# Dynamic Control of Abnormal M-L Motion of the Os Calcis: The Cushion Heel Wedge—A Possible Solution

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The efficient control of excessive mediolateral motions of the foot has been a problem for many years. Opinions remain mixed as to the best approach to managing the variety of problems which result from foot imbalance. The growing child's feet continue to be of particular concern, since the restoration of foot balance at an early age is generally considered to be the best way to prevent bony deformation later.

At present, the mechanical methods of controlling abnormal varus or valgus motion of the os calcis may be said to share a common feature—the control they offer is static. That is the os calcis is pre-positioned in the position of "correction" or "balance," and held there forcibly. The most frequently used method of control for children is the heel wedge, in conjunction with, or without, a "Thomas heel." The practice of prepositioning the os calcis to achieve foot "balance," by wedging, forces the os calcis to rest on an *inclined surface* that is *not parallel* to the floor. It is, therefore, difficult to accept the claim that such a practice does indeed restore foot balance. The analysis that follows led to a search for a dynamic yet simple means of controlling abnormal M-L motion in the subtalar joint. The cushion-heel wedge appears to be a practical solution for either varus or valgus conditions involving the hind foot.

## THE STANDING POSITION

The downward arrow in Figure 1 represents the body's weight passing through the midline of the os calcis, shown in dotted outline in a standing position. The circle in the center of the os calcis represents its axis,

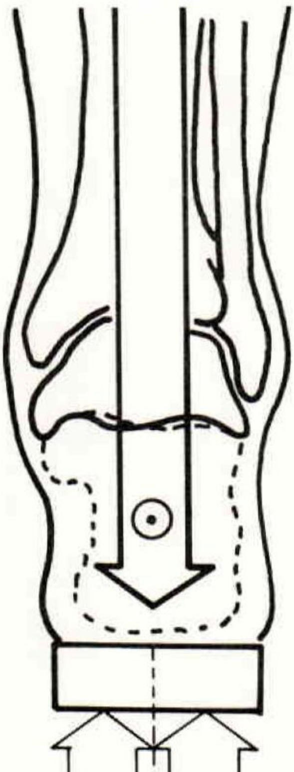

Fig. 1. Schematic posterior view of the right heel in balance in the standing position.

arbitrarily located. The rectangular block represents the heel of the shoe. The two upward arrows represent the floor reaction force, and the assumption is made that the

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distribution of the reaction force has to be equal on both sides of the midline of the heel of the shoe in order to maintain normal foot balance.

## BETWEEN FOOT-FLAT AND STANDING

Figure 2 attempts to show the os calcis at an arbitrary point in time between the instant that foot-flat has occurred and the time the tibia reaches the standing, or upright position.

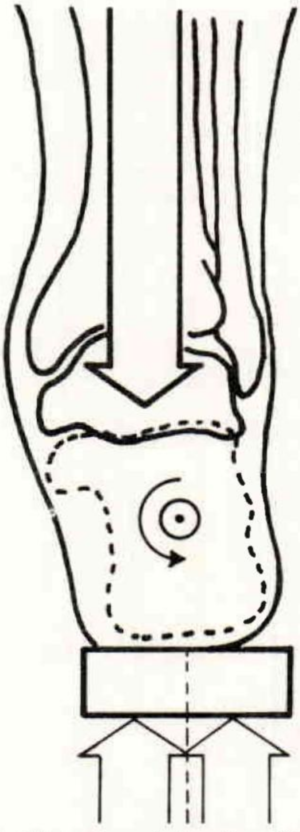

Fig. 2. Schematic posterior view of the right heel showing eversion of the os calcis when the foot is pronated.

tion. As the tibia rotates forward during this period, the weight-bearing line moves medially and the amount of the body's weight that is being borne by the foot increases and reaches its peak as the full weight of the body is registered at midstance of the walking cycle, or one-half the body's total weight, when both tibiae reach the standing position.

The standing position subjects the foot to a *constant* load for much longer durations. The assumption is made that the constant load of long duration during periods of standing is the major destructive force to normal foot balance when structural weakness is present.

In the common situation where inversion motive power and/or the ligament system on the medial portion of the foot is inadequate, there appears to be no internal means of resisting the counterclockwise (eversion) rotation which occurs, except the configurations of the superior articulating surface of the os calcis and the inferior articulating surface of the talus. It should be noted that, at this time, the fatty pad and skin under the bottom of the os calcis has not fully flattened, yet the counterclockwise rotation of the os calcis has begun.

