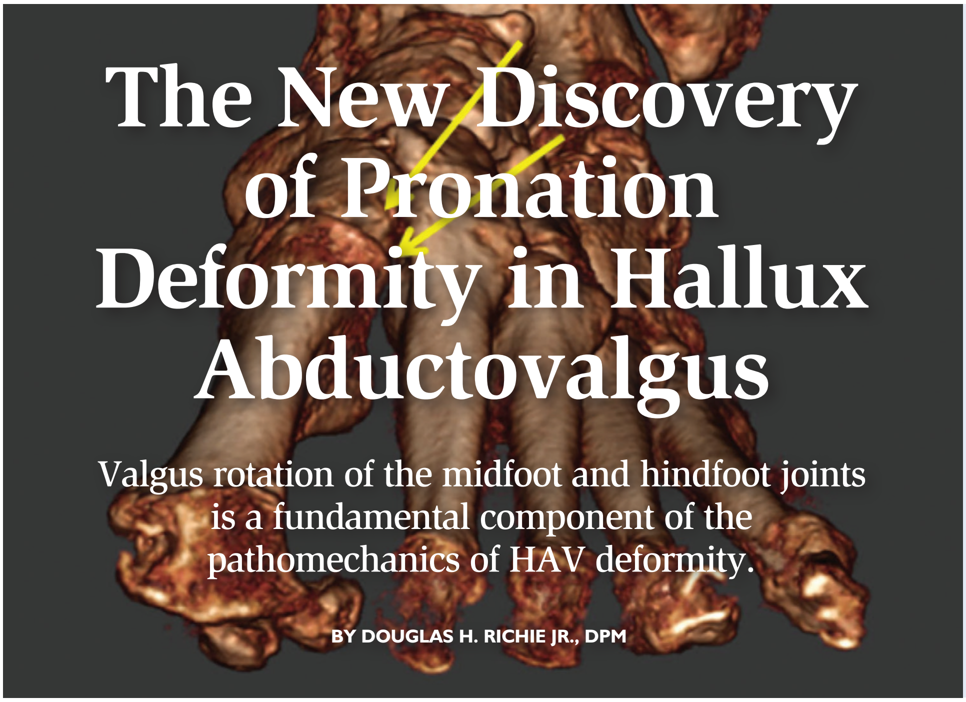

The New Discovery of Pronation Deformity in Hallux Abductovalgus

Valgus rotation of the midfoot and hindfoot joints is a fundamental component of the pathomechanics of HAV deformity.

BY DOUGLAS H. RICHIE JR., DPM

Objectives

1) To review the pathomechanics of hallux abductovalgus deformity

2) To review the biomechanics of the first ray of the human foot

3) To understand first metatarsal pronation in hallux abductovalgus deformity

4) To understand sesamoid rotation in hallux abductovalgus deformity

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Introduction

Over the past 30 years, significant insight has been gained about the contributing factors and events leading to the formation of hallux abductovalgus (HAV) deformity in the human foot. Newer surgical approaches are now being utilized for correction of so-called "pronation" deformity of the first metatarsal in HAV surgery. Further scrutiny will reveal that pronation of the first metatarsal is not related to the pathomechanics of HAV deformity. Whether surgical treatment or conservative care is being utilized to treat HAV deformity, a thorough understanding of the pathomechanics of the condition is critical in selecting appropriate treatment interventions.

Basic Concepts of Foot Biomechanics

The normal and abnormal function of the first ray of the human foot is fundamental to the initiation and propagation of HAV deformity. Understanding the direction of motion of the first ray relative to the *rest of the foot,* versus motion relative to the *supportive surface,* is essential to understanding the pathomechanics of HAV.

The first ray of the human foot consists of the first metatarsal and the medial cuneiform bones (Figure 1). The main articulations of the first ray include the first metatarsocuneiform joint (1st TMT joint) and the medial naviculocuneiform joint. With weight bearing and loading, the first metatarsal ***dorsiflexes and inverts relative to the remainder of the foot.***[1]

The first ray moves independent of the sesamoid apparatus at the first metatarsophalangeal joint (1st MTPJ). Specifically, the sesamoid apparatus

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is firmly attached and fixed to the adjacent metatarsals, i.e., the remainder of foot. The motion of the first ray relative to the foot and sesamoids is a critical factor in the pathomechanics of HAV deformity. Specifically, the first metatarsal will dorsiflex and invert away from the foot with weight bearing. This motion will occur *regardless of the position of the first metatarsal relative to the supportive surface.* As will be shown, patients with HAV deformity have excessive transverse plane motion of the first ray such that dorsiflexion and inversion of the first ray is also accompanied by adduction of the first metatarsal away from the remainder of the foot. This medial displacement of the first metatarsal, relative to the sesamoid apparatus and the second metatarsal, is the focus of surgical procedures designed to correct HAV deformity.

The foot, not the supportive surface, is the frame of reference for surgical correction of HAV deformity. All surgical procedures commonly used to correct HAV deformity use the angular relationship of the first and second metatarsals (intermetatarsal angle deviation), as well as the relationship of the first metatarsal to the sesamoid bones (sesamoid position) as primary determinants of deformity. Surgical correction of alignment of the first metatarsal relative to the second metatarsal and the position of the first metatarsal head relative to the sesamoids is performed using *foot landmarks,* rather than the *supportive surface* as a frame of reference. Radiographic measures of deviation of the first metatarsal from the second metatarsal and from the sesamoids are made without any reference to the supportive surface. In the operating room, surgeons attempt to realign the first metatarsal to the second metatarsal and to the sesamoids without any ability to reference the alignment of these skeletal segments to the supportive surface. It is important to point out that the new approach to reducing "first metatarsal pronation" in HAV surgery must somehow take into account the alignment of the whole foot relative to the supportive surface.

