CHAPTER 48

RADIOLOGY AND BIOMECHANICAL FOOT TYPES

Donald R. Green, D.P.M.

Most every physician takes or orders x-rays in his practice. What do foot x-rays tell you? They may demonstrate fractures or dislocations, pinpoint opaque foreign bodies, suggest various arthritides, reflect a variety of systemic diseases, show osseous growths or lesions, and illustrate various osseous relationships which help in our evaluation of the pathological foot types.

DEFINITIONS

Angle and Base of Gait

In order to compare any radiographs, there must exist a standard of comparison. The standard for podiatry has become the angle and base of gait x-rays.[1,2] The angle of gait is the amount that each foot deviates from the line of progression. The normal range is 7.5° to 10° The base of gait is the distance between the medial malleoli during gait (Fig. 1).

Figure 1. The angle of gait is the amount each foot deviates from the line of progression. The right foot is approximately 7° abducted from the line of progression. The base of gait is the distance between the medial malleoli during gait. This is approximately one inch in this patient.

Dorsoplantar (AP/DP) X-Ray

The AP x-rays are taken one at a time, with one foot positioned on the x-ray while the second foot is placed in the angle and base of gait. The x-ray beam is 15° from the perpendicular and is directed toward the midtarsal joint. The patient should be facing in the direction of progression when placed in the angle and base of gait. If the patient is not placed in his angle and base of gait, there can be a large variation in the osseous relationships. Adduction can cause supination; abduction can cause pronation.

Lateral X-Ray

When taking a lateral x-ray, the patient is placed on the ortho-poser simulating his or her angle and base of gait. The patient is directed to face in the direction of normal progression of gait. The x-ray unit is directed at the midtarsal joint. One foot is parallel to the film; the other foot is placed in the angle and base of gait. A standard lateral weight-bearing x-ray is taken of each foot in the angle and base of gait (Fig. 2).

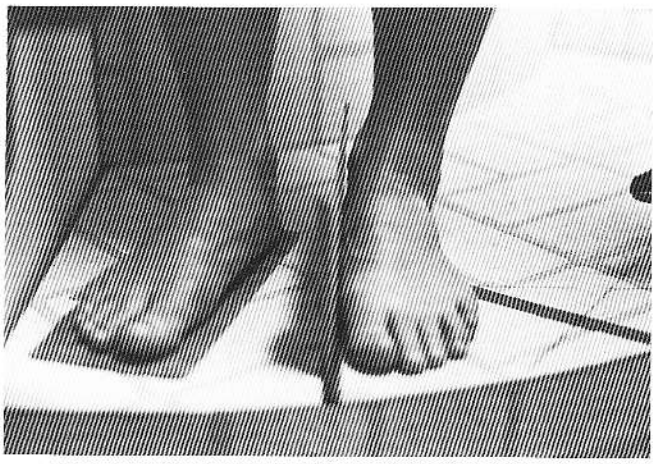

Figure 2. This shows the technique for the left foot lateral x-ray angle and base of gait.

Standard Parameters

When these standard lateral and AP x-rays are compared, certain parameters can be followed. The foot can be divided into three basic parts rearfoot, midfoot and forefoot. The relationships between the various parts of the foot will tell us a lot about the foot type. To compare the relationships of various parts of the foot, however, we need standard references.

The rearfoot is made up of the calcaneus and the talus. The longitudinal direction of the rearfoot is measured by a line that passes through the bisection of the posterior aspect of the calcaneus, and passes through the anterior superior medial aspect of the calcaneus. This will give us the general direction of the rearfoot (Fig. 3).[3]

Practically speaking, this cannot always be measured accurately on an AP view. The posterior aspect of the calcaneus is often obliterated by overriding tibia and fibula. However, the line also parallels the distal trabecular pattern in the calcaneus (Lateral border of the calcaneus).[2] We label this line the *longitudinal bisection of the tarsus* (rearfoot). This is the reference line showing the general direction of our rearfoot (calcaneus and talus).

The midfoot or lesser tarsal area is made up of the navicular, the three cuneiforms, and the cuboid. The general direction of the midfoot is measured by a line that passes equi-distant between the talonavicular articulation and the first cuneiform-first metatarsal articular and between the calcaneal cuboid articulation and the cuboid-fifth metatarsal articulation excluding the styloid process of the fifth metatarsal. (This latter articulation point is very close to the lateral aspect of the fourth metatarsal cuboid joint).[5] This simply gives a scientifically measurable line to the general direction of the lesser tarsus. To find the longitudinal direction of the lesser tarsus, we simply drop a perpendicular to this line which is given the label *longitudinal bisection of the lesser tarsus.* This line is the reference line showing the general direction of the lesser tarsal area (Fig. 4).

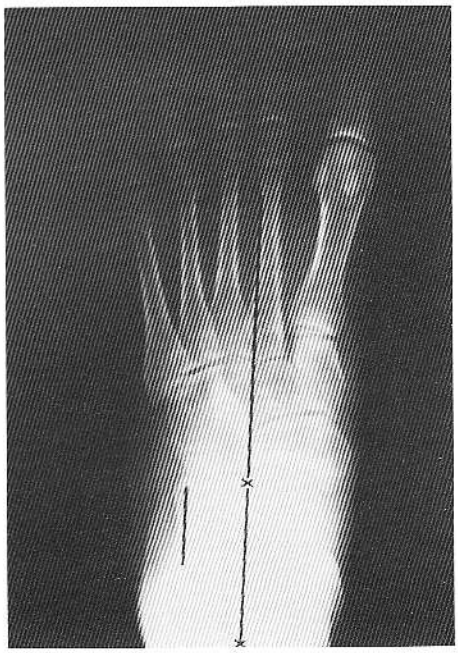

Figure 3. Longitudinal Bisection of the Tarsus (Rearfoot). Classically, the bisection is measured by a line from the bisection of the posterior aspect of the calcaneus that passes through the anterior superior medial aspect of the calcaneus. Clinically, it is often difficult to locate the bisection of the posterior aspect of the calcaneus due to obliteration by the overriding tibia and fibula. A more practical parallel reference line that mirrors the above reference line is often used. This line parallels the lateral aspect of the calcaneus and distal calcaneal trabecular pattern (ignoring the small distal calcaneal condyle).

Figure 4. Longitudinal Bisection of the Lesser Tarsus. The general direction of the lesser tarsus is measured by a line that passes equidistance between the medial talonavicular and medial first metatarsal first cuneiform articulations and between the lateral calcaneal cuboid articulation and the cuboid fifth metatarsal articulation, *excluding the styloid process of the 5th metatarsal.* (The latter articulation point is very close to the lateral aspect of the 4th metatarsal cuboid joint.) To get a longitudinally directed reference line, a perpendicular is drawn to this general bisection of the lesser tarsus.

The general direction of the forefoot is demonstrated by the second metatarsal. Since the direction of each individual metatarsal can be varied (especially the first and fifth metatarsals), the most characteristic and least variable metatarsal is the second metatarsal. Thus, if we measure the direction of the second metatarsal, we can obtain the general direction of the forefoot. The reference line for the forefoot is the *bisection of the shaft of the second metatarsal* (Fig. 5).[5]

EVALUATIONS AND RELATIONSHIPS OBTAINABLE FROM THE AP VIEW

There is a great deal of information that can be obtained from the AP view taken in the angle and base of gait.(Table 1)

Table 1

EVALUATIONS FROM THE AP VIEW

1. Forefoot adductus angle
2. Metatarsus adductus angle (Engle's Angle)
3. Lesser tarsus abductus angle
4. Cuboid abduction angle
5. Talocalcaneal angle (Kite's Angle)
6. Percent of talo-navicular articulation
7. Metatarsus primus adductus
8. "True" intermetatarsal angle
9. 1st metatarsal calcaneal angle
10. Hallux abductus angle
11. Sesamoid position
12. Tibial sesamoid 2nd metatarsal distance

Figure 5. Bisection of the Second Metatarsal The general direction of the forefoot is measured by bisecting the second metatarsal. The metatarsal is measured by a line that passes through the shaft bisection just proximal to the neck and just distal to the flare of the base.