It is suggested that the os calcis will be "prepositioned" in pronation before the vertical loading has reached its peak, and that the final "settling," as the standing position is reached, is probably compression of soft tissues. At the point when even a small fraction of the vertical load makes contact with the articulating surface of the os calcis, the body's weight might be described as being in "free-fall"—there being negligible known resistance until full "bone-to-bone" contact serves as a positive mechanical stop. The pronated foot then becomes "locked" between two equal and opposite forces—the body's weight from above and the floor reaction force from below.

The force moment created by the body's weight in "free-fall" about the axis of the rotating os calcis can be assumed to be of a high magniture. For example, as the os calcis rotates laterally from under the limb above, the weight line will then fall *medial* to the axis of the os calcis. If the patient weighs 50 lbs. and the weight line passed ¼ in. medial to the axis, the moment would be 6.25 inch-pound about each foot in the *standing position.* The "trigger" that sets the counterclockwise direction of the os calcis in the beginning appears to be the normal valgus accommodation that the foot makes to the normal internal rotation of the tibia in the transverse plane which occurs between heel-strike and midstance. In the previous example, the moment about the axis of the os calcis during *midstance* (the full weight of the body now being borne upon a single foot) increased to 12.5 inch-pounds[2]. Thus, the abnormal

[2] The fact that, at midstance, the weight bearing borne by the foot (especially the longitudinal arch) is *twice* that which is borne during standing is significant to arch supporters and/or shoe inserts designed to support the longitudinal arch when it is structurally weak. Since the

valgus position of the foot during standing may be said to be predetermined by conditions in effect *before* the standing position is reached.

The floor reaction force appears to be equalized on both sides of the midline of the heel. Its role now would seem to be that of maintaining the "overall" M-L balance of the body, rather than foot balance, to accommodate the changed circumstances.

## THE MEDIAL HEEL WEDGE

As the foot receives its peak load during the standing position, clinically, the wedge appears to restore M-L balance to the foot. The wedge "checks" the counterclockwise movement by prepositioning the os calcis on an inclined plane in relation to the floor (Fig. 3). This prepositioning is achieved by rotating the os calcis clockwise in the direction of inversion as it rests on the inclining wedge. In effect, the medial portion of the articulating surface of the os calcis is jammed upward to become the first point of contact with the medial portion of the inferior articulating surface of the talus as the body's weight is received. The heel counter of the shoe is expected to maintain the os calcis in its unnatural position. The "free-falling" of the vertical load from above appears to be effectively checked. However, the effect is more apparent than real.

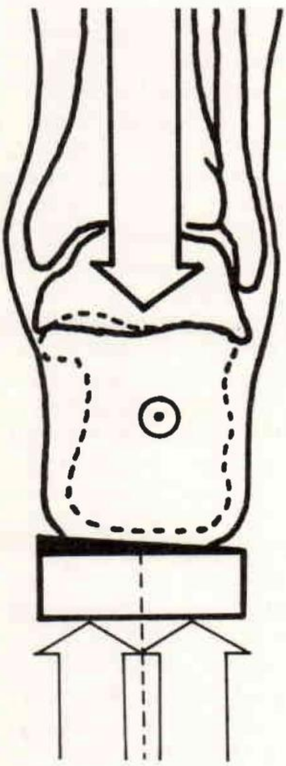

Fig. 3. Schematic posterior view of the right heel in the standing position when a conventional medial heel wedge is used.

The weakness of the arrangement provided by the medial heel wedge is that the os calcis rests on an *inclining plane* which slopes downward in the direction of *eversion*. By forcibly prepositioning the os calcis thus, its articulating surface is also inclined downward in the direction of eversion (Fig. 4). Under such circumstances, it would seem valid to conclude that as the talus receives the

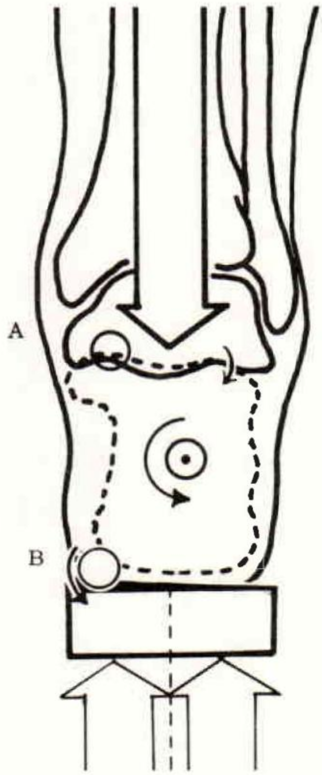


Fig. 4. Schematic posterior view of the right heel showing the relatonship between the os calcis and talus during the early part of the stance phase when the medial heel wedge is used.