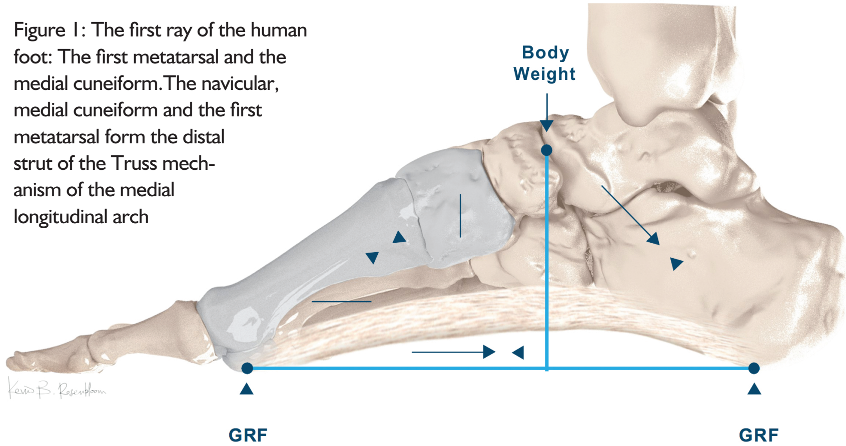

Figure 1: The first ray of the human foot: The first metatarsal and the medial cuneiform. The navicular, medial cuneiform and the first metatarsal form the distal strut of the Truss mechanism of the medial longitudinal arch

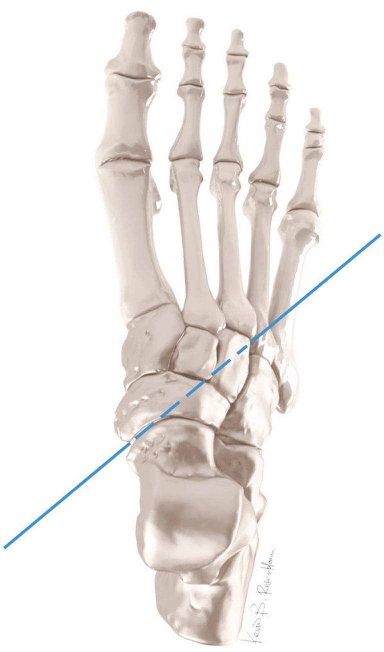

Figure 2: The axis of the first ray which allows equal magnitude of dorsiflexion with inversion.

Dorsiflexion and inversion of the first ray with loading of the foot was first described by Hicks, who plotted an axis of motion which passes from the navicular to the base of the third metatarsal, oriented 45 degrees from the transverse and sagittal planes (Figure 2).[1] This axis allows almost equal amount of sagittal and frontal plane motion of the first ray, while providing almost no motion in the transverse plane in the normal or healthy foot.

The first ray does not and cannot move independently in the direction of pronation. Pronation is the combined movement of dorsiflexion, abduction and eversion.[2] Dorsiflexion of the first ray with loading is accompanied by *adduction* and *inversion.* Thus, it is inappropriate and misleading to describe "pronation" deformity of the first ray in HAV deformity. Further scrutiny of articles promoting a triplane correction of HAV actually describe a perceived *everted* position of the first metatarsal on the ground.

In 1979, the author was part of a research team which verified the findings of Hicks that with dorsiflexion, the first ray inverts *relative to the rest of the foot.*[3] Our study of 24 cadaver specimens used pins and calipers to measure range of motion of the first metatarsal, as well as the medial cuneiform and navicular bones. In 1999, Johnson and Christensen used a sophisticated three-dimensional tracking device placed on the bones of the first ray of 7 cadaver specimens.[4] They also verified that with dorsiflexion, the first ray *inverts relative to the foot.* Also, an osseous "locking" mechanism was described when the first ray plantarflexed and abducted with peroneus longus activation. This locking of the first ray with plantarflexion and eversion was further studied and verified by Perez and co-workers (Figure 3).[5]

This research from Perez, et al. has significance for surgeons who wish to enhance stability of the first ray when adding frontal plane correction to a Lapidus bunionectomy procedure. Eversion with plantarflexion appears to engage a natural locking and improved stability of the first ray to resist ground reaction forces.[15]

Since the original study by Hicks in 1953, there have been over ten high-quality kinematic studies of the human foot verifying that the first ray

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independently moves in the direction of dorsiflexion with inversion.[3,4,7-14] As will be shown, this independent movement, when combined with additional adduction, is a fundamental factor causing the development of hallux abductovalgus deformity.

Position of the first metatarsal, relative to the ground, is also an important factor in the development of hallux abductovalgus deformity. In this case, overall foot position can ultimately place the first metatarsal inverted or everted to the supportive surface, even though independent motion within the joints of the first ray has changed the alignment of this segment relative to the remainder of the foot.

D'Amico and Schuster were among the first to document that overall position of the first metatarsal relative to the ground appears to be everted with end stage foot pronation.[15] The authors mistakenly challenged Hicks' description of the axis of the first ray, assuming that the first metatarsal was dorsiflexing and everting relative to the foot and the ground. However, they did not isolate pure first ray motion *relative to the foot* when making their observations.

While the first ray will always dorsiflex and invert relative to the remainder of the foot with loading, total foot pronation may carry the entire medial column into eversion relative to the ground. With more modern measurement techniques, this notion has been verified. Kimura and co-workers studied the rotation of bones in the medial column of the foot with loading in 10 patients with HAV deformity using weight bearing CT imaging.[12] With loading of the foot, the first metatarsal rotated in the direction of dorsiflexion and inversion at the first metatarsocuneiform joint. This motion at this joint was also accompanied by adduction of the first metatarsal to a greater extent in HAV patients than seen in healthy controls. Inversion was also seen in the medial cuneiform in healthy controls, while HAV patients showed slight eversion, relative to the navicular. At the talonavicular joint, the navicular moved into eversion in both groups, with greater dorsiflexion of the navicular in the HAV patients.

Hallux abductovalgus deformity is associated with flatfoot.

To summarize the findings of Kimura, et al.,[12] with loading of the foot:

- the first metatarsal moves 4.9 degrees into inversion;
- the medial cuneiform moves 1.5 degrees into eversion;
- the navicular moves 9.6 degrees into eversion; and
- the net motion of the entire medial column results in 6.2 degrees of eversion.

Therefore, when the entire foot pronates, the net pronation or eversion of the proximal joints ultimately place the first metatarsal everted to the ground.

