The Negative Anatomically Modified Foot Orthosis (NAMFO)

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INTRODUCTION

A method of taking a non-weightbearing impression, during which considerable modifications may be achieved, has been developed to produce a corrected foot orthosis. Significant advantages include enhanced skeletal stabilization, correction, and shock absorption. The term Negative Anatomically Modified Foot Orthosis (NAMFO) has been coined to differentiate between this and other methodology.

The procedure involves taking a non-weightbearing impression, which has two important effects:

1. It allows ready access to the complete foot in order to achieve an accurate, intimate impression with desired correction.
2. The plantar surface soft tissues including the hydrostatic pads under the heel and the metatarsal heads are not displaced medially or laterally.

The University of California Berkeley Laboratories (UCBL) shoe insert and subsequent adaptions to the original model are well-documented. Traditional attempts are to achieve a flattening under the calcaneal and metatarsal head areas by taking the negative impression in weightbearing and by affecting positive impression modifications. It would appear that the primary concern is on fitting the orthosis to the shoe (truly a "shoe insert") with orthotic management fairing a poor second. Two articles are of particular note. Campbell and Inman (1977) describe a method of tibial rotation, weightbearing casting in which tension on the plantar aponeurosis and longitudinal arch is avoided. Colson and Berglund (1979) proposed the removal of plaster from the positive impression under the Sustentaculum tali to try to achieve greater calcaneal control. The shoe is dictating and limiting the potential of foot orthoses.

It is proposed by the authors to take a different perspective on foot orthoses, to fit a corrected orthosis to the foot, by designing a Negative Anatomically Modified Foot Orthosis (NAMFO). The system has two significant advantages:

1. The retention of the natural soft tissue cushioning promotes shock absorption.
2. As there is less interposing soft tissues between the sides of the orthosis and the underlying boney configuration, there can be enhanced skeletal stabilization and correction, enabling an intimate orthotic fit. There is little emphasis on relief. There is little need for anything but the most stringent buildups over boney prominences on the positive impression (Figure 1).

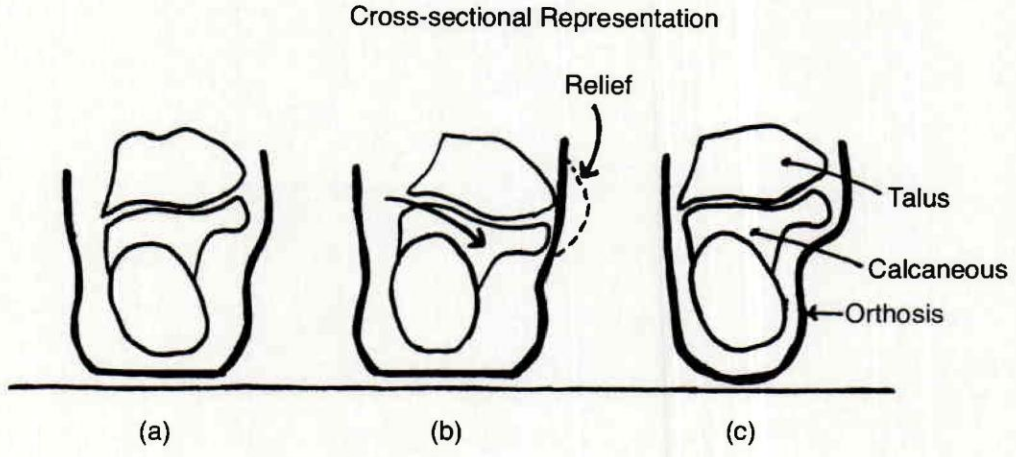

Figure 1. Diagram (a) demonstrates poor skeletal stabilization, resulting in excessive boney movement, necessitating reliefs (b). Improved stabilization end control makes reliefs unnecessary (c).

One of the concerns regarding an impression taken in non-weightbearing is that it should be rounded on the heel and over the metatarsal heads. Traditionally, these areas are flattened parallel to each other to minimize "rocking" and motion of the orthosis within the shoe.

However, slight movement of the orthosis relative to the shoe is not necessarily undesirable. During normal locomotion for the normal person, about six degrees of inversion/eversion occurs at the subtalar joint. Complete skeletal stabilization is only possible by surgical fusion. There will be some extra soft tissue compression before skeletal stabilization occurs, even with the best designed orthosis, as complete preloading of the soft tissue would not be tolerated. The plastic is not completely rigid, therefore, there will still be slight inversion/eversion of the foot within the orthosis and simulated inversion/eversion of the orthosis within the shoe, involving a loading time. The NAMFO will facilitate normal locomotion.