application of the body's full weight is inexorably applied *prior* to reaching the standing position and can be lowered only when both feet share the load, it appears that an important element of the dynamics of the normal foot is not being considered in the design of current arch supporters. Assuming that the orthotic goal should be to achieve as close a mechanical simulation to nature's dynamics as possible, the ideal longitudinal arch supporter should yield sufficiently, up to and at midstance, to permit the normal amount of valgus to occur and then *return* to sustain the arch in a normal standing position.

body's weight its first point of contact with the inclined articular surface of the os calcis must be its medial edge. It would appear to follow that this point of contact then becomes an instant center, A, about which the talus must rotate. Since the os calcis position is fixed, the moment about the instant center will be lateral, where it may be assumed there exists little, or no, resistance. The direction of rotation of the talus is now inevitable—clockwise and downward in the direction of inversion. The vertical load might be described as "free-falling," until the abnormal spacing within the talocalcaneal joint has been reduced by full contact of the two surfaces. The rapid increase of body weight upon the talus "locks in" its inclined position as it rests upon the inclined os calcis.

In such a situation, it appears that one of two things takes place:

1. Assuming that the mortise formed by the malleoli of the tibia and fibula does not permit mediolateral rotation of talus within the ankle joint, the leg must then follow the talus as it rotates clockwise within the talocalcaneal joint, as previously described. Thus, the line of the body's weight as it is borne through the talus to the os calcis and down to the floor would no longer be a true vertical line. The weight-bearing line would now be oblique and medial to the axis of the os calcis. The net effect is that all forces are so aligned that conditions are "go" for the foot to revert to the pronated position. It is merely a matter of time, for no shoe can resist the forces being generated under the conditions just described.
2. The final "settling" mentioned earlier, i.e., the compression of the fatty pad under the os calcis, may be sufficient to allow the entire leg (fixed os calcis, talus, *et al.*) to "right" itself and bring the weight-bearing line to a true vertical line. The contact point between the soft tissues of the heel and the innersole of the shoe becoming the center point, B, of rotation. It appears reasonable to assume that there would be some translatory motion, along with the rotation occurring tween the heel and innersole. The key factor that would determine which of the two above events would occur would seem to be that the soft tissue under the heel must be able to compress (when the peak load is reached) an amount equal to the height of the thickest portion of the wedge, thus enabling the weight-bearing line through the leg to "right" itself to a true vertical line in relation to the floor. The net effect, in the latter case, is that the os calcis *immediately* reverts to a position of eversion taking the foot with it.

In addition, regardless of which event occurs, the propensity of the tibia to rotate internally between foot-flat and the standing position, accompanied by the valgus accommodation of the foot, continues to apply a counterclockwise moment about the axis of the os calcis with each step. The os calcis, as it rests on the sloping wedge, it in an extremely weak position to resist what can be assumed to be a counterclockwise moment of considerable magnitude. With surprising rapidity, the lower, lateral portion of the os calcis will force the lateral heel counter to bulge outward. The outward bulging of the lateral counter permits the os calcis to slide down off the wedge and resume its pronated position. A shoe that fits poorly at the heel, or a loosely laced shoe, expedites the process. Throughout the process described, the floor reaction force seems to be a "negative factor" in terms of foot balance *per se*. It appears to be constantly equalizing (either side of the midline of the heel) to accommodate to each change as it occurs, thus maintaining M-L balance of the body, whatever the foot's position.

## THE CUSHION-HEEL WEDGE

Figure 5 attempts to depict the action of the cushion heel wedge the instant that the foot-flat position has been achieved and the leg is beginning to rotate forward over the foot now "fixed" to the floor to receive the weight of the body. As the leg rotates forward, there is a rapid increase in the amount of body weight passing through the leg to the foot and downward to the floor. This increase continues until the peak of significance to foot balance is reached, that is, when the tibia is at right angles to the foot and/or floor.