New surgical approaches are designed to correct the everted position of the first metatarsal (to the ground) and purposefully rotate the first metatarsocuneiform joint into the direction of *inversion* via a Lapidus procedure.[16] Yet, this everted position of the first metatarsal, relative to the ground, has resulted from whole foot pronation causing eversion across the talonavicular joint, not the first metatarsocuneiform joint. A Curve Beam® weight bearing CT image of a patient with HAV deformity

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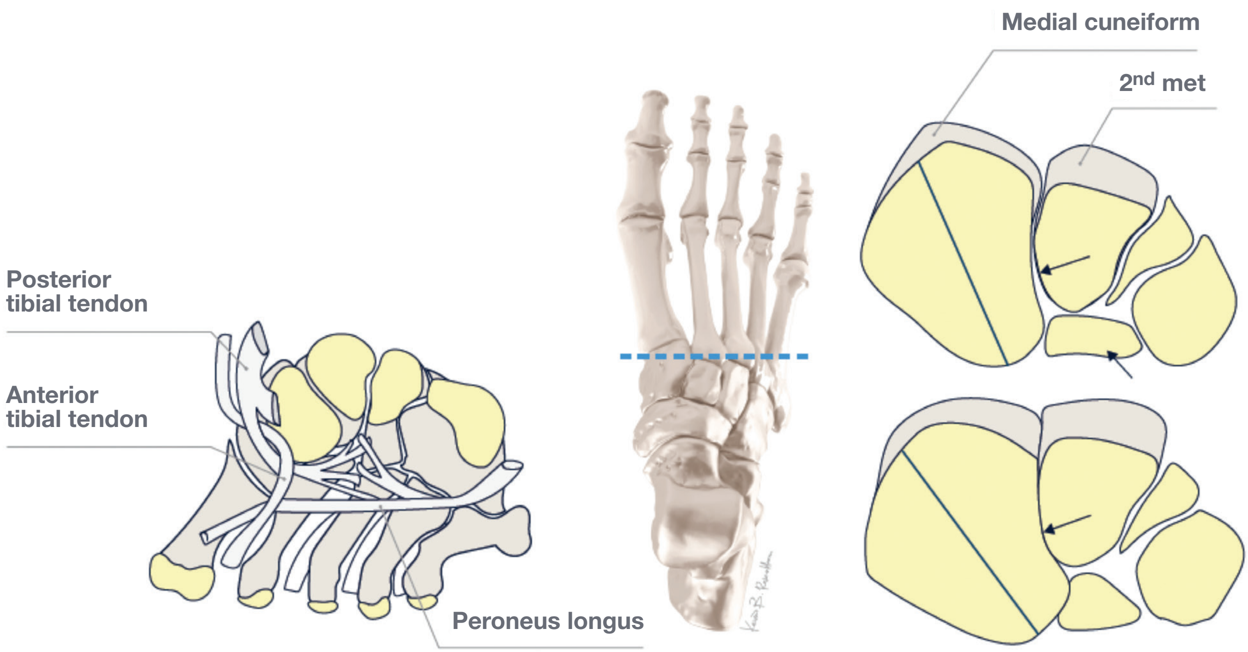

Figure 3: Osseous locking of the first ray via peroneus longus eversion. With eversion, the medial cuneiform "locks" against the second metatarsal

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clearly shows the inversion subluxation of the first metatarsocuneiform joint (Figure 4). Pronation of the first metatarsal in HAV deformity should be corrected proximal to the first metatarsocuneiform joint. Rotating the first metatarsocuneiform joint into inversion augments the entire pathomechanics of HAV deformity and moves the first ray into a more unstable position.[5]

Whole foot pronation is closely linked with the development of HAV deformity.[17-21] A recent study with weight bearing CT imaging showed a significant correlation between HAV deformity and adult acquired flatfoot.[22] Plantar pressures shift medially in flatfoot deformity, which may increase loading across the 1st MTPJ.[23] Shibuya and co-workers used center of pressure excursion index to study the relationship between radiographic findings seen in patients with HAV deformity.[24] An increased intermetatarsal angle and hallux abductus angle were both associated with calcaneal inclination angle and talar declination angle, showing a connection between HAV and flatfoot deformity.

The Framingham Foot Study identified 1,764 patients with HAV deformity and compared them to 3,707 patients without the deformity,[25] Pressure mapping and the center of pressure excursion index (CPEI) showed that people with HAV deformity had a lower arch height. Also, the modified arch index (MAI) demonstrated lower height of the navicular in HAV patients.

A lower arch and lower navicular height will change the orientation of the axis of the first ray to allow greater range of transverse plane adduction (Figure 5). This concept was verified in two studies conducted by Glasoe and co-workers who concluded that a lower arch was associated with a more vertical axis of the first ray.[26,27] With lowering of the medial arch of the foot, the navicular drops below the stable 3rd metatarsal base, which tilts the axis of the first ray downward, or more vertically oriented. Glasoe, et al. showed how a more vertical axis of the first ray caused more abduction/adduction of the first metatarsal and increased the intermetatarsal angle (IM angle) with loading.[27] Hallux valgus deformity would thus develop as a secondary condition from this deviated first ray axis.

Figure 4: Cone beam weight-bearing CT image of HAV deformity: First metatarsal is INVERTED on the medial cuneiform.

Excessive transverse plane rotation of the first ray is seen in HAV patients. Faber and co-workers, in a cadaveric study, showed that HAV deformity had significant increased transverse plane adduction, primarily at the first metatarsocuneiform joint.[28] In the previously cited study by Kimura, et al., a three-fold greater transverse plane motion at the first metatarsocuneiform joint was shown with weight bearing CT imaging of HAV patients compared to healthy controls.[12]

