to restrain the foot against the effects of pronatory force. The removal of the tendon from its insertion therefore leaves the foot without this crucial protective mechanism. An antipronatory appliance as described here will compensate, to some extent, for the loss of normal tibialis posterior action.

FIGURE 17-5 Anti-pronatory appliance– **Action:** Resists the eversion of the calcaneus; Stabilises the foot against the affects of pronation; Enhances first ray function.
Indications: Feet demonstrating excessive STJ pronation.

Note: *Whilst TPT surgery should be conducted to address the gross insult of foot drop (a sagittal plane problem) the effect of muscle transfer on frontal plane action should not be ignored. Although less likely to lead to acute trauma the affects of hyper pronation after TPT surgery are an insidious threat to the integrity of the foot. Soft tissues are challenged but there may also be a significant threat to joints. If the STJ is pronated at the propulsive phase of gait the tarsal joints will be more vulnerable to trauma because the articulating surfaces of opposing bones will not be congruent. Loss of joint congruency favours rotational forces rather than stability. Rotational forces destabilise the joints and increase the risk of fracture. Furthermore loss of congruency can lead to foci of force being applied to small areas of an articulating surface which can cause joint destruction (as in osteochondritis dissecans).*

The Metatarsal Rocker

The metatarsal rocker is shaped to conform to the metatarsal formula and is situated immediately proximal to the metatarsal heads.[20] The author suggests that if a foot has been damaged such that the osseous structures of the forefoot no longer conform to normality, a metatarsal rocker can be shaped to correspond with the tread line of the foot. With such a foot the rocker is positioned immediately proximal to the tread line. The bar can be incorporated onto a tarsal platform or a tarsal cradle (Fig. 17-6). It can also be used independently of other options.

The author suggests that the action of the metatarsal rocker is that it should shift the tread line posteriorly, away from a vulnerable or traumatised area, to a less vulnerable area of the foot. In so doing it will mimic the pivotal role of the metatarsal heads. It must, therefore, be constructed to an optimal height to allow clearance of the vulnerable area. These devices may be particularly useful for feet that no longer demonstrate a normal heel toe gait.

The Plantar Metatarsal Pad

The full thickness of a plantar metatarsal pad (PMP) extends from beneath the heads of the three central metatarsals to two thirds of the length of the metatarsal shafts (Fig. 17-7). The anterior edge conforms to the metatarsal formula. It is bevelled from the metatarsal heads to extend beneath the anterior plantar fat pad, to a distance immediately proximal to the webbing of the toes. The lateral and medial edges are also bevelled from the area beneath the second and fourth metatarsals to the medial and lateral aspects of the forefoot respectively. A 1 cm bevel extends from the posterior limit of the full thickness of the pad. The effect is, that on weight bearing, the central metatarsals are elevated. The load on the metatarsal heads is relieved due to the combination of elevation and an increased area of weight bearing.[2]

Where feet are compromised by the chronic fixation, dislocation or subluxation of the metatarsophalangeal joints, the PMP is applied to palliate the metatarsal heads by redistributing the load. Where a foot presents with mobile claw toes or retracted toes the metatarsals are forcibly plantarflexed.[26] In the action of elevating the metatarsals, the PMP assists by correcting the alignment of the metatarsal heads.

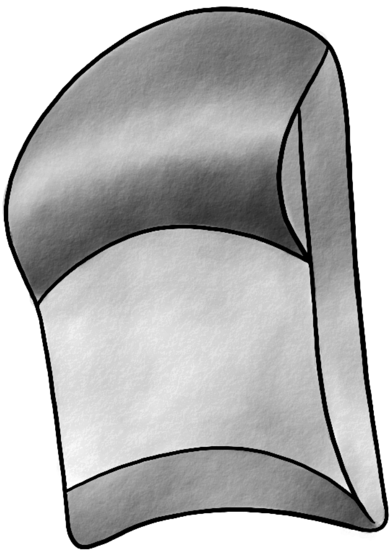

FIGURE 17-6 Combination Tarsal Platform and Metatarsal Rocker– **Action:** Deflects pressure from affected metatarsal heads; Shifts the treadline away from the metatarsal heads.
Indications: Multiple lesions distributed over the forefoot.

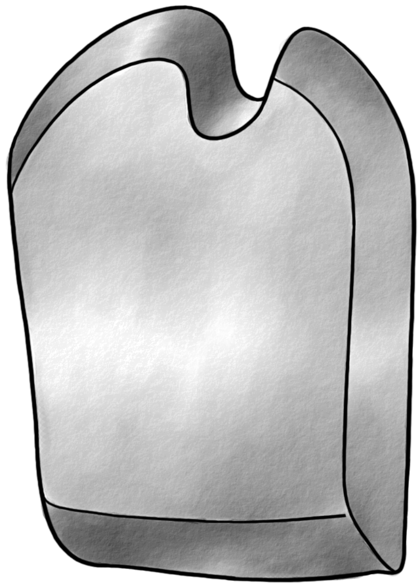

FIGURE 17-7 Plantar Metatarsal Pad (PMP)– **Action:** Deflects pressure from affected metatarsal head; Loads metatarsal shafts and unaffected metatarsal heads.
Indications: Pressure lesions affecting a rigid functioning foot (as with STJ supination).