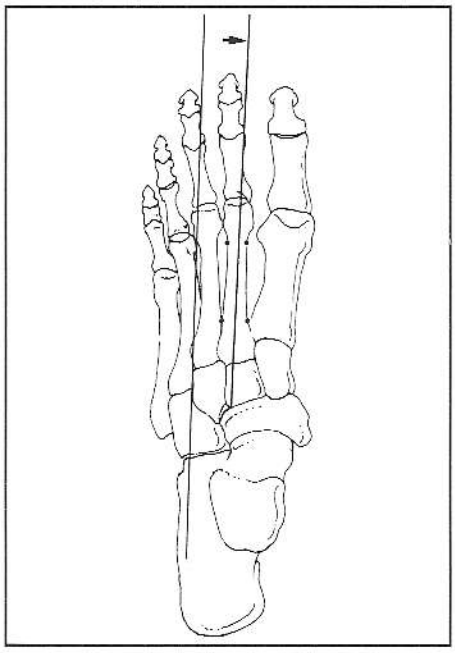

Figure 6A. Forefoot (Adductus) Angle. This is the angle formed between the forefoot (bisection of second metatarsal) and the rearfoot (longitudinal bisection of the tarsus).

Figure 6B. X-ray in a neutral position. This is usually slightly less than the metatarsus adductus angle in a neutral subtalar position.

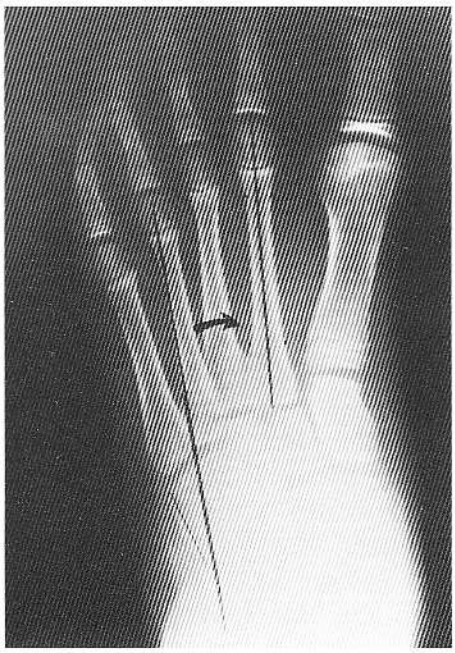

Figure 6C. This angle decreases in pronation as the forefoot abducts on the rearfoot and can even become an abducted angle as seen in this pronated foot x-ray.

Forefoot vs. Rearfoot

Forefoot vs. rearfoot is the relationship between the forefoot and the rearfoot (tarsus) as measured by the angle formed by the bisection of the second metatarsal and the longitudinal bisection of the tarsus (rearfoot). The normal value is undetermined. This relationship is called the forefoot angle and is a positional angle. Since the forefoot is usually adducted on the rearfoot, it is often referred to as the *Forefoot Adductus Angle* (Figs. 6A, 6B).[3] This is a positional angle. (In a neutral position x-ray, this is usually slightly less than the metatarsus adductus angle.) This angle will vary with pronation and supination. The angle decreases with pronation as the forefoot abducts on the rearfoot. The angle increases with supination as the forefoot adducts on the rearfoot (Fig. 6C).[3]

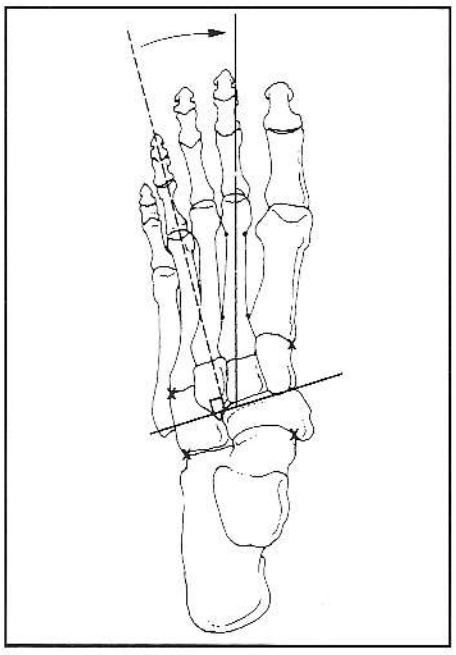

Figure 7A. Metatarsus Adductus Angle. This is an angle formed between the forefoot (bisection of the second metatarsal) and the midfoot (longitudinal bisection of the lesser tarsus).

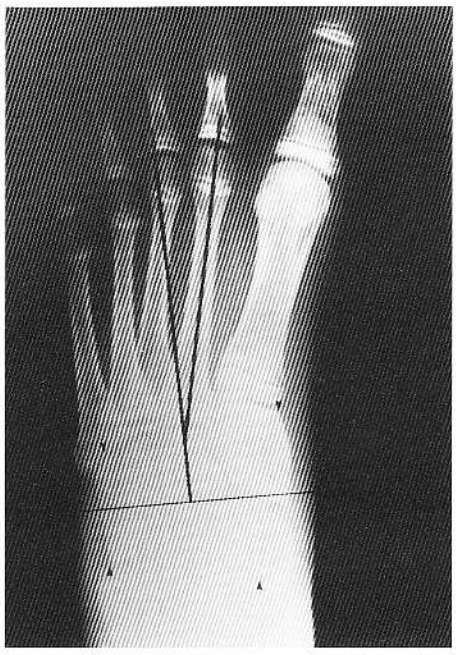

Figure 7B. X-ray in a *neutral position*. This angle is usually slightly more than the forefoot adductus angle in the neutral subtalar position.

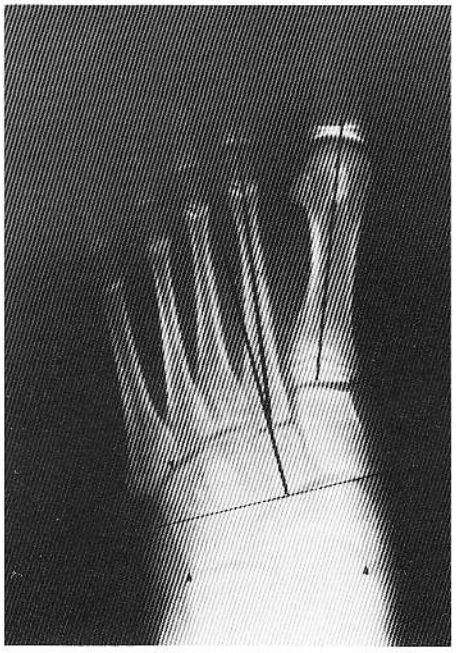

Figure 7C. This angle changes very little in a supinated or pronated foot x-ray, as seen by this pronated foot x-ray.

Forefoot vs. Midfoot

Forefoot vs. midfoot is the relationship between the forefoot and the lesser tarsus as measured by the bisection of the second metatarsal and the longitudinal bisection of the lesser tarsus. The normal value is 10° to 20° (average 15°). This is called the *Metatarsal Angle* and is a structural angle. Since the forefoot is usually adducted on the midfoot, it is often referred to as the *Metatarsus Adductus Angle* (Figs. 7A, 7B).[3] This is a structural angle. In a neutral position x-ray, this is usually slightly more than the forefoot adductus angle. This angle is variable from foot to foot but usually changes very little with supination and pronation.[3] The bony structures of the forefoot are somewhat osseously interlocked (Fig.7C). Note: This angle is probably the single most important angle used in determining the transverse plane foot structure (adductus vs. rectus foot type).

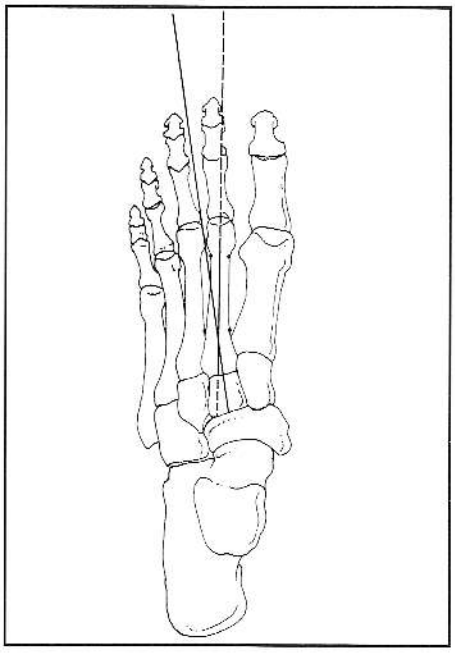

Figure 8A. Engle's Angle. This is a quick estimation reference of the metatarsus adductus angle. This angle is formed between the forefoot (bisection of the second metatarsal) and the bisection of the second cuneiform.