Pes planus and a pronated foot

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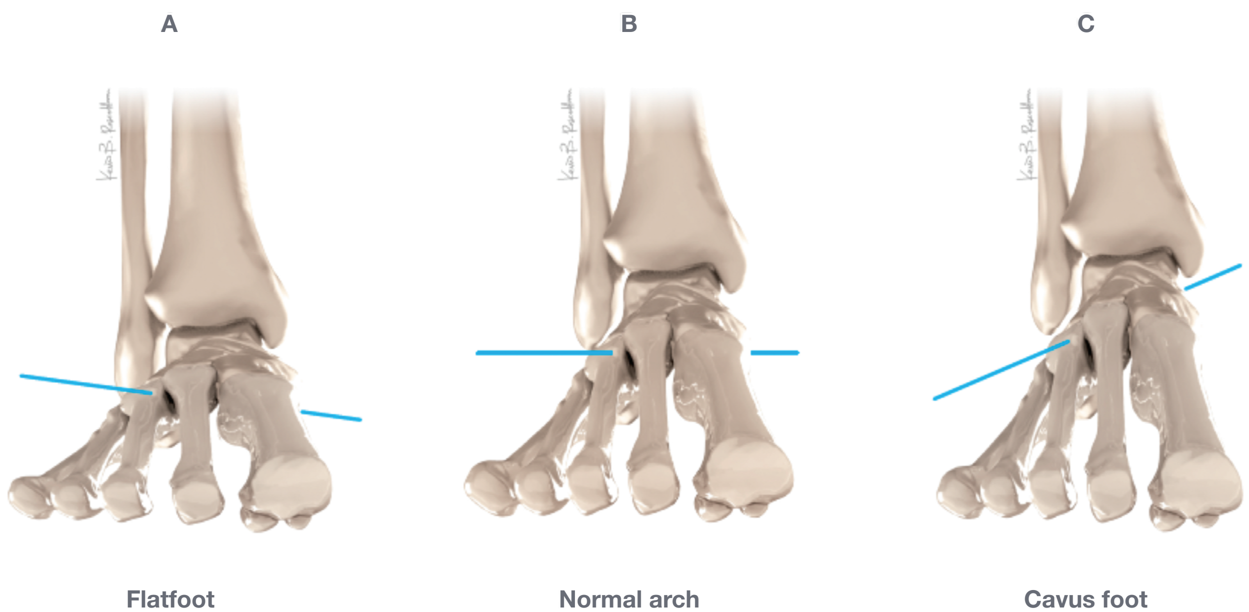

Figure 5: Foot posture determines orientation of the axis of the first ray. Pes planus orients the axis more vertical to allow more transverse plane motion.

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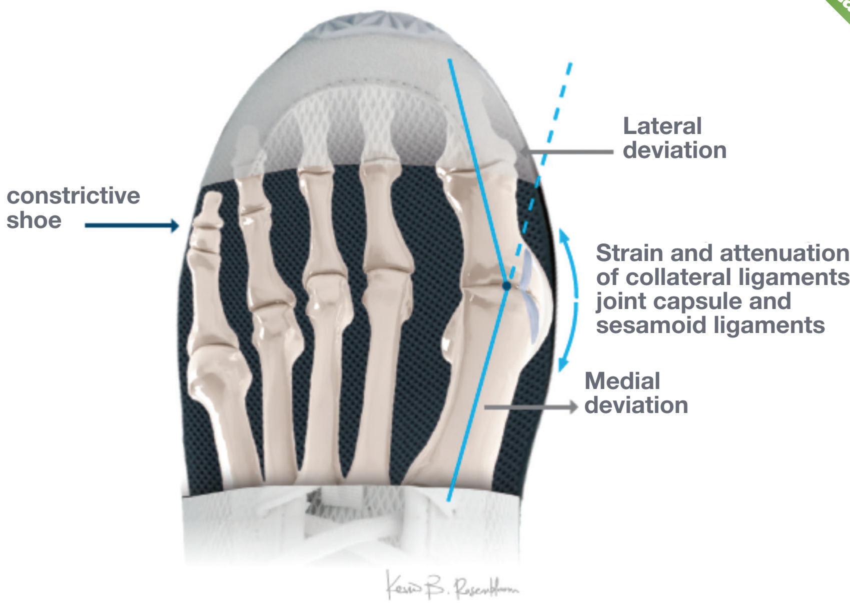

Figure 7: Step 1 of the progression of HAV deformity. Lateral shift of the hallux from constrictive footwear.

posture leading to excessive transverse plane motion of the first ray is just one intrinsic risk factor for developing HAV deformity. Decreased strength and reduced activation of the abductor hallucis muscle has been demonstrated in patients with HAV deformity.[29-31] Also, increased metatarsus adductus deformity has been identified by numerous authors as an extrinsic risk factor for developing HAV deformity.[32-36] Finally, chronic inflammation affecting the synovial lining of the 1st MTPJ has been proposed to increase the frequency of HAV as seen in patients with seropositive rheumatoid arthritis.[37,38]

The most well accepted extrinsic factor causing HAV deformity is improperly fitted footwear.[39-42] This finding is validated by several studies showing that women who are barefoot in early life and then change to a shoe-wearing lifestyle are at greater risk for developing HAV deformity compared to their barefoot counterparts.[43-46] In a survey of over 2,000 women, Menz and co-workers documented a graded increase in the risk of HAV deformity with increased narrowness of the shoe toe box when this type of footwear was worn between ages 20 to 29, and to a lesser extent when worn between ages 30 and 39 years.[47] Interestingly, no association with heel height of shoes and risk of developing HAV was noted.

When evaluating these intrinsic and extrinsic risk factors it must be concluded that HAV deformity can arise from multiple circumstances and conditions. While the initial primary inciting event might differ among patients, the progression of HAV deformity is relatively predictable. Understanding the pathoanatomy of HAV and the key features of progression of the deformity are essential to achieving effective surgical correction.

Key Events in the Development and Progression of HAV Deformity

Stage 1: Strain and Attenuation of the Medial Structures of the 1st MTPJ

Constrictive footwear or excessive medial deviation of the first metatarsal will both place strain on the medial soft tissue structures of the 1st MTPJ. Despite the fact that there are six tendons and ligaments which cross the 1st MTPJ medially, only two actually attach the hallux to the medial aspect of the first metatarsal head. These six structures are (Figure 6):

1) tendon of the abductor hallucis,
2) tendon of the medial head of flexor hallucis brevis,
3) medial insertion of plantar aponeurosis
4) medial collateral ligament
5) medial sesamoid ligament
6) medial sagittal hood ligament

Of these, only the medial collateral ligament and the medial sesamoid

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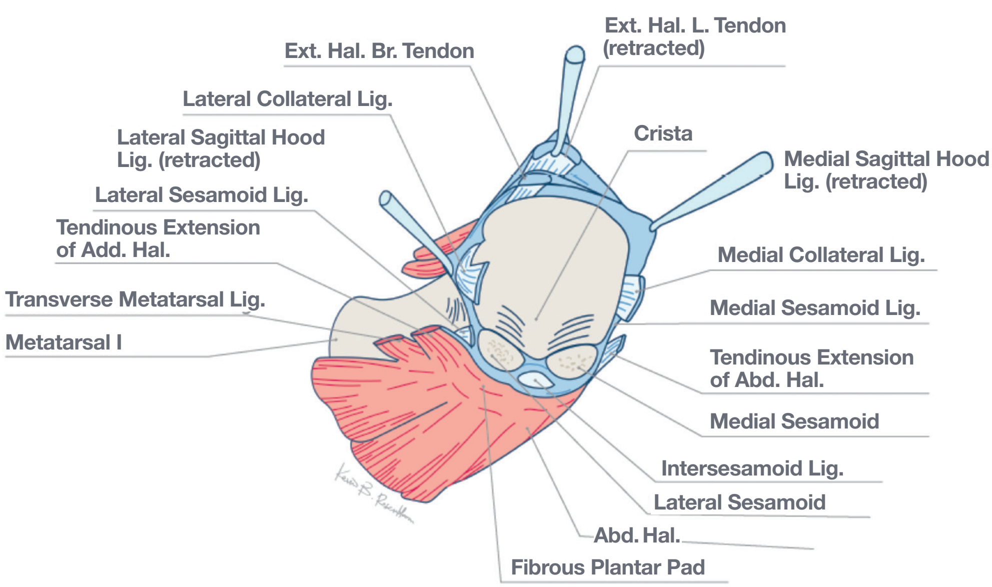

