Root Biomechanics – Does it Still Hold Water?

Even today Root's theories and applications remain relevant.

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Earliest Efforts

The earnest effort to understand the mechanics of the human foot and the mechanical origins of foot pathology did not begin until the first half of the twentieth century. In 1941, JT Manter's article "Movement of the Subtalar and Transverse Tarsal Joints" attempted to define a normal and relatively consistent motion of the human foot from which foot abnormalities could be defined. This was a quantum leap in thought from previous authors who usually categorized feet by external appearance or even national origin.

Manter, his contemporaries, and Root truly started a paradigm that helped define human foot function and ultimately the mechanical source of pathology. Has the value of this information been validated by other researchers today in the medical literature? Do clinicians know enough about the theory to apply it effectively?

Hicks, in 1953, followed Manter's work and expanded on the concept that there were normal mechanics; abnormal mechanics and the different in between normal and abnormal could be defined as pathology. The theme of these papers was still focused on defining normal joint motion, so that we could better see how abnormal motion produced deformities.

Elfman, in 1960, began to investigate the abnormal motions relative to the earlier suggestions of normal, and found a mechanical interrelationship between the subtalar joint and the midtarsal joint. This revelation made things much more complicated, especially for a clinical world that saw foot deformities as something to be either cut out, arthrodeised, or rearranged. The thought that mechanical variations in feet may be the origin of pathology persisted, even as treatment was misdirected solely at the symptoms.

Morton and others, before 1935, used anatomical size variations of the human foot to clarify and described pathologic motions as hypermobility in feet. The exploration of human feet was changing from measuring and comparing size and deformities to attempts to deduce the cause of the deformities. This transition from form to function was all about accuracy, attributing the smaller variations in motion to the cause of foot deformities.

Merton Root

Merton Root saw the transition and said "prior to the 1950's there were no criteria to define a structurally or functionally normal foot. Furthermore, only gross structural abnormalities of the foot could be identified, like classic clubfoot deformities. Medical practitioners generally identified abnormalities by arch height. Pes planus and pes cavus feet were considered to be abnormal, and normal fell into some vague arch height position between these two assumed abnormalities, depending on the perception of the practitioner."

The medical effort at this time relegated treating foot pathology and its resulting deformities to those treatments that reduced symptoms without regard for their origin or etiology. The clinical outcomes of many of the early twentieth century treatments, whether surgery, padding, arch supports, or corn and callus reduction, were poor and the results were usually temporary.

Even today, the exact mechanism of mechanical treatment of the foot with functional orthoses is not clear. As several authors have suggested, orthoses may function as a result of a change in muscle function, alteration in ground reactive force, or as an effect of biofeedback. We do know, thanks to modern research and technology, that orthotic therapy does work and works well. Recently, peer reviewed medical literature is replete with positive documentation of what is often referred to as the "Root theory of biomechanics" and relate it to the contemporary research and clinical investigation that now demonstrates that functional custom orthoses, born from this theory, are an effective intervention in many mechanically induced pathologies of the foot and ankle.

What is "Root Biomechanics"?

A review of several articles and the three books reveal several statements which truly changed the way our profession, and later other disciplines, looked at the workings of the foot and ankle. The original theory of Root Biomechanics tried to develop "criteria defining a normal foot" so that "structural abnormalities of the foot could be both identified and measured and their effect on foot function measured." This was the first step toward settling a controversy that existed in our profession: which feet would develop pathology and deformity? It was also a beginning of the search to understand why pathology ultimately occurs.

The theory proposed, "for every degree of motion of the subtalar joint, the plantar contour of the heel changed slightly." This could mean the converse that if the plantar contour of the foot could be changed, maybe the position of the subtalar joint could be altered in stance and gait. Was there a possibility this change could affect the motion of the midtarsal joint, improve pathomechanics, and reduce symptoms and deformity? The articles cited later demonstrated that this was ultimately true.

How did Root know that this was true, and how did he know that capturing the shape of the foot in the neutral position was the best for making an orthoses? This was, by Root's own admission, "by trial and error rather than as a result of any knowledge about normal function of the foot." Later, as more knowledge of foot function and structure was acquired, this neutral position was found to be the best position in which to cast the foot.

It turns out that a million custom orthoses later, this was probably one of the best guesses in the history of podiatry. Root was apparently frustrated in the profession's inability to compare one foot type to another. The high arch/low arch classification was not much help in defining symptoms or predicting deformity. It was also not a standard for defining pathology. He stated in his development of the functional orthoses paper, "It became evident that this neutral position could be determined (consistently) in any foot and that a position had been found for comparing structural variations from one foot to the next." This was the constant yardstick the profession was looking for to accurately classify feet and communicate to one another about feet in our discussions and in our writings. It was so simple. Of course, everyone had a neutral subtalar position!