THE ARCHES

The normal foot is basically directly loaded on the plantar surface of the calcaneous and the metatarsal heads. By accentuating both the longitudinal and transverse arches in the orthosis a number of objectives are achieved:

1. Abnormal weight distribution over the metatarsal heads can be redistributed.
2. Loading the longitudinal arch reduces the forces exerted on the metatarsal heads.
3. Loading the longitudinal arch, in eversion deformity allows larger force distribution area, therefore greater correction.
4. In loading the shafts of the metatarsals by utilizing a transverse metatarsal dome, pressures are lowered on the metatarsal heads (see Figure 1).

If you press behind the metatarsal heads you will find a point where pressure will cause the digits to extend. This is due to the attachment of the deep fibres of the plantar aponeurosis, the Sagittal Septa, into the sides of the flexor sheaths and the plantar ligaments. As the plantar ligaments are firmly attached to the bases of the proximal phalanges, pulling of the basically inextensible plantar aponeurosis up over the shafts of the metatarsals will produce digital extension. This is in part a reversal of the so called "Windlass action" that occurs on dorsiflexion of the toes (Figure 2).

The superficial fibres of the plantar aponeurosis insert into the skin of the anterior part of the ball of the foot, and as Bojsen-

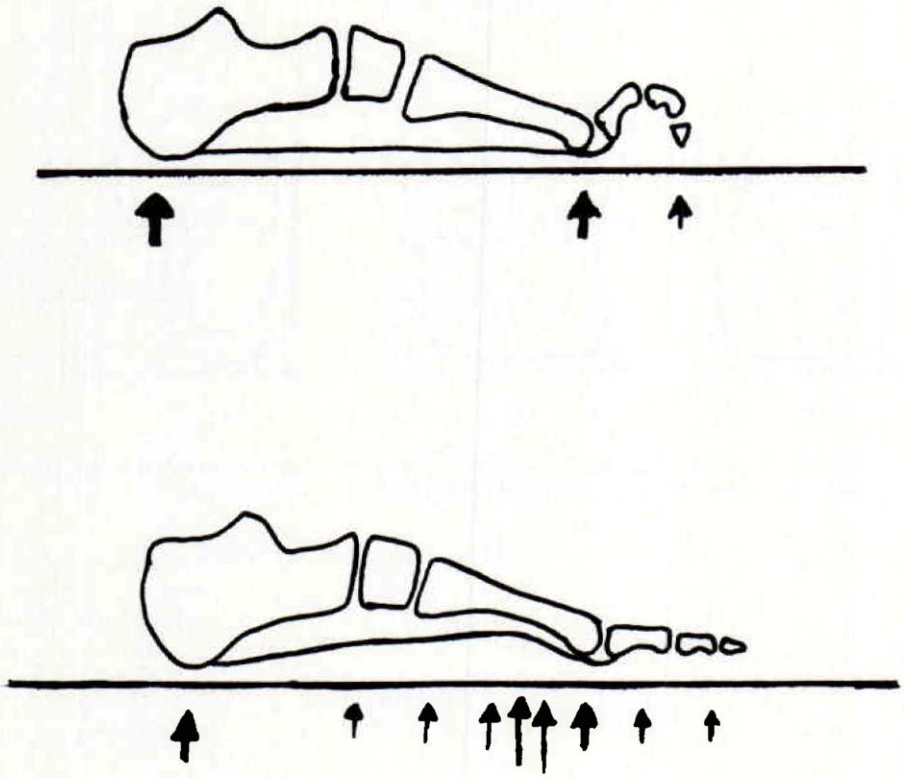

Figure 2. In toe clawing, forces are borne on the metatarsal heals and tips of the digits. The dome leads the metatarsal shafts and pulls on the plantar aponeurosis causing digital extension. For long standing deformity, therapy to elongate the intrinsic musculature would be recommended.