Figure 6: Soft tissue structures of the 1st MTPJ

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(suspensory) ligament actually attach to the first metatarsal. The attachment is small and discreet, located at a tubercle located on the dorsal medial aspect of the head of the first metatarsal. Ironically, the entire sesamoid complex as well as the muscular attachments to the proximal phalanx are entirely dependent upon their indirect attachment to the head of the first metatarsal.

Lateral translation of the hallux or medial subluxation of the first metatarsal will create tensile strain on the medial structures of the 1st MTPJ (Figure 7).

Lateral rotation of the hallux on the head of the first metatarsal from constrictive footwear places tensile load on the medial collateral ligament. Dorsiflexion and inversion of the first metatarsal creates tensile load on the medial sesamoid (suspensory) ligament. Chronic tensile loading of the medial collateral and medial sesamoid ligaments can lead to attenuation of these structures with loss of medial stabilization of the 1st MTPJ.

A coronal section through the 1st MTPJ will demonstrate the mechanism whereby strain is developed in the medial structures when the first metatarsal moves in the direction of dorsiflexion with inversion (Figure 8). It is clear that inversion of the head of the first metatarsal places tensile strain on the suspensory medial sesamoid ligament and medial collateral ligament while the sesamoid bones remain firmly anchored to the deep transverse metatarsal ligament.[48,49] If "pronation" or eversion of the first metatarsal head were actually a contributor to the development of HAV deformity, that movement would *reduce*, rather than increase strain on the medial structures of the 1st MTPJ.

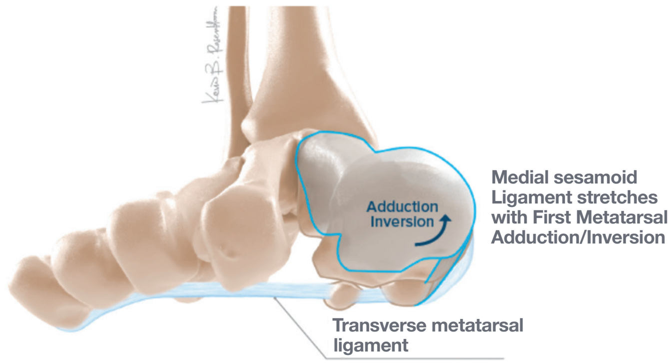

Figure 8: Step 2 of HAV medial shift of the first metatarsal in HAV deformity. Note inversion as well.

Stage 2: Progressive Medial Shift of the First Metatarsal

Excessive transverse plane adduction of the first ray causes attenuation of the medial capsular structures of the 1st MTPJ, leading to lateral drift of the hallux. Conversely, lateral displacement of the hallux from constrictive footwear can cause retrograde medial drift of the first metatarsal. Either way, a progressive cycle of hallux abduction along with first metatarsal adduction will develop once the medial structures of the 1st MTPJ are attenuated. The severity of the hallux abductus angle is proportional to the severity of the intermetatarsal angle.[50,51]

Stage 3: Formation of the Bunion

The "bunion" deformity develops from the medial prominence of the first metatarsal head, secondary to medial displacement of the first ray. Research has shown that there is no true bone hypertrophy to explain the medial eminence of the bunion deformity.[52] The overall width of the head of the first metatarsal is not increased in HAV deformity. Clinically, the painful bunion is actually soft tissue hypertrophy around the damaged medial capsular structures as well as exposure of the medial aspect of the first metatarsal head.

A bunion deformity, or bone hypertrophy in the form of a "medial eminence" may be observed intraoperative in the head of the first meta-

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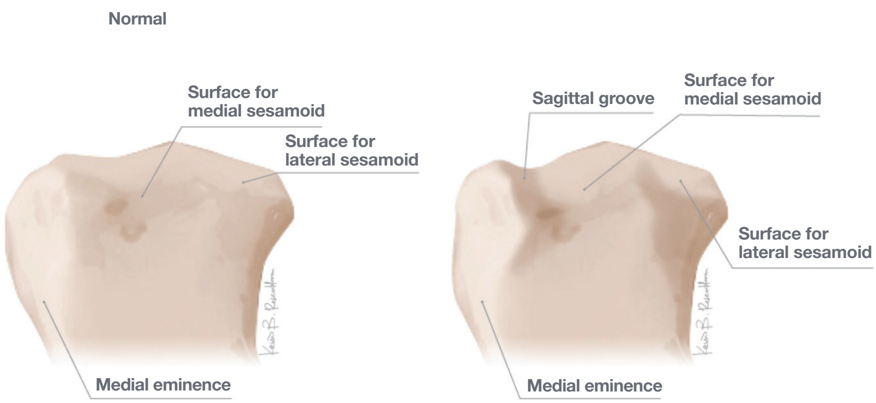

Figure 9: Adaptive changes on the first metatarsal head in HAV deformity.

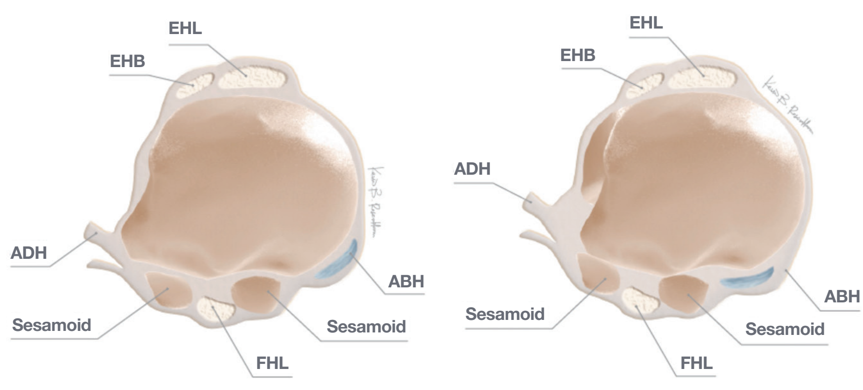

Figure 10: Impingement of the medial sesamoid on crista of the first metatarsal head.