The PMP can be modified to palliate the first of fifth metatarsal head or any other metatarsal head in isolation. The width of the PMP is extended so that the full thickness of the PMP supports the first and fifth metatarsals. An appropriate shape, conforming to the metatarsal head, is cut from the PMP and bevelled to allow the metatarsal head to be accommodated in the cut away area. The effect of a "U" or "wing" shaped section cut away from the PMP is that pressure is deflected from the vulnerable metatarsal head to the PMP and other metatarsal heads.[2]

Note: *If the foot is affected by aphasic subtalar pronation a PMP should not be used unless it is incorporated as an extension of a tarsal cradle (Fig. 17-3). The reason is that when the STJ pronates, the foot becomes hypermobile and demonstrates a tendency to spread and elongate as it bears weight. The instability of the foot with associated mobility of the plantar surface can result in a traumatised plantar site being forced repeatedly over the bevelled edges of the PMP. The resulting shearing stress can exacerbate the trauma.*

Moulded Insoles

These appliances should be used with care. They are best prescribed for patients with gross rigid deformities or those for whom surgical correction has resulted in multiple joint fixation. The function of a moulded insole is to maximise the weight-bearing surface and thereby reduce the risk of high pressure lesions at vulnerable prominences. The manufacture of a moulded insole is based on a static impression. They are suitable therefore for people who present with feet that only function as a supportive prop and are not expected to facilitate the more dynamic functions of the normal foot.

Note: *Moulds should always be taken with the patient fully weight bearing so that a valid impression of the foot's surface can be recorded.*

The method of manufacture limits the usefulness of the moulded insole. Moulds are made from a static impression but it must be considered that the foot may not be static on weight bearing. Before any appliance is made to accommodate the shape of the foot, therefore, it should be ascertained whether the foot is mobile during stance. It is not sufficient to determine only whether the foot can dorsiflex and plantarflex. It must also be ascertained to what extent the foot responds to frontal plane demands. If the foot everts on weight bearing the foot could be at risk in a moulded insole.

The entire plantar aspect will shift laterally and distally thereby potentially placing vulnerable sites out of the areas moulded for their protection.

CONCLUSION

Mechanical problems require mechanical solutions. The more that can be understood about the underlying mechanisms that lead to tissue breakdown, the more we will be able to address the cause. However, man is not merely a machine. Function relates, in the first instance, to managing the challenge to the intellect and emotions of social and economic realities. There is a hierarchy for preservation against physical realities: hunger, shelter and security head that hierarchy. While poverty persists our efforts to save the feet of people will, therefore, depend on pragmatic solutions. Foot orthoses will not solve all problems. They will at best be an adjunct to treatment, but the therapies suggested here follow a simple and pragmatic methodology that is known to help.

GLOSSARY OF TERMS RELATING TO ORTHOTIC THERAPY

KINETICS: The study of forces that cause motion

MASS: The quantity of matter in an object. i.e.: The number of atoms that make up an object will remain the same no matter if that object is affected by gravity or not.

CENTRE OF GRAVITY: This is an imagined point in an object around which all other parts of the object exactly balance each other so that, if this point is supported, the object will remain at rest. In the body, its location will vary according to the position of body segments. For most practical purposes the location of the CENTRE OF GRAVITY has the same location as the CENTRE OF MASS.

CENTRE OF MASS: An imagined point in an object that moves in the same direction as any particle would move if it was responding to the same forces.

GROUND REACTION FORCE: The force that acts on a body as a result of the body's contact with the ground.

SI UNITS: (System International Units) A system where mass is measured in Kilograms Length is measured in meters Time is measured in seconds.

NEWTON: 1 Newton is the force that will give a mass of 1kg. an acceleration of 1 meter per second/per second.

WEIGHT: Force due to the gravitational pull of the earth. Without gravity we would have mass but no weight.

GRAVITY: An attraction between objects. On the Earth's surface all objects are pulled toward the earth so that they have an acceleration of 9.81 m/s.

ACCELERATION: A change in velocity

$$\frac{\text{Velocity 1 - Velocity 2}}{\text{Time}}$$

FORCE: Mass x Acceleration

PRESSURE: Force / Area

LOAD: To apply force

COMPRESSION: When an object is loaded by collinear forces acting on it from opposite directions to push it together.

TENSION: When an object is loaded by collinear forces which act in an opposite direction to pull the object apart.

SHEAR: When an object is loaded by forces which act on it in opposite but parallel directions.

FRICTION: Friction is the property that objects have which makes them resist being moved across one another. If two objects with flat surfaces are placed one on top of the other, the top object can be lifted without any resistance except that of gravity. But if one object is pushed or pulled along the surface of the other, there is a resistance caused by friction.

STRESS: Force that develops in an object in response to externally applied loads. Stress may be tensile if the object is subjected to tension, compressive if the object is subjected to compression or shearing if the object is subjected to shear. Normal stress changes the length of a structure. Shear stress changes the angle of a structure.

FATIGUE: The failure of tissue or other material due to loading.

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