Pathologic Foot Types

This discovery helped Root define four pathologic foot types that had a predictable pernicious effect on the foot and produced a predictable and describable dysfunction. He first defined a calcaneus that is inverted to the leg, in neutral position, as a rear foot varus, a foot that had an inverted forefoot, in neutral position, as a forefoot varus and an everted forefoot as a forefoot valgus. Each of these could be measured as a determinant of severity within two degrees of accuracy. The fourth foot type was one that had, insufficient dorsi-flexion at the ankle to allow the tibia to pass over the foot (equinus) and result in excessive subtalar pronation as compensation.

The conclusion in this part of the development of the theory was to postulate, "an orthoses must support the forefoot (in addition to affecting the plantar heel), in any abnormally inverted or everted forefoot position, to the full extent of the deformity if the orthoses was to prevent an abnormal subtalar or midtarsal joint position and motion." The device must, in other words, be bent in a way that supports the forefoot in its abnormal inverted or everted position. This gave birth to the Root functional device that has been constructed for over forty years and is now used to test the orthotic effect on plantar fasciitis, metatarsalgia, functional hallux limitus, patella femoral syndrome, stress fractures of the foot, and PT dysfunction.

It is amazing to think that someone hypothesized and investigated the possibility that abnormal foot structure produces abnormal foot function, and that this is the origin of symptoms and pathology. This was basically a foreign thought at the time. Further, he attempted to prove this concept by developing methods to measure structural deformities consistently from individual to individual.

Root accepted the responsibility of defining normal and abnormal foot types, and then establishing the mechanical goal of a piece of plastic which when stood upon, might relieve symptoms and prevent deformity, with nothing more than a theory to back him up. The literature continues to demonstrate through new studies that provide concrete evidence that this theory, given some modifications and even errors, is overwhelmingly valid and useful in treating the human foot and describing the mechanical origins of foot and leg pathology.

The ultimate practical result of the theory was the development of a casting method, positive cast construction method and specialized custom semi-rigid functional foot orthoses intended to alter subtalar and midtarsal joint compensation for the classified deformities. The research community applied these methods and materials to specific pathologies that appeared amenable to clinical success. The professional community used anecdotal experiences of success with the technique and devices during this period.

Evidence-based research during the last decade has, in most cases, demonstrated the value of the custom functional foot orthoses for specific pathologies. Unfortunately, some research projects utilized inexperienced personnel, and misunderstood correction techniques or alterations in materials that resulted in mixed results. We do, although, now have a body of peer-reviewed literature that have used the Root theory and orthotic device and have demonstrated positive results.

Plantar Fasciitis and the Root Custom Functional Device

J.H. Hicks, in 1954, wrote a paper about plantar aponeurosis and related its function to the mechanics of the arch. Following his paper, most clinicians related plantar fasciitis and heel pain syndrome to a variety of arch heights.

The Root theory was somewhat more complicated than just high arch equals supination and low arch equals pronation. Forty-five years after Hicks, Kogler attempted a cadaver study in which he used a semi-rigid custom functional foot orthosis, very similar to the device described by Root, to prove that orthoses do decrease the strain on the plantar fascia.

Several years after that successful project, he demonstrated that by adding wedges, particularly valgus forefoot wedges, to his protocol, he further decreased the strain on the plantar fascia. The mechanics of the subtalar joint and its interrelationship with the midtarsal joint, as Root had suggested, were becoming more evident.

The California College of Podiatric Medicine, in 1991, produced a clinical outcome study that used the Root casting and his semi-rigid custom functional foot orthoses to treat heel pain secondary to plantar fasciitis. The study designed and tested both mechanical treatments as well as combined medical and mechanical treatment.

The study demonstrated that the device (from a proper neutral cast) provided 89% of the patients with total or more than 80% relief of their symptoms, in an average of 5.4 weeks. The study's design also demonstrated that 115 of the 133 feet had a structural abnormality as defined by Root that would supinate the long axis of the midtarsal joint (invert the forefoot on the rearfoot). The study further postulated that the Root type of device would prevent some of this motion, relieve the strain on the plantar fascia, and improve symptoms.

Lynch, in 1998, also used a similar custom functional orthosis, and compared the outcome for plantar fasciitis with patients receiving cushioning heel pads. He demonstrated that the functional control of the foot, after 12 weeks of treatment, resulted in 70% of the patients achieving good to excellent results, while within the heel pad patients group only 30% of the patients received relief. Obviously the mechanical origin of the pathology was more than just the shock-absorbing quality of pads.

A 1999 paper by Pfeffer attempted to compare the Root casting technique and custom functional foot orthosis with pre-fabricated heel pads and exercise over an eight-week period. The clinicians performing a neutral position, locked midtarsal joint casting, had no experience in this technique. The results demonstrated this fault by concluding that the difference between the prefabricated and custom orthoses were "not statistically significant" in reducing pain.