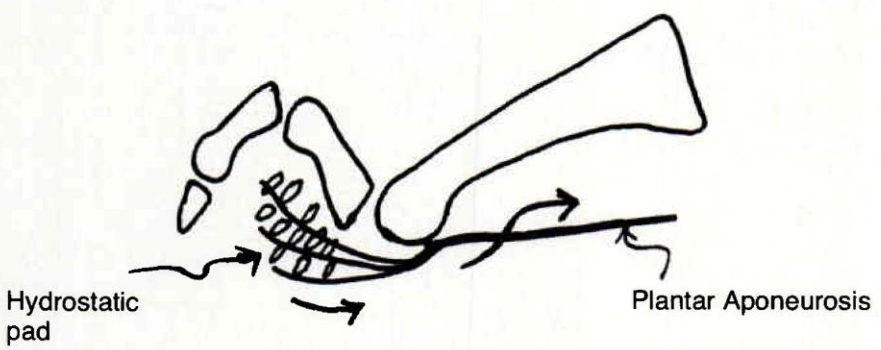

Figure 3. The hydrostatic pad, incorporated into the vertical fibres of the plantar aponeurosis, is pulled anteriorly in toe clawing. The metatarsal dome will pull this protective pad back under the metatarsal heads.

Møller (1978) points out, restrain the skin from sliding anteriorly during the pre-swing phase of gait. In toe-clawing or hammertoe deformity, the vertical fibres of the plantar aponeurosis—including its cushioning fat—that lie superficial to the metatarsal heads are drawn anteriorly, leaving the heads exposed to the trauma of locomotion. The exaggerated metatarsal dome we advocate will re-draw this protective cushion back under the metatarsal heads, take excessive pressure off the tips of the toes (frequently the site of pressure necrosis) by extending the digits, and will load the metatarsal shafts (Figure 3).

Soft commercial domes have long been available. Because they are compressible they serve predominantly to pad the foot and achieve limited correction. The hard plastic metatarsal dome incorporated into the NAMFO is markedly superior.

POSITION FOR TAKING THE IMPRESSION

Probably the easiest position is that with the patient prone on an examination table. Ready visual and manual contact can be made with the plantar and dorsal surfaces of the foot, and accurate alignment of the forefoot to the hindfoot, and the foot to the crura, can be achieved. The knee should be in some flexion to ensure the gastrocnemus is relaxed. If heel height is of concern, the position of the hindfoot to forefoot can be easily manipulated. In our practice we made no allowance for the normal range of heel heights.

THE METHOD

Boney prominences are marked. The joint spaces of the first and fifth metatarsal heads may be marked to confirm the location of the metatarsal heads. The foot is manipulated to ascertain the degree of correctability desired in the cast.

A 75 to 100mm plaster of paris bandage is wrapped around the foot.* There is no need to encapsulate the entire dorsum of the foot or the complete malleoli. It only makes it difficult to remove the negative impression. A measure above the trim is sufficient.

Figure 4. Gripping the calcaneous to achieve hindfoot control and position. The talus is outlined.

Moulding is commenced under the longitudinal arch. The calcaneous is grasped between thumb and forefinger, the second finger passing down under the sustentaculum tali. With a drawing motion the pressure-tolerant soft tissue under the sustentaculum tali and other medial and lateral soft tissue are compressed to stabilize the calcaneous. Calcaneo-talar joint control is sought and the amount of inversion/eversion is determined by manipulating the gripped calcaneous. This is the primary control for the entire foot (Figure 4).

Moulding is done in such a fashion as to draw the medial and lateral soft tissue

*No casting stocking is used, but a little lubricant over hairy areas may be applied.

down under the calcaneous. The rubbing is done in a downwards direction.

To locate the position of the apex of the metatarsal dome, pressure is applied with the pad of the thumb behind the metatarsal heads. Correct location is indicated when the digits extend. There is usually some breeching of the plastic during vacuum-moulding, so do not be afraid of over-emphasizing the dome.

With the calcaneous stabilized in the above manner, pressure is applied with the thumb pad to fashion the dome. The fingers curl up over to the dorsum of the forefoot and it is manipulated relative to the (stabilized) hindfoot to provide pronation/supination twist of the forefoot. The amount will depend on the degree of correctability and the desire to align the forefoot parallel to the hindfoot (Figure 5).

When the plaster of paris is cured, the impression is removed from the patient by sliding it off the heel. Distortion is minimal, even though the wrap is still slightly malleable.

Figure 5. Manipulating the forefoot relative to the (stabilized) hindfoot to achieve pronation/supination twist.