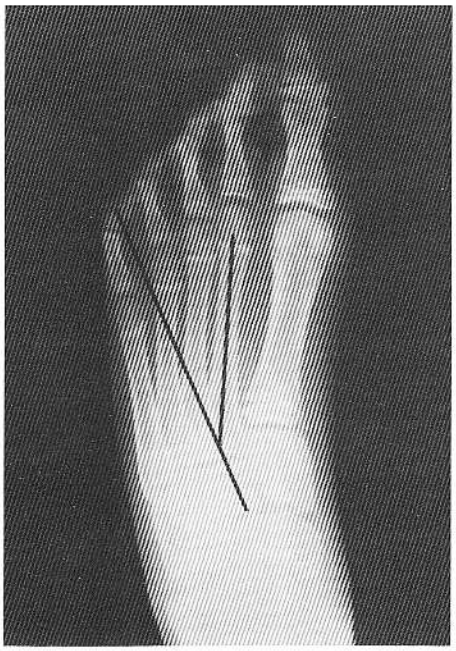

Figure 8B. X-ray in the neutral position, demonstrating a 3-4° higher angle than the metatarsus adductus angle.

Figure 8C. This angle mirrors the metatarsus adductus and also changes very little with pronation and supination as shown by this pronated foot x-ray.

Engle's Angle is a quick estimation of the metatarsus adductus angle. The normal value is 18°. The angle is formed by the bisection of the 2nd metatarsal and the longitudinal bisection of the second cuneiform bone. It is usually 3° to 4° degrees higher than the metatarsus adductus angle. This will mirror the metatarsus adductus angle (Figs. 8A-8C).[4]

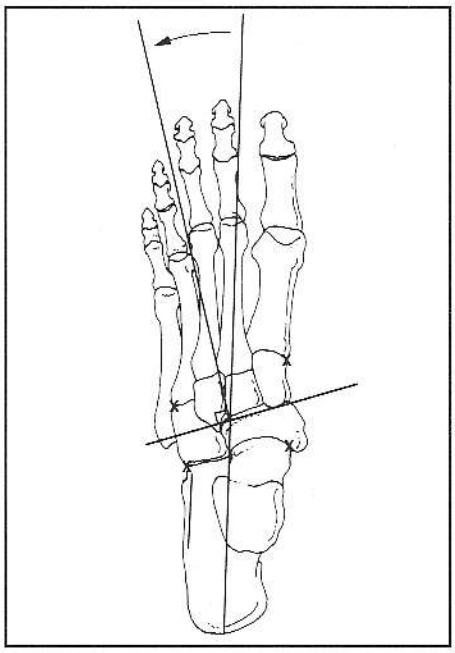

Figure 9A. Lesser Tarsus Abductus Angle. This is an angle formed between the midfoot (longitudinal bisection of the lesser tarsus) and the rearfoot (longitudinal bisection of the tarsus).

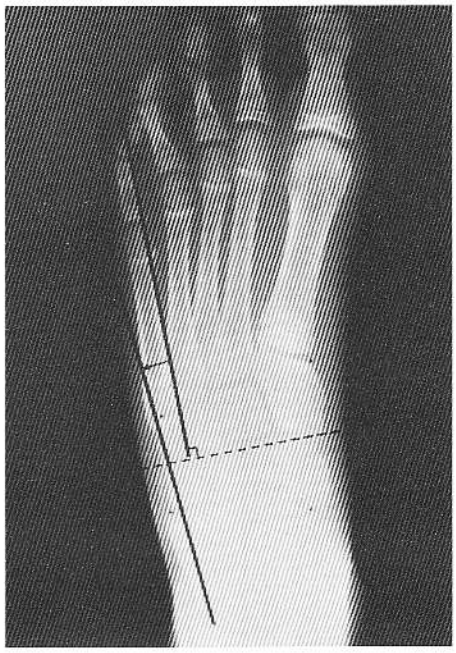

Figure 9B. X-ray in the neutral position.

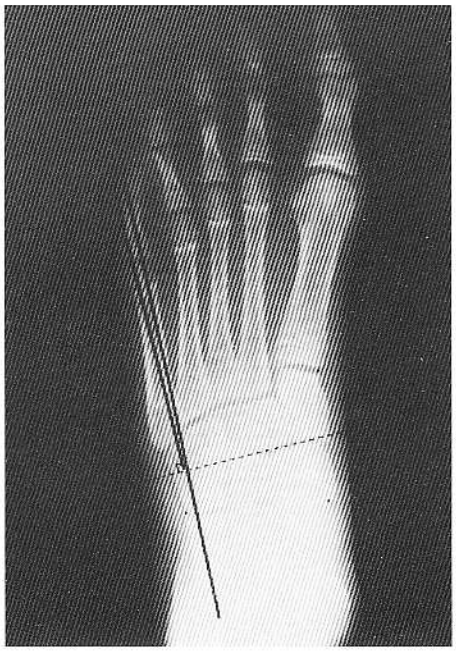

Figure 9C. This angle increases with pronation as the forefoot and midfoot abduct on the rearfoot as shown in this pronated foot x-ray.

Midfoot vs. Rearfoot

Midfoot vs. rearfoot is the relationship between the lesser tarsus and the rearfoot as measured by the longitudinal bisection of the lesser tarsus and the longitudinal bisection of the tarsus. This is called the *Lesser Tarsus Angle*. Since the midfoot is usually abducted on the rearfoot, this is called the *Lesser Tarsus Abductus Angle* (Figs. 9A, 9B).[3] This angle is a positional angle and will vary with subtalar joint pronation, increasing with pronation at the midtarsal joint and abduction of the midfoot (Fig. 9C). This angle will decrease with supination of the subtalar joint and adduction of the midfoot.[3] This angle is not commonly measured, as the relationship between the cuboid and calcaneus is easier to measure, and gives a good indication of midfoot to rearfoot relationship.

Relationships between the individual bones can provide a great deal of information about the foot.

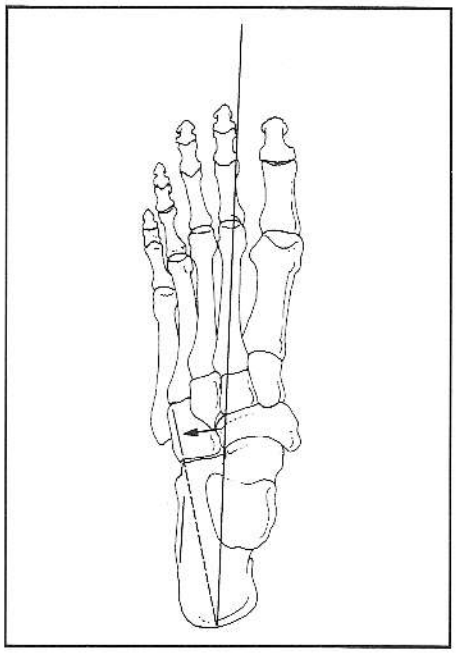

Figure 10A. Cuboid Abduction Angle. This is an angle measured between the general direction of the cuboid (lateral border trabeculae) and the rearfoot (longitudinal bisection of the tarsus).

Figure 10B. X-ray in neutral position.

Figure 10C. This angle increases with pronation as the forefoot and midfoot abduct on the rearfoot as shown in this pronated foot x-ray.

The Cuboid Abduction Angle is an estimation of the amount of abduction of the cuboid on the calcaneus as measured by the longitudinal bisection (or lateral border) of the cuboid and the longitudinal axis of the calcaneus. The normal value is 0 to 5°. The calcaneal reference line remains the longitudinal axis of the tarsus (rearfoot). This angle estimates the amount of abduction of the midfoot on the rearfoot and mirrors the lesser tarsus abductus angle (Figs. 10A, 10B).[5,6] This is a positional angle. With pronation of the subtalar joint and abduction of the forefoot and midfoot on the rearfoot, the cuboid abducts, increasing this angle (Fig. 10C). With supination of the subtalar joint and adduction of the forefoot and midfoot on the rearfoot, the cuboid adducts, decreasing this angle and occasionally causing a cuboid adductus angle.

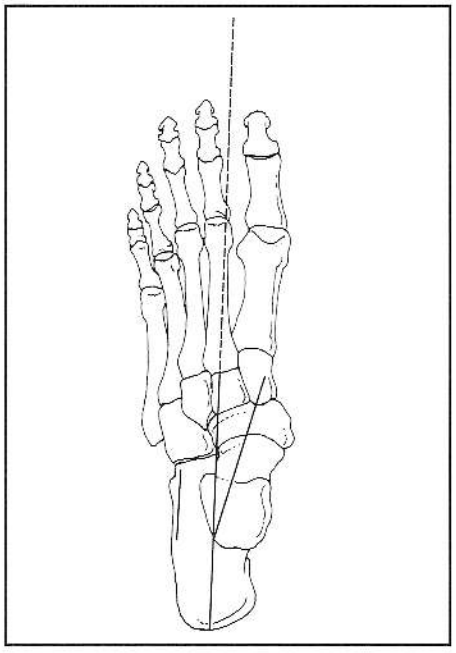

Figure 11A. Talocalcaneal (Kite's) Angle. This is an angle formed between the bisection of the head and neck of the talus and the calcaneus (longitudinal bisection of the tarsus) on a dorsoplantar x-ray.

