CORRECTION OF THE PRONATED FOOT

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In a previous paper on this subject (Rose 1958) consideration was given to the mechanical properties of the peritalar joint, the calcaneo-contact joint, and their inter-reaction with the hip joint in the standing, weight-bearing foot. Deductions were also made on the efficiency of the methods at present in use for the correction of the pronated foot; it was pointed out that certain theoretical considerations raised at that time could not be dealt with until the inter-reaction of the hind and forefoot had been considered.

A model was therefore constructed as shown in Figures 1 and 2 incorporating the axes of the ankle, the subtalar and the first and fifth metatarsal ray joints. These axes were in the correct relationship to each other as defined by Hicks (1953), and the scale of the model was that of an adult foot. The mid-tarsal joint was not represented because it is functionally an extension partly of the peritalar joint and partly of the metatarsal rays. It was found in practice that the model behaved like the foot, and served to emphasise certain well known but often ignored principles in foot posture. 1) That the posture of the standing foot is not dependent upon muscular activity. It can be demonstrated radiologically that a particular foot will, in the defined conditions, always assume the same posture, which will not alter even if it is loaded for a considerable period by a weight several times greater than the ordinary body weight. Furthermore, electromyographic investigations have shown a muscular quiescence under these circumstances, with the exception of the triceps surae which acts only on the ankle joint. It follows from this that, in order to achieve correction of the pronated

Figures 1 and 2—Model of combined forefoot and hind foot. Figures 3 and 4—To show the change from pronation (Fig. 3) to supination (Fig. 4) when the first metatarsal ray is both lengthened and flexed.
foot, some alteration in the skeletal structure of the foot must be achieved. 2) That while the ankle and peritalar joints are somewhere in the middle of their range in this posture the joints at the bases of the metatarsal rays are always in full extension, and it is this limiting extension of these joints which, in the main, determines the posture that the foot will assume under these conditions, with a factor which derives from the relative lengths of the metatarsals. Although Harris and Beath (1947) showed that Morton's (1935) method of measuring the relative lengths of the metatarsal bones was invalid—and indeed this model shows their point very clearly—there is no doubt that this concept of short metatarsals, and hypermobility at the base of the first metatarsal bone is important (Figs. 3 and 4).

3) That the foot and leg represent a track-bound linkage (Fig. 5). It is a property of hinge joints that they are what Steindler has called "track bound"; that is to say the plane of movement of the joint is always perpendicular to its axis, and different forces applied to this joint, although they may run in oblique direction, always produce one of two movements, a clockwise or anti-clockwise rotation about the axis. When a series of such joints are joined together without the intervention of any ball and socket joint a track-bound linkage is formed, the movement of which in space is limited by the characteristics of the individual joints. Whereas it is evident that rotation of the tibia is not a practical means of correcting a pronated foot, it can nevertheless be a valuable guide to the degree of correction obtained, particularly when the foot itself is concealed by a shoe.

![Fig. 5](image)

**Fig. 5**
A tracing of a photograph of the track-bound linkage of the leg and foot showing the change in rotation of the patellar axis, and, therefore, the tibia, associated with the change from pronation to supination and the shape of the weight-bearing area of the foot.

With this model and the rotation bar attached to that part which represents the tibia the following orthodox methods of correction were tried. 1) Wedge elevation of the inner border of the heel. On the model this showed no correction whatsoever (Figs. 7 and 8), and it is clear that it cannot be expected to do so (Fig. 6). If this is applied to the outside of the shoe some temporary improvement will be achieved because the stiffened inner portion of the upper will act in the way a Helfet (1956) insole does, as indicated in a previous paper. Because the force applied by the foot to this correction is equal at least to the body weight it is clear that this corrective device will soon be distorted and this is shown by the characteristic deformation of the shoe in this condition. If this type of wedge elevation of the heel is applied inside the shoe—as in certain proprietary brands—no correction whatsoever is to be expected, even temporarily.

2) Wedge elevation of the inner border of the sole and heel of the shoe. This clearly does correct the pronation of the foot as shown by the rotation of the tibial bar (Fig. 9). However, it must be remembered that, in order to correct pronation of the foot permanently, some alteration in skeletal shape must be achieved. It is clear that this method of correction
Figures 7 and 8 show that no rotation occurs in the tibia with a wedge elevation of the heel. Figure 9 shows that rotation does occur with elevation of the first metatarsal, as it does with an elevation of the inner border of the heel combined with the first metatarsal.