BALANCING THE ORTHOSIS

With a rounded heel and metatarsal heads, the orthosis will be stable within the shoe so long as the calcaneous and the first and fifth heads form a stable tripod. The still-green impression is placed on a flat surface. The second and third fingers of one hand are put inside the impression over the first and fifth heads and the index finger of the opposite hand is applied to the site of the calcaneous, gently adding pressure to achieve the stable tripod. The ma-

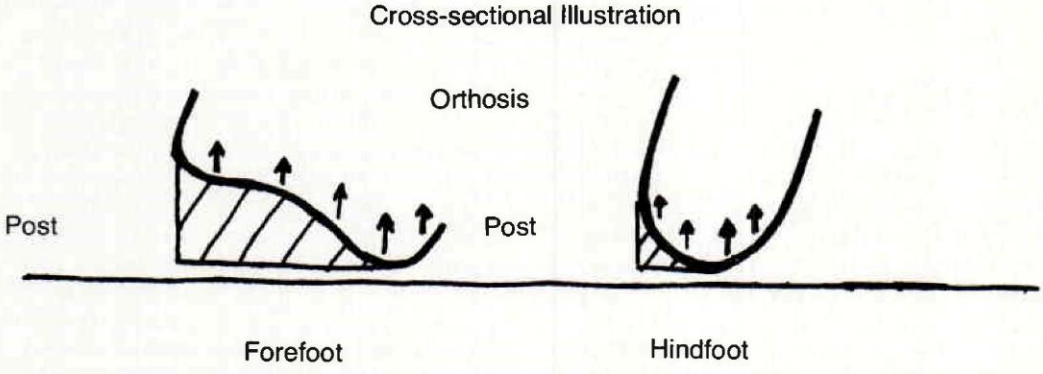

Figure 6. Posting the orthosis so as to distribute weight-bearing forces more evenly over the entire plantar surface of the foot in cases of non-correctible deformity. This reduces pressure on the borders of the forefoot and calcaneous.

nuever may correct error in taking the impression or it may introduce a greater than desired element of correction (this would be changing the amount of forefoot pronation twist). Judgment has to be exercised. It has been our experience that the great majority of patients can be balanced in this manner.

If deformity, fixed or functional, prohibits full correction to allow the calcaneous, first, and fifth metatarsal heads to be in contact with the floor, one may elect to post the orthosis to establish the tripod. Remember the NAMFO is designed to fit the patient's foot. It is not merely a shoe insert (Figure 6).

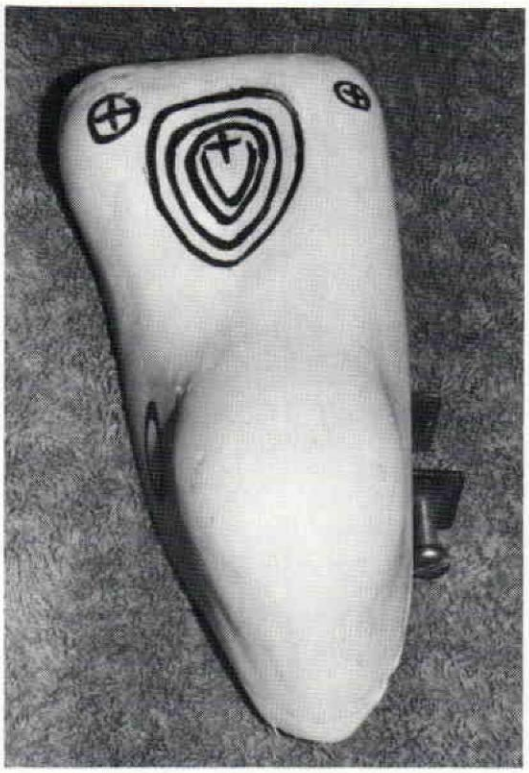

Figure 7. The completed positive impressions. The topographic lines indicate depth. The 'X' marks the highest point of the dome. Note the natural contours achieved and the definition around the calcaneous indicating the "grasping" effect that gives the control.

MODIFICATIONS TO THE POSITIVE IMPRESSION

As extensive modifications can be accurately achieved on the negative impression, few modifications are needed on a skillfully executed impression. Usually only a smoothing and the blending in of the "dome" into smooth profile is required. A vacuum hole may be drilled in the apex of the dome.

Occasionally, the dome needs to be widened and deepened (the apex is over the third metatarsal). Or, the area under the sustentaculum tali must be more heavily screened to enhance subtalar control (Figure 7).