Figure 11B. X-ray in a neutral position.

Figure 11C. With adduction of the talus in pronation, this angle increases as shown in this pronated foot x-ray.

The Talocalcaneal (Kite's) Angle is an estimation of the amount of divergence of the calcaneus and talus. This angle is measured between the bisection of the head and neck of the talus and longitudinal axis of the calcaneus. The normal value is 18°. The calcaneus already has a reference line - the longitudinal axis of the tarsus (rearfoot) (Figs. 11A, 11B).[3,7] Note: Don't confuse this with the lateral talocalcaneal angle that is measured on a weight bearing lateral x-ray view. This is a positional angle. With pronation of the subtalar joint and adduction of the talus, the talocalcaneal angle increases (Fig. 11C) With supination of the subtalar joint and abduction of the talus, the talocalcaneal angle decreases.[7]

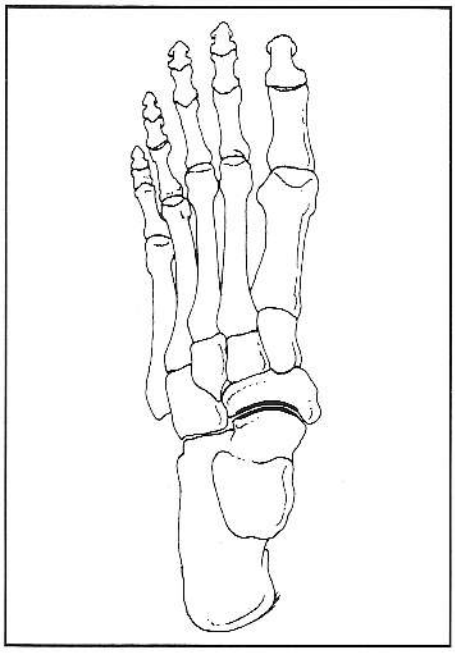

Figure 12A. Percentage of Talonavicular Articulation. This is an estimation of the percentage that the head of the talus articulates with the navicular. The amount of navicular articulation with the talus is estimated. The amount of total talar articulation at the head is estimated. The percentage of articulation versus the amount of talar head articulation available is then estimated.

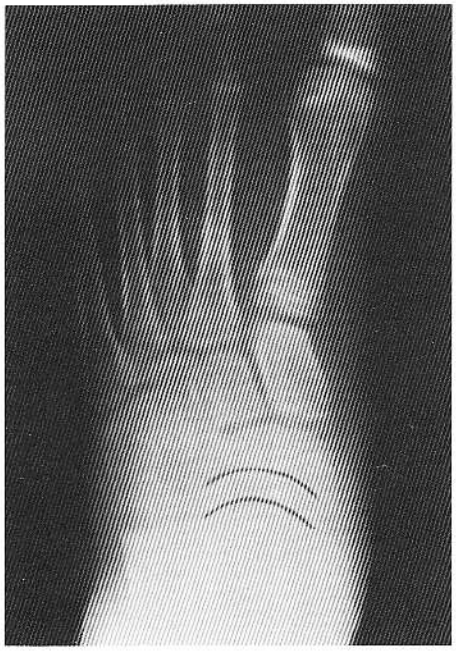

Figure 12B. X-ray in neutral position.

Figure 12C. With adduction of the talus in pronation, the percentage of talar head articulation diminishes, as seen in this pronated foot x-ray.

The Talonavicular Congruity is an estimation of the amount that the head of the talus articulates with the navicular. The normal value is >75°. This is determined by the percentage of apparent articular surface which is articulating with the navicular (Figs. 12A, 12B).[2] This is a positional angle. With pronation of the subtalar joint and adduction of the talus, the percentage of talar head articulation diminishes. With supination of the subtalar joint and adduction of the talus, the percentage of talar head articulation increases (Fig. 12C).

The Metatarsus Primus Adductus Angle is an estimation of the amount of deviation of the first metatarsal from the rest of the forefoot as measured by the bisection of the first metatarsal and the bisection of the second metatarsal. The normal value is 8°. This is also referred to as the IM (intermetatarsal) angle (Figs. 13A, 13B).[3] This is mostly a structural angle. (However, in bunionectomy surgery, this can be reduced a significant amount without osteotomy correction.) This angle increases (subluxes) with the lack of stability of the 1st ray. The 1st ray stability depends on the stability of the joints proximally. Thus, with unlocking of the midtarsal joint, the first ray becomes unstable, allowing the metatarsus primus adductus angle to increase over time. Subluxation will allow adduction of the first ray and therefore increase the metatarsus primus adductus angle (IMA).

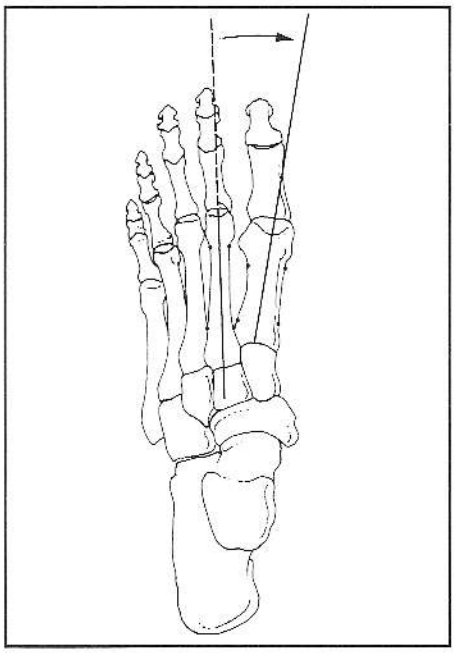

Figure 13A. Metatarsus Primus Adductus Angle (Intermetatarsal Angle). This is the angle formed between the bisection of the first metatarsal and the rest of the forefoot (as measured by the bisection of the second metatarsal).

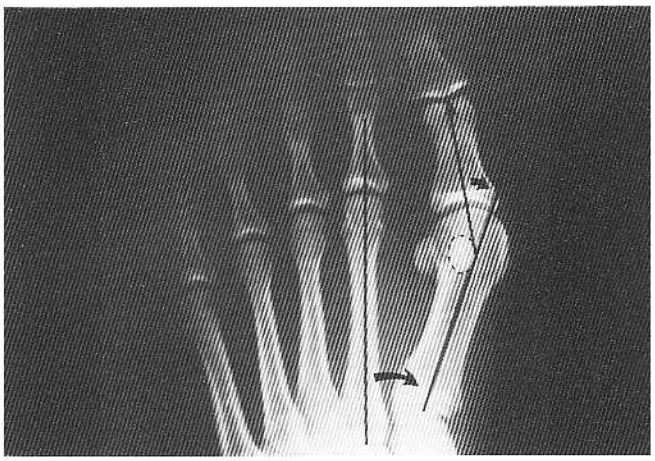

Figure 13B. This angle increases (subluxes) with lack of stability of the first ray, demonstrated in this x-ray.

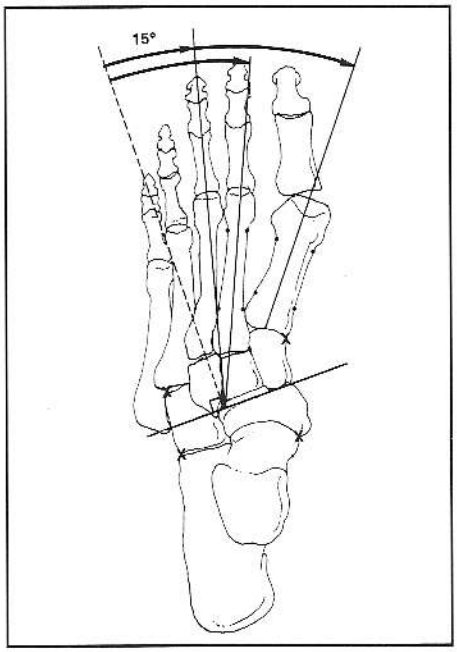

Figure 14A. True Intermetatarsal Angle IMA_T. This angle measures the structural deviation of the first metatarsal from the midfoot (longitudinal bisection of the lesser tarsus) minus the normal amount of the metatarsus adductus angle.