Figure 10—The metal pin is shown embedded in the tibia. Figure 11 shows the pin, from a tracing of Figure 10 superimposed on a photograph of the same foot with a quarter inch inside raise of the heel of the shoe. The pin (in black) has not rotated. When the sole and heel of the shoe are raised, rotation of the tibia occurs with correction of pronation (Fig. 12).
represents only the application of a special environment to the foot like that achieved by walking on the point of a roof. When this correction is removed, no matter how many years it is maintained, the foot will revert to its previous posture because no alteration in the skeletal form will have occurred.

Theoretically, to secure permanent correction of the pronated foot the heel alone must be corrected so that the metatarsal rays come into a degree of flexion, in the hope that, if this position is maintained during growth, alteration in the shape of the metatarsal bones will occur so that this posture of the foot becomes one in which the metatarsal rays are fully extended. It might seem at first sight that it would be easier to secure such a correction by operative means, but there are considerable dangers in this because the foot is growing and the bones are therefore liable to alter in shape even after the initial correction has been obtained, and, perhaps more important, because it is essential always to maintain an even distribution of weight throughout the five metatarsal heads if that condition of localised excessive pressure, with its sequelae of callosity and thinned subcutaneous tissue, is not to occur later in life. This is particularly true because such a condition often produces more symptoms in the adult than does an untreated pronated foot.

It would, of course, be unwise to accept the evidence of such a model without confirmation in the living subject, and to this end a volunteer had a pin driven into the tibia to act as a
rotational indicator. This fully confirmed the findings of the model (Figs. 10 to 12) but it was realised later that such heroic procedures were not necessary, because it was found, for practical purposes, that the correction could be investigated clinically by the use of a "pronatometer". This consists of a small block of wood with a piece of dowling fixed to it at right angles (Fig. 13), and the whole secured to the subcutaneous border of the tibia by either a crepe bandage or a strap (Fig. 14). A simple wooden frame indicates the degree of rotation and also maintains the feet in a fixed position (Fig. 15).

![Diagram](image)

**Fig. 19**
A theoretical analysis of the function of the wedge in action where BW represents body weight, and R represents the resultant corrective force.

![Image](image)

**Fig. 20**
The Schwartz meniscus on the left and the modification on the right.

Using this method two forms of heel correction were investigated: the Helfet insole and the Schwartz meniscus. Produced in the way described in a previous article the Helfet insole is highly efficient, but, as has been pointed out, it takes at each step at least the full body weight and it is therefore liable to break or distort and become inefficient. The difficulties of producing an accurate cast of the foot in the corrected position initially, combined with technical difficulties in manufacture, have led us to seek a corrective device produced in a more simple way. The Schwartz meniscus was shown to me by Professor Plato Schwartz of Rochester, New York State, and I am indebted to him for permission to publish this description. Again, as was indicated
in the previous paper, this acts in a different way and prevents the "wheel-like" rolling of the calcaneum described above. At that time we did not appreciate that the effectiveness of this device could be assessed by so simple a means as the pronatometer, but now, using this appliance, we can see at once what degree of correction is produced in any patient and, if necessary, modify the insole in order to produce a greater or lesser degree of correction for the individual needs of each patient (Figs. 16 to 18).

This device acts in a totally different way from the Helfet insole, and is analogous to the wedge-shaped stone placed behind the wheel of a vehicle on a hill and is represented mechanically in Figure 19. It is a particularly efficient method of holding correction, because in order to overcome the correction the foot has to be lifted upwards, a trend which is opposed by the body weight itself. Indeed the only way in which the foot can relapse in these circumstances is for the heel to slide laterally, which is prevented by the horseshoe shape of the appliance (Fig. 20). In practice it is found that the modification of the appliance as shown in the figure produces a greater correction than the original shape and, provided that this is carefully contoured, is entirely comfortable to wear and does not produce pressure areas such as have been seen from time to time with the Helfet insole.

The material used for this insole is laminated leather which is carved to the correct shape. The appliance is particularly valuable because it is placed in the shoe at the time of purchase and lasts for the whole life of the shoe, being hardly affected by wear. It can be equally effective in sandals and shoes made from modern materials.

This insole is also very effective in relieving the joints of the adult foot from strains after fractures of the leg and foot or as the result of osteoarthritis.

SUMMARY
1. A simple model embracing both the hind and forefoot is described.
2. From this model the expected results of various methods of correcting the pronated foot can be deduced, and these were confirmed by human experiment.
3. It is indicated that a permanent correction requires a biological modification of foot posture achieved by mechanical means.

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REFERENCES