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tarsal in HAV patients. This finding actually occurs from a loss of cartilage medially on the head of the first metatarsal which results from gradual lateral shift of the hallux. As the hallux shifts laterally, so does the articular cartilage, leaving behind a section of bone with cartilage loss. A "sagittal groove" will appear at the junction of remaining cartilage and the area of cartilage loss at the medial aspect of the head of the first metatarsal. Therefore, the sagittal groove and medial eminence on the head of the first metatarsal of HAV patients are the result of cartilage loss rather than bone hypertrophy medially (Figure 9).

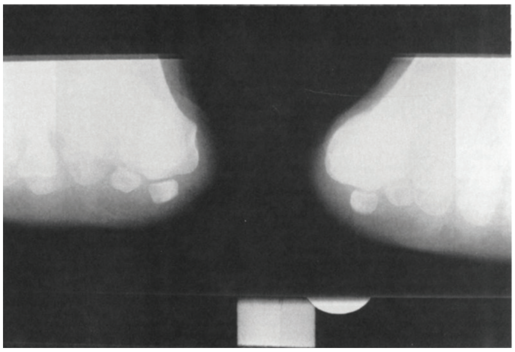

Figure 11: Valgus alignment of the sesamoid complex relative to the first metatarsal in hAV deformity.

First metatarsal pronation, viewed on an axial sesamoid radiograph is the result of whole foot pronation.

Stage 4: Escape of First Metatarsal Away from the Sesamoid Complex: The Transverse Plane Deformity

As HAV deformity progresses, the sesamoid complex remains firmly attached to the second metatarsal via the deep transverse metatarsal ligament.[48,49] The deep transverse metatarsal ligament is not directly attached to the first metatarsal which escapes medially leaving the sesamoids behind (Figure 10).[53,54]

There are several mechanisms driving the first metatarsal medially. The axis of motion of the first ray provides an adduction motion combined with dorsiflexion, which occurs with weight bearing and loading. Abduction of the hallux also drives the first metatarsal medially via retrograde forces generated from soft tissue attachments.

The crista, also known as the intersesamoid ridge, located on the plantar aspect of the first metatarsal, controls medial and lateral displacement of the sesamoids. As the first metatarsal dorsiflexes and inverts, the crista loses congruency with the sesamoids. Further medial displacement of the first metatarsal erodes the crista due to abutment against the medial sesamoid. Adaptive changes appear radiographically on the inferior surface of the first metatarsal as the crista and the lateral-inferior surface of the articular cartilage erode. The erosive changes on the central and lateral portion of the inferior aspect of the head of the first metatarsal give a valgus angulation to this bone when viewed on coronal plane imaging (Figure 11).

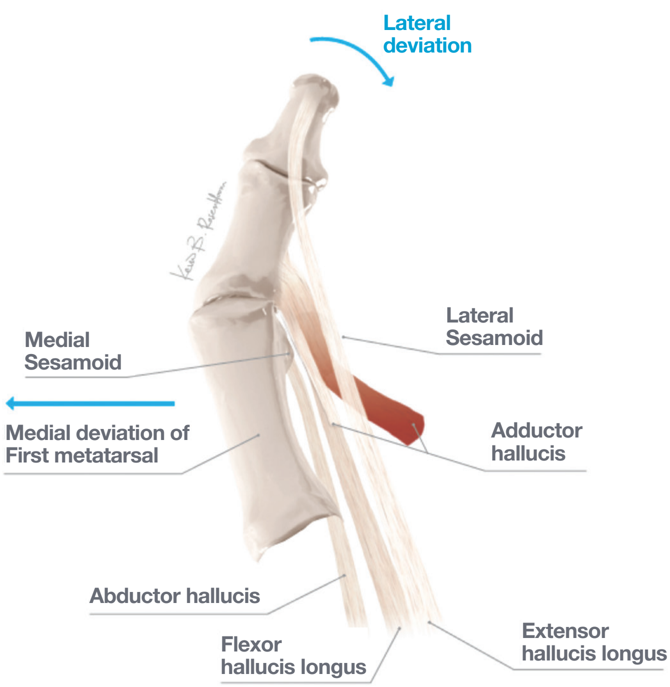

Figure 12: Muscle imbalance at the 1st MTPJ

STAGE 5: Progressive Muscle Imbalance Around The 1ST MTPJ: The Frontal Plane Deformity

Lateral positioning of the sesamoids relative to the 1st metatarsal head shifts the abductor hallucis from a medial position to a plantar position, providing more plantarflexion torque rather than abduction torque to the hallux. The adductor hallucis gains advantage, pulling the hallux laterally. The movement of the abductor hallucis tendon from a pure medial position to a plantar-medial position initiates a valgus torque on the hallux. Lateral positioning of the sesamoids allows gradual frontal plane rotation, progressively everting these bones relative to the head of the first metatarsal, which is in an inverted position. The flexor hallucis longus tendon, centered between the sesamoids and the two heads of the flexor hallucis brevis, attached to the sesamoids, also rotate and produce a valgus torque on the hallux (Figure 12).

Increased plantar-abduction moment at the lateral aspect of the proximal phalanx, without opposing plantarflexion-adduction moment applied at the medial proximal phalanx will cause a frontal plane imbalance at the base of the proximal phalanx of the hallux, resulting in valgus rotation.

Controversy and Misunderstanding: The Pronation Deformity in HAV

The plantar-axial radiograph has been the primary resource for measuring first metatarsal "pronation" in HAV patients.[55] With this view, the frontal plane position of the sesamoids or the frontal plane

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position of the head of the first metatarsal may appear everted or "pronated" in patients with HAV deformity.[55-59] However, there are several reasons why the first metatarsal or the sesamoids will appear everted to the supportive surface when a plantar-axial radiograph is taken of patients with HAV deformity. In each case, it is important to differentiate between sesamoid rotation and first metatarsal rotation. With a two-dimensional radiograph, it is difficult to differentiate between the two deformities (Figure 13).