Gross, in 2002, used a custom functional semi-rigid orthosis in his study to document that the Root type device, which was intended to change subtalar and midtarsal joint motion, could reduce pain and disability in patients with plantar fasciitis. There was a 75% reduction in disability rating and a 66% reduction in pain.

Although Root did not have the advantage of an operating cadaver manipulation apparatus, he was sure that the faulty mechanics that resulted from his rearfoot varus and forefoot to rearfoot deformities could be reversed with a particular casting method and custom orthoses. It seems he was right, as was demonstrated in the Kogler experiment.

Reducing Tensile Strength on the Plantar Fascia

Considering the previous studies in relationship to Root biomechanics, what could be the best orthotic prescription that would direct efforts at reducing the tensile force on the plantar fascia? There seems to be two different situations that must be addressed when treating mechanically induced heel pain– the everted calcaneus from an accessible pronated subtalar

joint or a perpendicular calcaneus with an everted forefoot to rearfoot relationship (forefoot valgus).

This classification of resulting foot positions are not intended to make things more complicated; orthotic fabrication, as well as some new information like Kogler's and Kirby's modifications to the Root-type device work, and have made orthotic construction slightly more sophisticated. Could the rearfoot eversion compensation be better addressed by adding a medial skive technique? Could the forefoot valgus compensation benefit by a valgus extension to the Root cast correction technique? This is also a theory that might be substantiated some day, but is now in frequent use within the profession.

Controlling Eversion of the Rearfoot

The goal of orthotic therapy for treating plantar fasciitis should be to control the eversion of the rearfoot since this is one of the origins of the inversion of the forefoot (supination of the midtarsal joint). The other origin of forefoot inversion is the everted forefoot, which compensates (supination of the midtarsal joint) when contact with the horizontal plane of the ground occurs. A pathology-specific orthosis must support the medial side of the calcaneus in one type, or support the lateral side of the forefoot in the other type. How can we manipulate ground reactive force to our advantage in these two cases?

Casting

The suggested orthotic prescription requires a non-weight-bearing negative cast. The cast must be taken in a neutral position with the midtarsal joint at the end of its range of motion, if the resulting device is going to hold it there and not allow midtarsal supination. Semi-weight-bearing and weight-bearing casting or imaging techniques, are of little use here because both place increased force on the medial side of the forefoot and reposition the midtarsal joint into supination. The resulting image will have an artificial forefoot varus deformity (think Root's supinatus) and according to Kogler's article, this will increase the strain on the plantar fascia.

Shell material – I suggest using semi rigid polypropylene simply because of studies that demonstrate the effectiveness used this material. This does not mean that graphite composites or other thermoset materials are less effective.

Cast fill – Many orthotic laboratories use several different arch fills in order to either dampen the effect of the orthosis in arthritic patients or to increase the comfort of the device. For this pathology, it is essential to use the original Root-type of cast fill now referred to as minimal, if the midtarsal joint is to be bridged and braced.

Orthoses width – Many orthotic laboratories also use several different widths in order to assist in shoe wear. The majority of the studies cited use the original Root design that places the medial anterior edge of the device just behind the tibial sesamoid. This allows the body of the device to rest firmly under the base of the 1st metatarsal to assist in plantar flexion of this structure during stance. A significant debate ensues now about first ray cutouts in the mechanical control of patients with plantar fasciitis, but little data is available on its effectiveness when compared to the original Root design.

Special additions – Contemporary thought and theory recommends the use of the medial skive technique to shift the ground reactive force more medially in patients with an everted heel. This technique, described by Kirby, flattens the medial side of the heel of the Root positive cast and raises the medial side of the orthosis heel cup. This could be added to the orthosis of the plantar fasciitis patient who has an everted calcaneus. A 14 mm heel cup and a rearfoot post are necessary to accommodate this modification.

Valgus Extensions

A valgus extension can be added to the everted forefoot type. This is a deviation from the Root theory, which requires capturing the true forefoot to rearfoot relationship "to within two degrees of the actual" deformity. Kogler's cadaver research possibly demonstrates that the clinician can't always capture all the original forefoot valgus, especially after so many years of the patient walking in the compensated position. Adding a top cover is necessary if this forefoot extension is added.

Conclusion

The effort to understand the mechanical origin of foot pathology began more than 50 years ago with the development of a theory, application for the clinicians, and the design of a custom functional orthosis made from a specific cast of the foot. Today, we know a great deal more about the foot, its function, the effect of orthoses and clinical outcomes. There is still a lot we don't know and only suspect. Where we are now would not be possible if it weren't for the original theory, which we continue to use, modify, and challenge.

I uncovered a quotation of Dr. Root from a lecture he gave at the 1963 APA Annual Meeting. It is an appropriate lesson today. "Podiatry must contribute to the medical literature basic knowledge upon which to build a regime of treatment rather than remain a parasitic profession dependent entirely upon other medical fields for the advent of knowledge upon which to improve treatment techniques."

Have we accepted this challenge regarding orthoses and the mechanical origins of foot pathology?

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