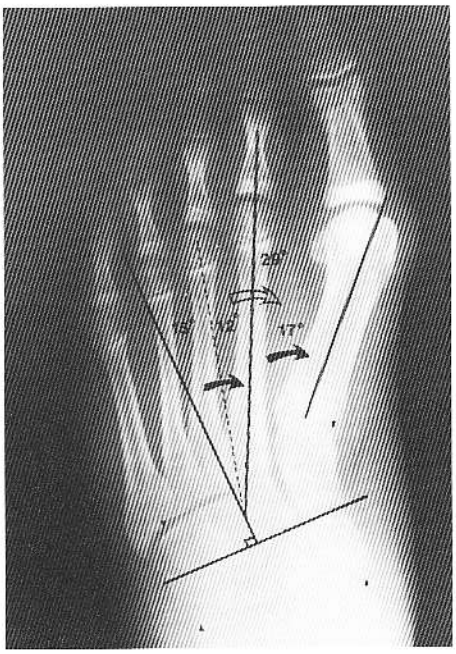

Figure 14B. X-ray of a foot with a high metatarsus adductus.

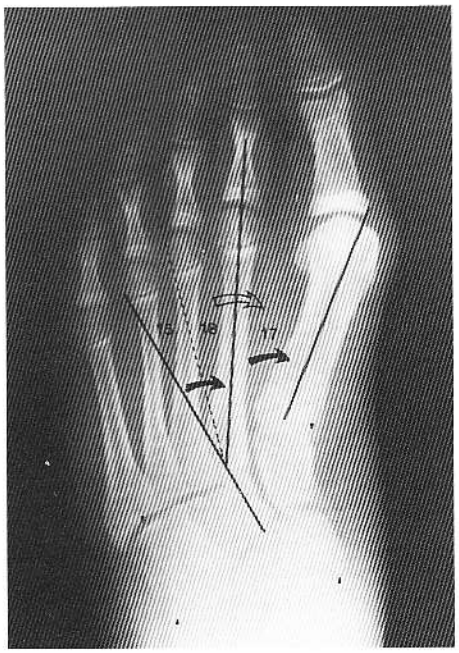

Figure 14C. Different foot with larger metatarsus adductus.

The True Intermetatarsal Angle (IMA_T) is an estimation of the amount of deviation of the first metatarsal from the normal midfoot. This takes into account the metatarsus adductus angle. The normal value is 8°. Since any increase to the metatarsus adductus angle increases the medial deviation of all the metatarsals, the 2nd metatarsal reference line is also deviated medially. Thus, the true intermetatarsal angle equals the measured IMA + any increase in the metatarsus adductus angle over the normal 15° (Figs. 14A, 14B).[8]

$$IMA_T = IMA + (MAA - \text{Normal } 15^\circ)$$

This is a structural angle and will change very little with supination and pronation. This angle more accurately measures the structural adductus of the first ray as it relates to the foot. It is a clinically important angle (Fig. 14C).

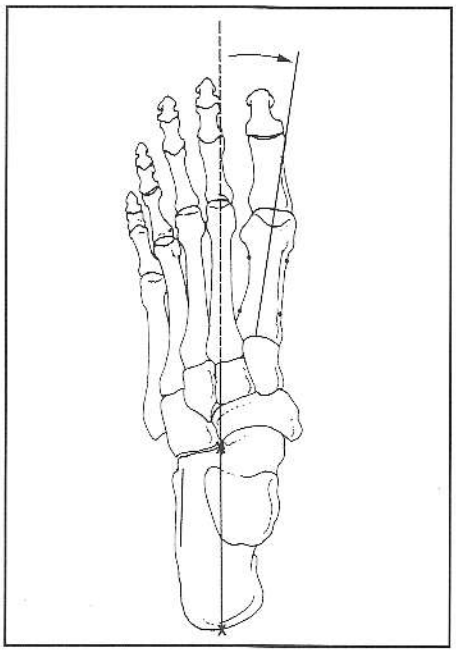

Figure 15A. First Metatarsal-Calcaneal Angle (1st Met-Calc Angle). This angle measures the deviation of the first metatarsal bisection from the rearfoot (longitudinal bisection of the tarsus).

Figure 15B. The structural medial prominence of the first metatarsal can be hidden with abduction of the forefoot and midfoot on the rearfoot in a pronated foot x-ray. This can result in a low first metatarsal-calcaneal angle.

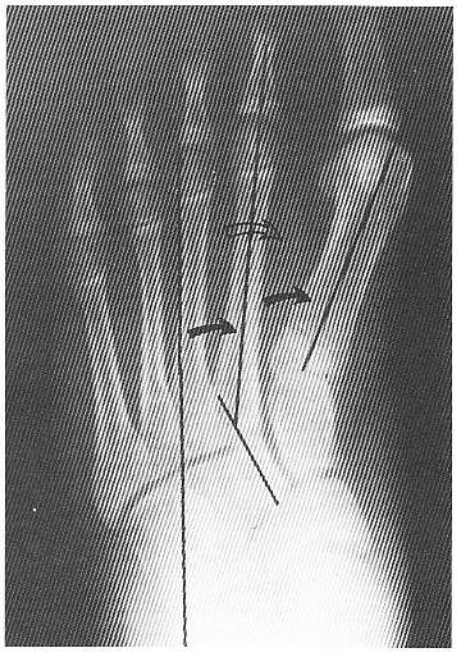

Figure 15C. When the foot is placed in a neutral position, the first metatarsal prominence (high IMA and/or high metatarsus adductus angle) may become unmasked as the first metatarsal-calcaneal angle is increased.

The First Metatarsal-Calcaneal Angle (1st met-calc angle) is an estimation of the transverse deviation of the 1st metatarsal from the rearfoot. The normal value is undetermined. This takes into account the structural metatarsus adductus angle and the positional forefoot adductus angle (Figs. 15A, 15B). This is a clinical evaluation of the relationship of the 1st metatarsal to the foot in a compensated position. This is an important evaluation, especially when the pronated foot is controlled in a more neutral position. This is a structural and positional angle. This angle will decrease with pronation as the forefoot abducts on the rearfoot. This angle will increase with supination as the forefoot adducts on the rearfoot (Fig. 15C).

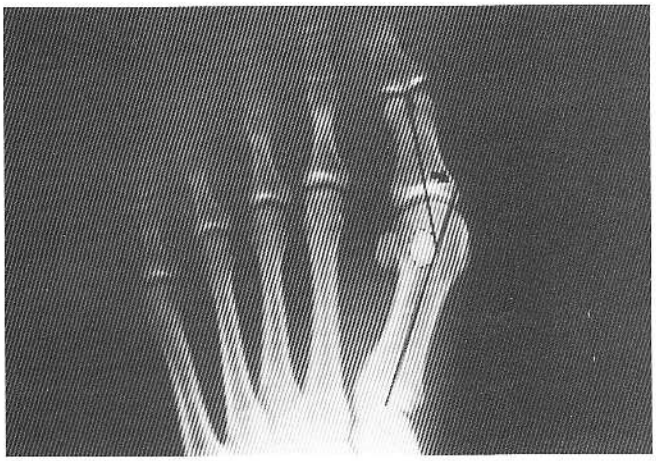

Figure 16. Hallux Abductus Angle (HAA). This is the angle formed between the bisection of the proximal phalanx of the hallux and the bisection of the first metatarsal.

The Hallux Abductus Angle is an estimation of the deviation of the hallux as measured by the longitudinal bisection of the proximal phalanx and the bisection of the first metatarsal (Fig. 16).[9] The normal value is 15°-16°. This is a combined structural and positional angle. This angle will increase in proportion to the amount of adduction of the first metatarsal. Consequently, a hypermobile pronated foot which allows an increase in the metatarsus primus adductus angle will also lead to an increased hallux adductus angle.

The Tibial Sesamoid Position is an estimation of the lateral deviation of the sesamoids in relation to the first metatarsal head as measured by the relationship of the tibial sesamoid and the bisection of the first metatarsal (Figs. 17A, 17B).[10] This is a combined structural and positional alignment. The sesamoids show a relative lateral drift with the increased medial deviation of the first metatarsal. This occurs in a bunion deformity with any increased metatarsus primus adductus angle and an increased HA angle. The 7-position scale is as follows:

#1. Entire tibial sesamoid is medial to the 1st metatarsal bisection.

#2. Lateral aspect of the tibial sesamoid is tangential to the metatarsal bisector.

#3. The lateral 1/3 of the tibial sesamoid overlaps the bisector.

#4. The tibial sesamoid is centered over the bisector.

#5. The medial 1/3 of the tibial sesamoid overlaps the bisector.

#6. The medial aspect of the tibial sesamoid is tangential to the bisector.

#7. The entire tibial sesamoid is lateral to the bisector. The normal values are 1 and 2.