Increased intermetatarsal angle deviation in the transverse plane leaves the sesamoids in a lateral position relative to the first metatarsal. However, the sesamoids do not actually shift or move in the transverse plane because they are firmly attached to the deep transverse metatarsal ligament, which is anchored to the adjacent second metatarsal.[48,49] In the frontal plane, the loss of contact of the lateral sesamoid with the overlying head of the first metatarsal may allow some valgus rotation of the sesamoid apparatus. Ground reaction forces drive the lateral sesamoid bone into a dorsal position, unopposed by any overlying metatarsal.

Another cause of a pronated position of the sesamoids in HAV deformity is the role of frontal plane hallux rotation. The hallux is pulled into abduction and eversion from progressive muscle imbalance around the 1st MTPJ (Figure 12). Valgus rotation of the hallux may pull the sesamoids into valgus rotation, or vice-versa, since the medial ligaments of the 1st MTPJ are attenuated. Thus, HAV patients will demonstrate various magnitudes of valgus or lateral rotation of the sesamoid apparatus relative to the head of first metatarsal with plantar-axial radiographic imaging of the forefoot (Figures 11,13). Some patients will demonstrate more valgus rotation of the sesamoids, depending upon the amount of varus rotation of the first metatarsal. However, as we will see, simple correction of the intermetatarsal angle with standard osteotomy of the first metatarsal without need for frontal plane correction will reduce valgus rotation of the sesamoids in HAV deformity. Both the hallux and the sesamoids will rotate out of valgus when the intermetatarsal angle is reduced to normal and the soft tissue imbalance is corrected at the 1st MTPJ with conventional distal osteotomy at the first metatarsal.

A new trend in HAV surgery is performing a triplane correction of alignment of the first metatarsal to reduce a perceived "pronation" deformity. The term pronation is inappropriate as the first metatarsal would have to dorsiflex, evert and abduct to fulfill the requirements of this triplane direction. Investigators reporting a "pronation" deformity in HAV patients are actually describing an eversion deformity of the first metatarsal and this relationship is measured *relative to the supportive surface.*[56-59]

The valgus rotation of the sesamoids in HAV deformity along with erosion on the plantar-lateral surface of the head of the first metatarsal will give the illusion of a "pronated" position of the first metatarsal in the plantar axial radiograph (Figures 11,13). Erosion of the plantar-lateral surface of the head of the first metatarsal will show an everted deformity relative to the supportive surface. In reality, the first metatarsal is inverted relative to the sesamoids.

A recent published study from Kent State University College of Podiatric Medicine showed the shortcoming of relying on axial sesamoid radiographic imaging to detect frontal plane deformity in HAV patients.[60] Using weight bearing computerized tomography, Kawalac and co-workers measured the angle of the sesamoid complex to the supportive surface (sesamoid rotation angle) in 12 subjects with HAV deformity. Measurements were taken with the subjects standing with their feet in maximal pronation and maximal supination. The measurements from the CT scans were then compared to standard axial sesamoid radiographs.

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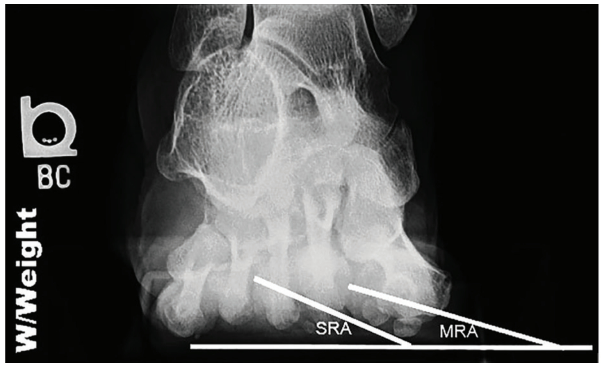

Figure 13: It is clear that the first metatarsal pronation angle is not the same as the sesamoid rotation angle and both deformities result from different mechanisms: SRA=Sesamoid Rotation Angle MRA=Metatarsal Rotation Angle

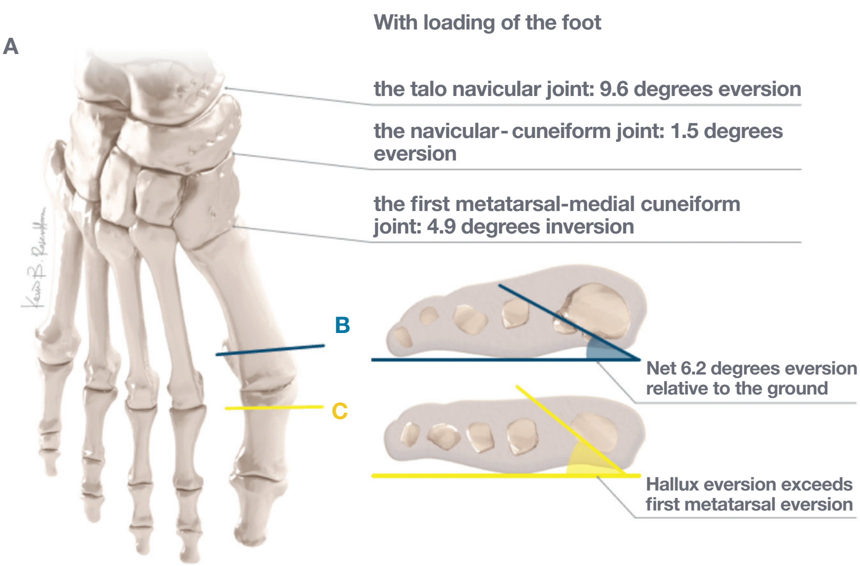

Figure 14: Pronation of proximal joints causes net eversion of the first metatarsal in HAV deformity.

New Discovery *(from page 120)*

The results showed that pronation of the foot increases the sesamoid rotation angle while supination of the foot decreases that angle. The standard axial sesamoid radiograph underestimated the true sesamoid rotation. Without standardization for foot position, the authors concluded that measurements measuring sesamoid position and rotation with the axial sesamoid radiograph are not reliable.