Buildups are not normally required. If the patient has excessive pressure over boney prominences, it indicates insufficient skeletal stabilization allowing the boney framework to move excessively within the orthosis. This spells two possibilities:

1. Poor cast-taking
2. Over-optimistic expectations from the NAMFO. A NAMFO with extended leverage, that is an Ankle Foot Orthosis (a NAMAFO) may be indicated.

VACUUM FORMING

It is not necessary to wait for the impressions to dry. A "pantyhose" is put over the impression and the plastic is cooled rapidly. A quick spray of silicone ensures the hot plastic will not stick to the nylon (Figure 8).

THE FITTING

The NAMFO fits intimately over the plantar, medial, and lateral aspects of the foot. It redistributes forces and allows accurate correction of the skeletal structure working through a soft tissue interface. Forces will be applied to unaccustomed areas and there will be a variance in individual tolerances. Some accept the orthosis immediately while others need to build up their tolerance by wearing the orthosis, for example, three hours the first day, four the second, and so on. It may require breaking

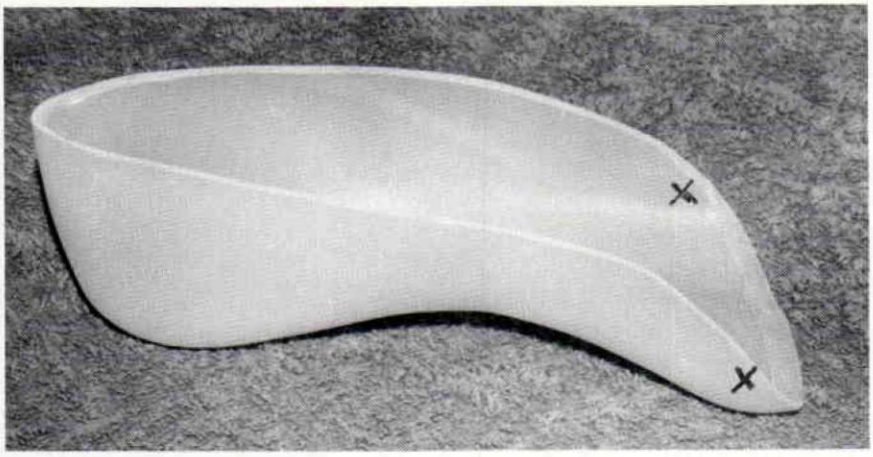

Figure 8.

the wearing into two periods during the day, with increasing increments. If the patient has not found the NAMFO comfortable within ten days, then the impression was incorrect.

Some reddening may be initially present, however, so long as you are confident of the impression, this is no cause for concern. Superficial reddening may occur until skin tolerance is achieved, just as a Patella Tendon Bearing Prosthesis (PTB) may initially cause reddening over the patellar tendon.

Patients should be instructed as to the variance in establishing tolerance. Most patients will describe a firm pressure from their new orthosis and will express frank or relative comfort. Occasionally you may not be able to achieve all the correction you want because the patient would not initially tolerate it. A later cast can be taken introducing the final correction.

The shoe is not part of the orthotic management as such. We often recommend inexpensive runners as the soft material holds the foot intimately within the orthosis, not allowing relative movement of the foot to the orthosis. The softer shock absorptive type heel is also advantageous.

Patients with diabetes and peripheral vascular disease require the usual extra care and attention to detail. Some restraint and slower introduction may be required until orthotic expertise is attained and the patient can provide reliable feedback. Otherwise, management is as described.

TIME

If accurate positive modifications are achieved, the impressions can be made, poured, screened, and vacuum-formed under the conventional time for producing UCBL shoe inserts.

APPLICATION

We have had outstanding success with a wide variety of patients whose feet are exposed to abnormal stresses due to imbalance or abnormal functional demands.

Rheumatoid feet with subtalar instability, exposed pressure-sensitive metatarsal heads and toe-clawing respond well to subtalar control, loading on the metatarsal shafts, the metatarsal cushioning redrawn posteriorly, toe extension, and the natural calcaneal pad enhanced.

Similarly, upper motor neuron lesion patients have responded well. The typical picture is of inversion/plantar flexion of the foot, toe-clawing and plantar thrust reflex. The calcaneal "gripping" provides greater subtalar control. The exaggerated dome will encourage digital extension, thereby reducing abnormal tone, as this is a distal "key point of control" used in physiotherapy technique.