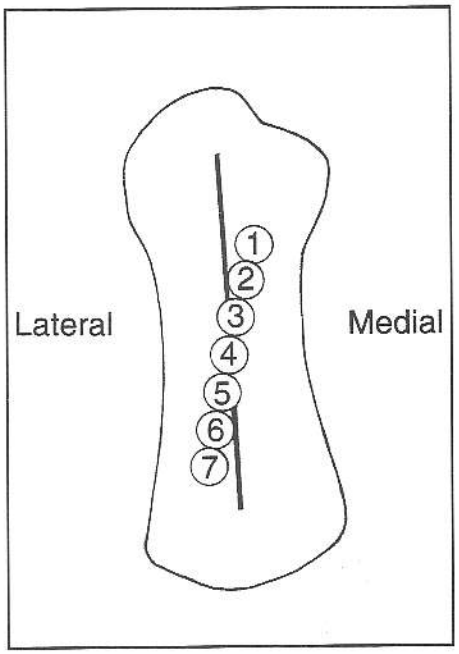

Figure 17A. Tibial Sesamoid Position. The position of the tibial sesamoid versus the bisection of the first metatarsal on a 7- position scale. #1. The entire tibial sesamoid is medial to the first metatarsal bisection. #2. The lateral aspect of the tibial sesamoid touches the bisector. #3. The lateral 1/3 of the tibial sesamoid overlaps the bisector. #4. The tibial sesamoid is centered over the bisector. #5. The medial 1/3 of the tibial sesamoid overlaps the bisector. #6. The medial aspect of the tibial sesamoid touches the bisector. #7. The entire tibial sesamoid is lateral to the bisector.

Figure 17B. X-ray demonstrating a #5 position of the tibial sesamoid.

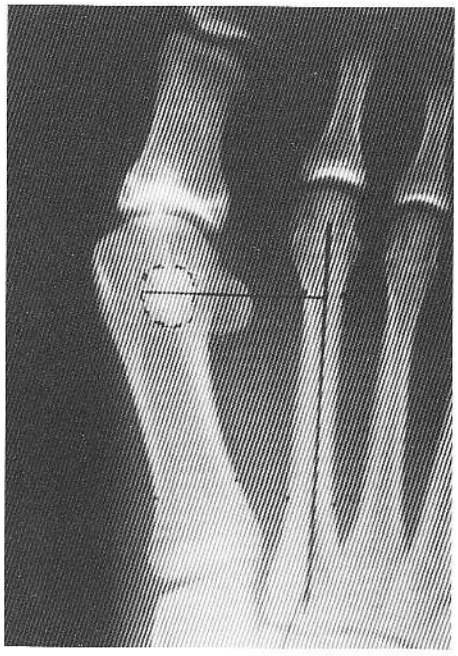

Figure 18. Tibial Sesamoid-Second Metatarsal Distance (TSMD). This is the perpendicular distance in millimeters from the medial aspect of the tibial sesamoid to the bisection of the second metatarsal.

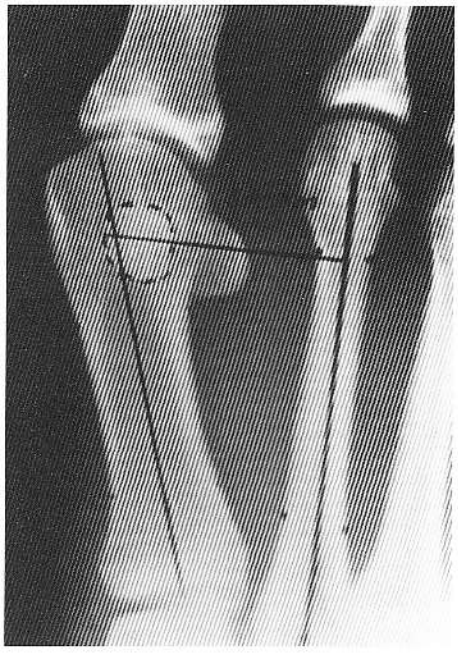

Figure 19A. Preoperative x-ray of a hallux abductovalgus demonstrating the hallux abductus angle, the intermetatarsal angle, the tibial sesamoid position, and the tibial sesamoid second metatarsal distance.

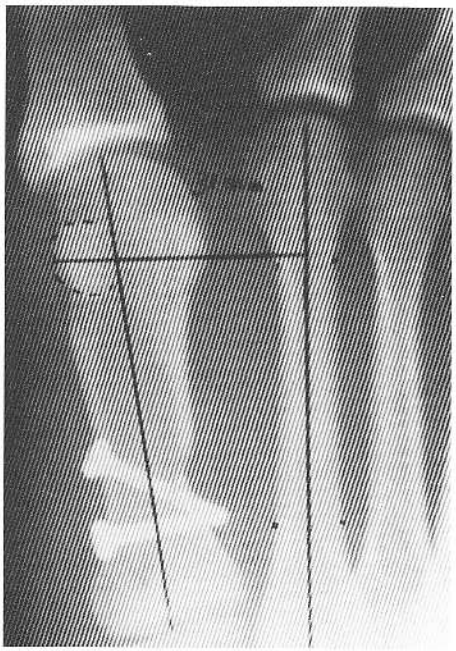

Figure 19B. Postoperative x-ray of a closing base wedge osteotomy-McBride bunionectomy showing reduction of the hallux abductus angle, the intermetatarsal angle, and the tibial sesamoid position. The tibial sesamoid - second metatarsal distance remains essentially unchanged.

The Tibial Sesamoid-2nd Metatarsal Distance (TSMD) is the perpendicular distance in millimeters from the medial border of the tibial sesamoid to the bisector of the 2nd metatarsal (Fig. 18).[11] This is a structural distance. The sesamoid apparatus is firmly fixed within the soft tissue structures of the plantar aspect of the foot. Any change in the relationship between the 1st metatarsal head and the sesamoid apparatus is primarily the result of movement of the first metatarsal. The distance between the tibial sesamoid and the second metatarsal remains fixed. In performing hallux abducto valgus surgery (bunionectomy), the intermetatarsal angle, the hallux abductus angle, and the tibial sesamoid position are all usually reduced. However, the tibial sesamoid-2nd metatarsal distance remains relatively unchanged (Figs. 19A, 19B).

EVALUATION AND RELATIONSHIPS OBTAINED FROM THE LATERAL VIEW

We can also obtain a great deal of information from the lateral weightbearing x-ray view taken in the angle and base of gait (Table 2). The standard weight-bearing reference is measured by a line from the plantarmost aspect of the calcaneus and the 5th metatarsal head (Fig. 20).[2,3,7]

The Calcaneal Inclination Angle is an estimation of the pitch of the calcaneus as measured by the line extending from the proximal plantar surface of the calcaneus to the anterior inferior aspect of the calcaneal cuboid joint. This line is compared to the weight-supporting surface.[2,3,7] This is primarily a structural angle. In general, this angle usually changes very little in the sagittal plane with weight-bearing pronation and supination (Figs. 21A, 21B).[7] The normal is 24.5° with a range of 18° to 30°.

Note: The plantar condyle of the calcaneus may become prominent with inversion and eversion. This may falsely appear to change the calcaneal pitch in supination or pronation. However, the calcaneal cuboid joint does not become significantly depressed or elevated itself. Thus, the calcaneal inclination angle depends more on the sagittal plane relationship of the forefoot to the rearfoot than on pronation or supination.[5,12]

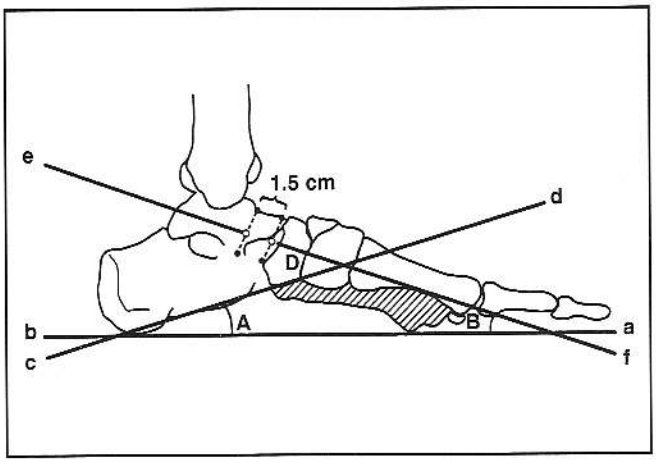

Figure 20. Angular relationships on a lateral x-ray - Line ab is the weight supporting reference measured by the plantarmost aspect of the calcaneus and the 5th metatarsal head. Line cd is the line from the anterior inferior aspect of the calcaneus to the anterior aspect of the calcaneal cuboid joint. Line ef is the bisection of the head and neck of the talus which passes equidistant from dorsal and plantar margins of the articular facet of the talar head and equidistant from dorsal and plantar margins of the talar neck 1.5 cm proximal from the articular margins. A. Calcaneal inclination angle. B. Talar declination angle. D. Lateral talocalcaneal angle.