The cushion heel wedge must begin to depress immediately as the body's weight is received by the os calcis. *Immediate depression is essential* in order to create a clockwise moment in the direction of inversion about the axis of the os calcis. Should there be a delay in the depression, as would be the case if the material used in the cushion portion of

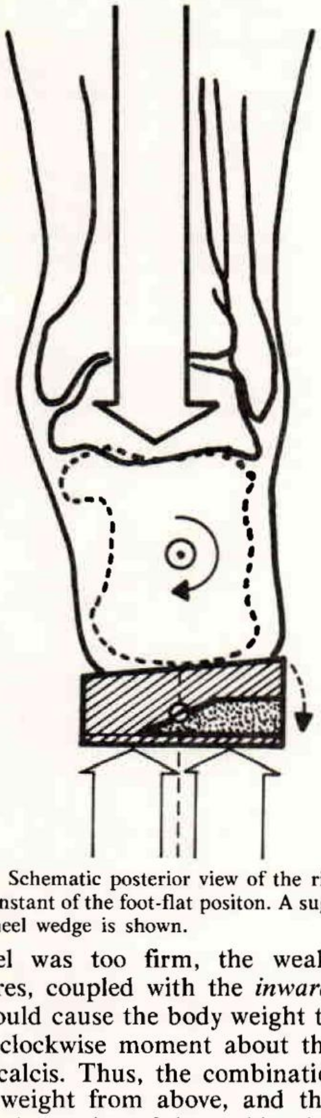

Fig. 5. Schematic posterior view of the right heel at the first instant of the foot-flat positon. A suggested new type of heel wedge is shown.

the heel was too firm, the weak medial structures, coupled with the *inward* sloping heel, would cause the body weight to place a counterclockwise moment about the axis of the os calcis. Thus, the combination of the body's weight from above, and the instantaneous depression of the cushion-heel wedge below dynamically prepositions and maintains the os calcis in normal alignment for the midstance and/or standing positions.

To accommodate for the standing position, the cushion heel wedge should be made so that the amount of depression has been sufficient to bring the whole heel parallel to the floor. The os calcis will rest on a level horizontal plane, parallel to the floor. The floor reaction force "shifts" to the medial half of the heel so that it is substantially greater under its firm medial portion.

The body's weight might still be described as "free-falling," since there is very little initial resistance to it as it is being absorbed by the cushion wedge. It is assumed that the cushion wedge stores an unknown portion of the vertical load before it can make contact with the floor. During this short period, an unknown portion of the vertical load is passing through the firm medial portion of the heel (note its extreme medial displacement) to the floor without interruption (Fig. 6). The floor reaction force must equal what appears to be a proportionally greater vertical load from above, passing through the medial

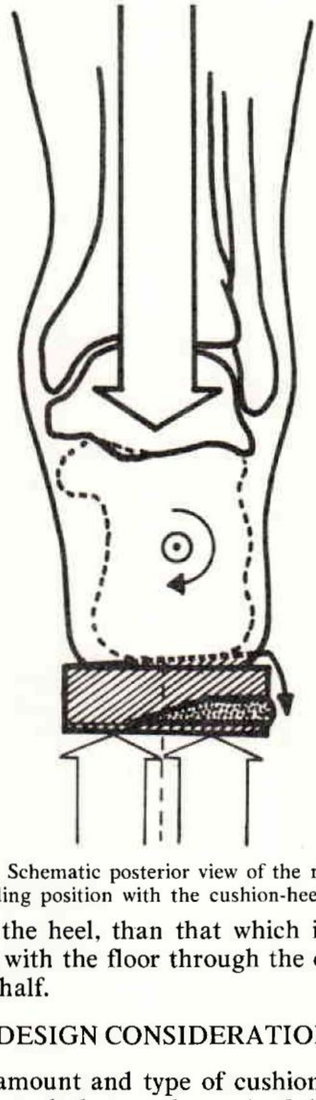

Fig. 6. Schematic posterior view of the right heel in the standing position with the cushion-heel wedge.

half of the heel, than that which is making contact with the floor through the cushioned lateral half.

## DESIGN CONSIDERATIONS

The amount and type of cushion material must be such that, as the peak of the vertical load is achieved, the cushion must not "bottom out" when the heel becomes parallel to the floor. If the cushion wedge were to "bottom out", the effect would be similar to a solid medial wedge. Thus, the lateral portion of the os calcis is somewhat "floating" on the remaining thin layer of air within the cushion. The combination of the body's weight having been forced to create a clockwise moment, and a preponderance of the floor reaction force being "shifted" to the medial side, under the medial half of the os calcis owing to the absorption of forces by the cushion wedge on the lateral side, results in what appears to be a constant force couple about the subtalar joint which maintains foot balance whenever the limb is in the standing position.

## SUMMARY

This analysis of conventional heel wedges raises doubts as to their effectiveness in controlling abnormal mediolateral rotation of the os calcis. Heel wedges do not appear to be an effective means of restoring foot balance in the young. A cushion-heel wedge is suggested as a possible solution for young patients. The cushion heel wedge is not intended to be used in situations where bony wedging or abnormal articulations, or both, are present.