Two particular kinetic reflexes, the plantar thrust reflex and the positive supporting reaction, are initiated by pressure on the ball of the foot. The dome will dampen these reflexes**. Thus, greater distal control may be achieved, which in turn facilitates proximal control. A significant number of patients who formerly would have been treated with an Ankle Foot Orthosis (AFO) respond with a NAMFO. This is psychologically more acceptable and suggests that this system has a definite role in early rehabilitation to facilitate voluntary control.

Impressive results have so far been achieved in the treatment of distance runners. Greater all-over plantar surface loading, natural soft tissue cushioning and the balance of forces suggest the NAMFO would have a vital place in the prophylactic as well as the sports-injury orthotic management. The marathon runner's foot requires all the assistance it can master to mitigate the enormous insults to which it is subjected. The system is compatible with the addition of a shock absorptive insole between the orthosis and shoe.

Plantar surface callosities, signs of abnormal forces, will resolve with the correct application of the NAMFO as the abnormal forces are resolved by anatomical correction. It is common experience for patients who have had years of podiatry treatment involving the continual removal of callosities, to return some months after initial fitting with soft smooth plantar skin, having had no subsequent podiatric attention. The pathological forces have been corrected, so the callosities disappear.

Thermoplastic A.F.O.'s, particularly for the rheumatoid and the neurological patient with abnormal reflexology and increased tone, should be cast in two stages—the first, the NAMFO, and the second part up the leg—to achieve the NAMAFO. Accommodation for heel height is made by manipulating the forefoot relative to the hindfoot. Similarly, the use of serial plaster for neurological patients with very marked, uncontrolled lower limb extensor tone and plantar thrust reflex should be conducted with attention to the principles raised in this article, and with similar techniques.

We would challenge many of the traditional treatments of the pediatric foot that involve the use of orthopaedic shoes with external modifications because of the lack of specific skeletal control. Preliminary work has shown encouraging results in a variety of conditions.

Once again, the improved control offered by this orthosis frequently enables a NAMFO to be used instead of an AFO. Advantages are all too obvious.

CONCLUSION

The thermoplastic NAMFO and the NAMAFO, taken in non-weight bearing, incorporates vastly improved subtalar control, and greater correction of abnormal forces on the forefoot by employing a metatarsal dome and increased shock absorption.

It is the authors' belief that with skill and understanding, possibilities not previously considered or achieved in the treatment of both the orthopaedic and neurological foot can be realized using this system.

**As the stimuli for these reflexes are considered to be stretch of the intrinsic musculature, and, to a lesser extent, cutaneous stimulation, we do not yet fully understand the mechanism behind this phenomenon. Certainly part of the answer would lie in the nature of the correction that is achieved, the total contact, and the resultant reduction of sudden stretch stimulating a clonus response and general extensor tone.

BIBLIOGRAPHY

Bobath, B., *Abnormal Postural Reflex Activity Caused by Brain Lesions*, 2nd Ed., William Heinemann, London, 1971.

Bojsen-Moller, F., "Anatomy of the Forefoot, Normal and Pathologic," *Clinical Orthopaedics and Related Research*, No. 142, 1978, pp. 10–17.

Campbell, J.W. & Inman, V.T., "Treatment of Plantar Fasciitis and Calcaneal Spurs with the UC-BL Shoe Insert," *Clinical Orthopaedics and Related Research*, Vol. 103, 1974, pp. 57–62.

Colson, M. & Berglund G., "An Effective Orthotic Design for Controlling the Unstable Subtalar Joint.", *Orthotics and Prosthetics*, Vol. 33, No. 1, 1979, pp. 39–49.

Henderson, W.H. & Campbell, J.W., "UC-BL Shoe Insert Casting and Fabrication," *Bulletin of Prosthetic Research*, BPR 10–11, 1979, pp. 215–235.

Lapidus, P.N., "Kinesiology and Mechanical Anatomy of the Tarsal Joints," *Clinical Orthopaedics and Related Research*, Vol. 30, 1963, pp. 20–35.

Mann, R.A., "Surgical Implications of Biomechanics of the Foot and Ankle," *Clinical Orthopaedics and Related Research*, No. 146, 1980, pp. 111–118.

Mann, R.A., & Hagy, J.L., "The Function of the Toes in Walking, Jogging, and Running," *Clinical Orthopaedics and Related Research*, No. 142, 1979, pp. 24–29.

Stupp, S.T. et. al., "Ice-Water Quenching Technique for Polypropylene," *Orthotics and Prosthetics*, Vol. 33, No. 1, 1979, pp. 16–21.

AUTHORS

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