Table 2

EVALUATIONS FROM THE LATERAL VIEW

1. Calcaneal inclination angle
2. Talar declination angle
3. Lateral talocalcaneal angle
4. Kirby sign
5. Cyma line
6. 1st metatarsal declination angle
7. Seiberg Index
8. Lateral talo 1st metatarsal angle (navicular cuneiform fault)
9. 5th metatarsal declination angle
10. Height of the navicular

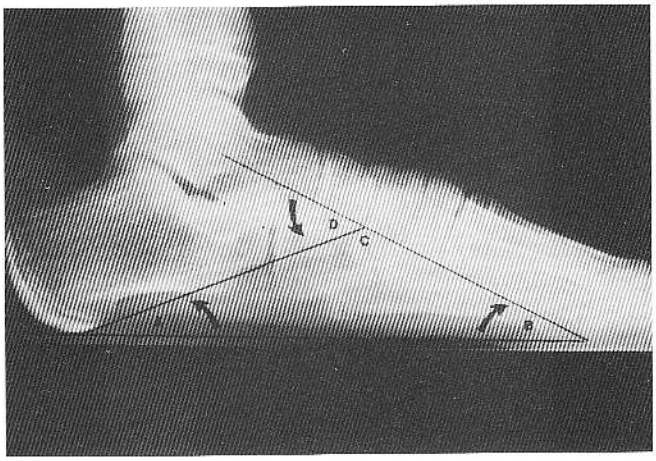

Figure 21A. Pronated foot x-ray. A. Calcaneal inclination angle changes very little with pronation. B. Talar declination angle changes quite a bit, increasing with pronation. D. The lateral talocalcaneal angle also changes a great deal, increasing with pronation.

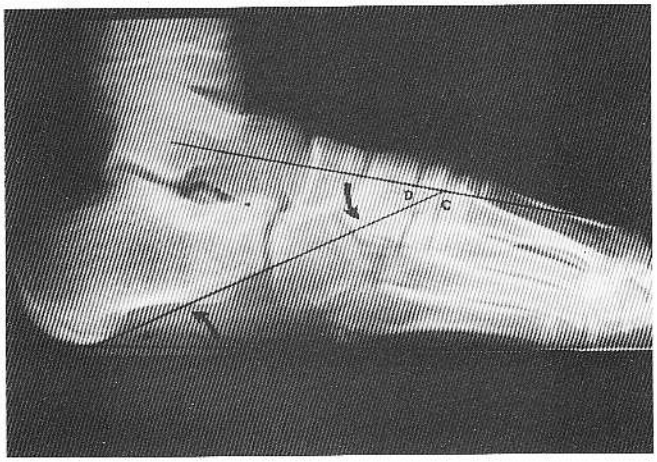

Figure 21B. Supinated foot x-ray. A. Calcaneal inclination angle changes very little with supination. B. Talar declination angle changes quite a bit, decreasing with supination. D. The lateral talocalcaneal angle also changes a great deal, decreasing with supination.

Pes Cavus. With a rigid forefoot or metatarsal cavus, a fixed plantar flexion of the forefoot or metatarsus on the rearfoot, there will be a reflex buckling of the rearfoot which will cause an increased calcaneal inclination angle. Moderate deformity is 31° to 40°; >40° is considered to be severe deformity. (Figs. 22A, 22B).[2,13] Supination and pronation from this position will once again not alter the calcaneal inclination angle significantly (22C, 22D).

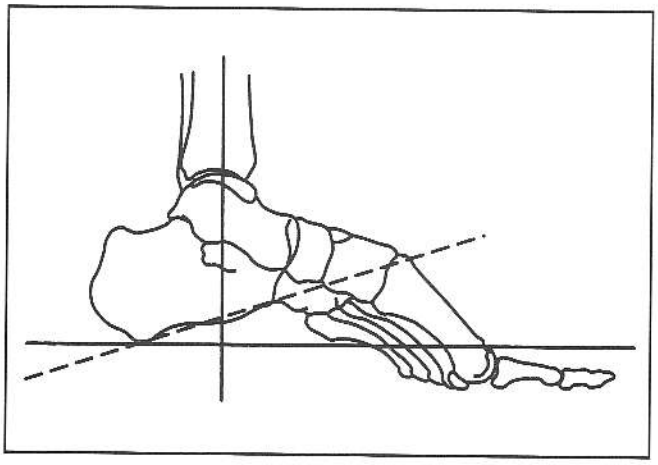

Figure 22A. Pes Cavus. Rigid increased declination of the forefoot.

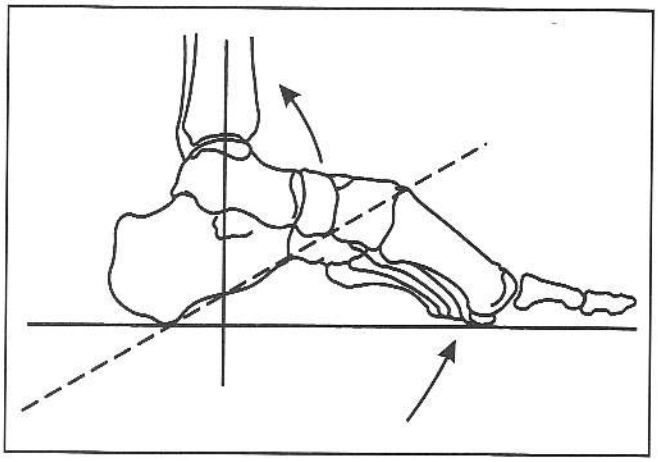

Figure 22B. Dorsiflexion of the foot at the ankle to get the forefoot and the heel on the same plane increases the calcaneal inclination angle.

Figure 22C. Supinated cavus (high arch) foot.

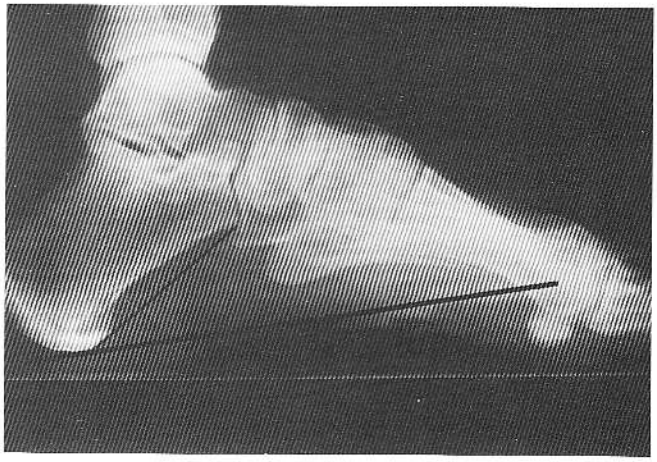

Figure 22D. Pronated cavus (high arch) foot.

Pes Valgo Planus. With unlocking of the midtarsal joint in the lateral column, the calcaneus and the talus can sublux plantarly as a unit over a period of time. This is often referred to as dorsiflexion of the forefoot on the rearfoot. However, in gait, this subluxation occurs in stance, as the pull of the gastrosoleus complex forces the rearfoot into plantar declination as it attempts to lift the foot and heel from the ground. The unlocking of the lateral column is most commonly caused by excessive pronation of the subtalar joint. This leads to lowering of the calcaneal inclination angle by structural subluxation.[14] Since the rearfoot is structurally lowered, supination from the pronated position will once again not alter the calcaneal inclination angle significantly (Figs. 23A-23C).[5,7,12]

Pes Planus is simply a low arched foot. This foot will function in a normal fashion with a neutral resting stance position. Although the x-ray of this foot will have a low calcaneal inclination angle, the remaining parameters will be essentially normal. A calcaneal inclination angle of 10° to 18° is considered moderate deformity; <10° is severe deformity (Fig. 24). Note: The calcaneal inclination angle is probably the single most important angle used in determining the sagittal plan foot structure (pes cavus vs. pes planus).