More important, the first metatarsal will plantarflex and evert when the foot is placed on an axial sesamoid positioning device for radiographic evaluation. In this position of plantarflexion and eversion, a greater amount of so-called "pronation" of the first metatarsal may appear. This will not be evident when the foot is placed flat on the ground and the first ray moves into dorsiflexion, abduction, and inversion. Therefore, practitioners should be cautious about making conclusions about the frontal plane position of the first metatarsal using plantar axial sesamoid radiographs. The only way that the first metatarsal can rest "pronated" or everted on the ground is if the entire foot is significantly pronated or if the first ray is actually plantarflexed below the plane of the lesser metatarsals. Indeed, Kimura, et al. demonstrated that pronation of the foot at the talonavicular joint will evert the entire first ray relative to the ground in HAV deformity (Figure 14).[12] It is evident that whole foot pronation, primarily at the talonavicular joint, will cause the first metatarsal to rest everted *on the ground* in HAV patients, even though the first ray is actually independently inverted *relative to the remainder of the foot.* Thus correcting the so-called pronation deformity of the first metatarsal in HAV patients should be directed to the joints proximal to the first ray, or primarily at the talonavicular joint.

Recently, Shibuya and co-workers studied the sesamoid rotation angle and metatarsal rotation angles derived from axial sesamoid radiographic views taken from 71 patients with HAV deformity and compared to 43 control patients.[61] This study showed that sesamoid rotation, on the axial sesamoid view, was directly correlated with lateral deviation of the sesamoids on the DP radiographic view. Indeed, several studies have shown that the sesamoid rotation angle will reduce to normal using traditional first metatarsal osteotomy without the need for frontal plane rotation of the metatarsal to correct HAV deformity.[62,63] Thus, when the first metatarsal is re-located over the sesamoids with standard osteotomy procedures to correct HAV deformity, "pronation" rotation of the sesamoids disappears. Therefore, the sesamoids will no longer rotate into valgus if they are properly centered under the head of the first metatarsal in the transverse plane.

The sesamoid rotation angle is directly related to magnitude of HAV deformity.

Shibuya, et al. also showed that apparent first metatarsal "pronation" as seen on the plantar axial radiograph is not directly associated with HAV deformity.[61] They speculated that the valgus rotation seen in the head of the first metatarsal in the axial radiograph may be a manifestation of total foot pronation. Shibuya, et al. cite two of their previous studies showing a clear association between flatfoot and HAV deformity using various data sets.[21,24] The authors conclude that, when performing HAV surgery, *"the need for derotation of the first metatarsal may have to be carefully examined, especially in persons with underlying flatfoot deformity."*

Summary

In summary, valgus rotation of the midfoot and hindfoot joints rather than the joints of the first ray is a fundamental component of the pathomechanics of HAV deformity. Pronation of the hindfoot leading to a lowering of the medial longitudinal arch will change the axis of the first ray to favor excessive medial translation of the first metatarsal and will propagate the progression of HAV deformity. Constrictive footwear, with or without rearfoot pronation, can also be an independent factor contributing to HAV deformity. Notwithstanding, the first ray moves excessively in the direction of dorsiflexion, adduction, and inversion in patients with HAV deformity. Each plane of this deformity must be addressed in the surgical approach to correcting HAV deformity. Using the axial sesamoid radiograph, first metatarsal pronation is related to whole foot pronation, not to the magnitude of HAV deformity. Conversely, frontal plane sesamoid rotation measured with this same axial radiograph is directly related to the magnitude of HAV deformity. Although the sesamoid rotation angle is a frontal plane deformity, it can be reduced with transverse plane surgical correction of the intermetatarsal angle without the need for a de-rotational Lapidus procedure. **PM**

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CME **EXAMINATION**

SEE ANSWER SHEET ON PAGE 125.

1) The axis of motion of the first ray of the human foot dictates that, with loading, the first metatarsal will move in the direction of:

- **A) Pronation**
- **B) Supination**
- **C) Dorsiflexion with inversion**
- **D) Dorsiflexion with eversion**

2) The medial collateral ligament and the medial suspensory ligament at the 1st MTPJ will be placed under tensile load when the first metatarsal rotates in the direction of:

- **A) Inversion**
- **B) Eversion**
- **C) Plantarflexion**
- **D) Pronation**

3) Hallux abductovalgus deformity is associated with which type of foot posture?

- **A) Cavus**
- **B) Equinus**
- **C) Flatfoot**
- **D) Clubfoot**

4) Instability of the first metatarsal mediocuneiform joint in HAV deformity has excess motion in the direction of:

- **A) Dorsiflexion and pronation**
- **B) Inversion and adduction**
- **C) Eversion and adduction**
- **D) Plantarflexion and abduction**

5) Which of the following are shortcomings of measuring first metatarsal position using the positioning device for the axial sesamoid radiograph?

- **A) The hallux is placed into extension at the 1st MTPJ**
- **B) The first ray is plantarflexed and everted**
- **C) The rearfoot is supinated**
- **D) All of the above**

6) Increased sesamoid rotation in the frontal plane in HAV deformity can be the result of:

- **A) Medial shift of the first metatarsal**
- **B) Erosion of the plantar surface of the first metatarsal head**
- **C) Muscle imbalance in HAV deformity**
- **D) All of the above**

Continued on page 124

7) First metatarsal pronation, viewed on an axial sesamoid radiograph, is the result of:
A) Progressive hallux abductovalgus deformity
B) Progressive increased sesamoid rotation
C) Whole foot pronation
D) A newly discovered axis of the first ray

8) Which of the following is not a risk factor for developing HAV deformity:
A) Constrictive footwear
B) Flatfoot deformity
C) Seropositive arthritis
D) Peroneal weakness

9) Sesamoid rotation angle is:
A) Directly related to magnitude of HAV deformity
B) Accurately measured on axial sesamoid radiographs
C) Caused by an underlying flatfoot
D) Caused by first metatarsal pronation

10) Surgical correction of a valgus or everted position of the sesamoids in HAV surgery can be accomplished with:
A) Lapidus procedure without frontal plane rotation correction
B) SCARF osteotomy of the first metatarsal
C) Distal metaphyseal osteotomy of the first metatarsal
D) All of the above

SEE ANSWER SHEET ON PAGE 125.

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EXAM #2/21
The New Discovery of Pronation Deformity in Hallux Abductovalgus (Richie)

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1.	A	B	C	D	6.	A	B	C	D
2.	A	B	C	D	7.	A	B	C	D
3.	A	B	C	D	8.	A	B	C	D
4.	A	B	C	D	9.	A	B	C	D
5.	A	B	C	D	10.	A	B	C	D

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