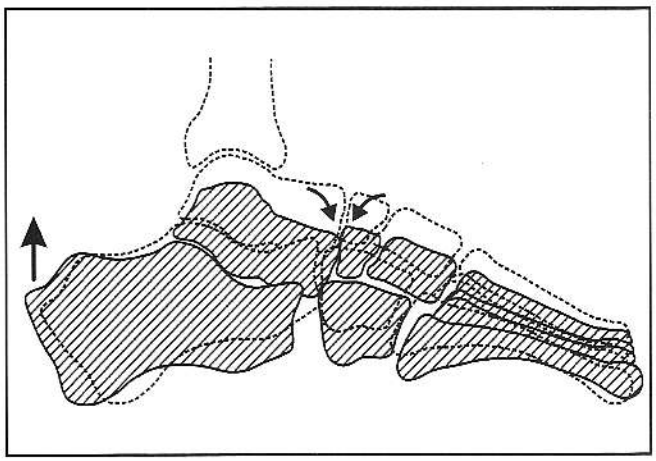

Figure 23A. With unlocking of the midtarsal joint in the lateral column, the talus and calcaneus can sublux plantarly as a unit over a period of time.

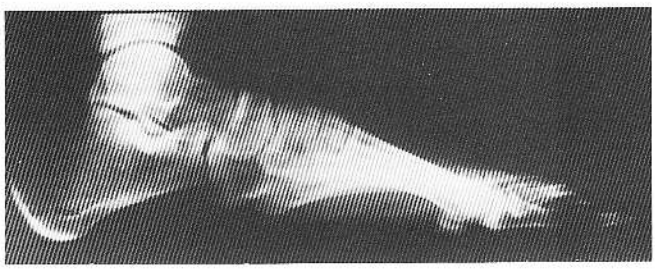

Figure 23B. A low calcaneal inclination angle is seen in this pronated foot x-ray.

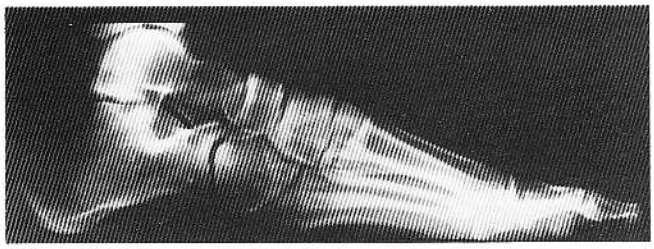

Figure 23C. The calcaneal inclination angle remains low as this foot is supinated.

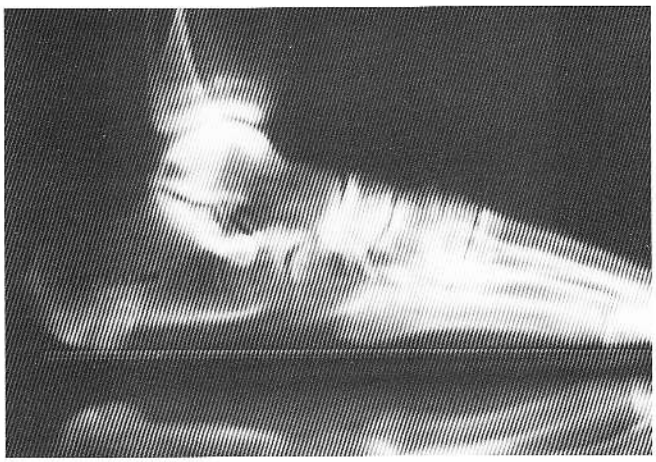

Figure 24. This pes planus foot has a low calcaneal inclination angle as it rests in neutral stance position.

The Talar Declination Angle is an estimation of the plantar flexion of the talus as measured between the bisection of the head and neck of the talus and the weight supporting surface measured by the plantarmost aspect of the calcaneus and 5th metatarsal head. The bisection of the head of the talus is measured by bisecting the dorsal and plantar articular surface of the talar head. The talar neck is bisected at a level 1.5 centimeters from the dorsal articular surface and 1.5 centimeters from the plantar articular surface of the talar head. The line connecting these equidistant points is the bisection of the head and neck of the talus.[2] Normal is 21°.

This angle increases (ie. increased plantar flexion of the talus) in subtalar pronation, especially pronation with calcaneal eversion past the perpendicular. This angle decreases (ie. increased dorsiflexion of the talus) in subtalar supination.[5,7,12] Normally, the extension of the bisection of the head and neck of the talus passes through the 1st metatarsal head in neutral position (Figs. 20, 21A, 21B).

The Lateral Talocalcaneal Angle (Lat-TCA) is an estimate of the amount of divergence in the talus and the calcaneus on the lateral radiograph. This angle is formed by the longitudinal bisection of the head and neck of the talus and the calcaneal pitch. The calcaneal pitch already has a reference line, a line extending from the plantar surface of the calcaneus to the anterior-inferior aspect of the calcaneal cuboid joint.[5,7]

This angle can be measured on the lateral radiograph or can be calculated from the calcaneal inclination angle and the talar declination angle. The lateral talocalcaneal angle equals the sum of the calcaneal inclination angle and the talar declination angle (Lat-TCA = CIA + TDA). Since the calcaneal inclination angle and the talar declination angles are measured against a common line (the weight-bearing surface), each makes an angle with this baseline. Thus, a triangle is formed. The normal is 45° (range 40°- 50°).

A triangle = 180°
If the calcaneal inclination angle (CIA)= A
If the talar declination angle (TDA)=B
And the remaining angle of the triangle = C
Then: (CIA)A + (TDA)B + C = 180° ..
(CIA)A + (TDA)B = 180° - C

A straight line = 180°
If the lateral talocalcaneal angle (LAT TCA) = D
And the remaining angle of the straight line = C
Then: (LAT TCA)D + C = 180° ..
(LAT TCA)D = 180° - C

Since (CIA)A + (TDA)B = 180° - C
And (LAT TCA)D = 180° - C and
C is the identical angle in both equations

Then: (LAT TCA)D = (CIA)A + (TDA)B
(Figs. 20, 21A, 21B)

The lateral talocalcaneal angle is a positional angle. Almost all of the sagittal plane motion for this angle comes from the talar motion.[7] With pronation of the subtalar joint, the talar declination angle increases, thus increasing the lateral talocalcaneal angle. With supination of the subtalar joint and dorsiflexion of the talus, the talar declination angle decreases, and thus the lateral talocalcaneal angle decreases. This angle changes quite a bit with pronation and supination.[5,7,12]

The Cyma line is an estimation of sagittal plane relationship of the two rearfoot bones -the calcaneus and the talus, as measured by the relationship of the talonavicular articulation to the calcaneal cuboid articulation.[5] Normally, the line formed by the talonavicular and calcaneal cuboid joint surfaces forms a gentle "S" curve (Figs. 25A, 25B). A broken cyma line means these surfaces are not contiguous.

With subtalar joint pronation, the talus adducts, allowing the lateral silhouette of the talus to be more prominent and "appears" to move anteriorly in relation to the calcaneus. When the talonavicular articulation is anterior to the calcaneal cuboid articulation, it is known as an anterior break in the cyma line (Fig. 25C).

With subtalar joint supination, the talus abducts, allowing the talar silhouette to become less longitudinal and "appears" to move posterior in relation to the calcaneus. When the talonavicular articulation is posterior to the calcaneal cuboid articulation, it is known as a posterior break in the cyma line.[5,12]

Kirby's Sign is a sign of maximum pronation of the subtalar joint and occurs when the leading wall of the posterior facet of the talus occludes the sinus tarsi and abuts the calcaneal floor of the sinus canal.(Personal Communication, Kevin Kirby, 1987) This is a positional angle (Fig. 25C).

As the talus adducts and plantar flexes, the leading wall of the posterior facet of the talus rotates forward, until it is stopped by the bony calcaneal floor of the sinus tarsi. Thus, the sinus tarsi is occluded, and the talus can rotate no further

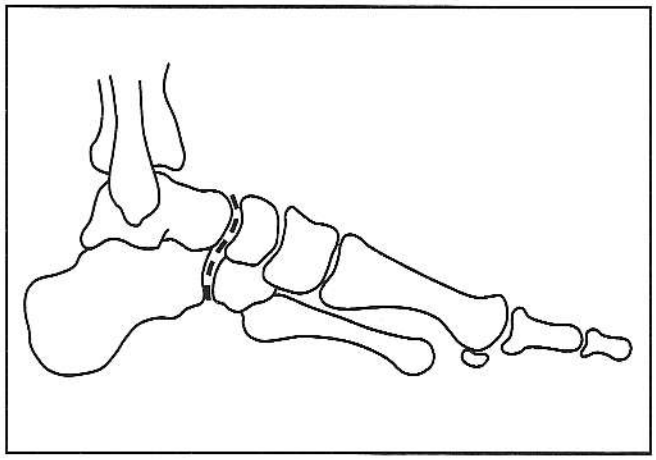

Figure 25A. The cyma line is a gentle "S" curve formed by the talonavicular and calcaneal cuboid joint surfaces. This normally occurs when the foot is in neutral stance position.

Figure 25B. X-ray in neutral stance position.

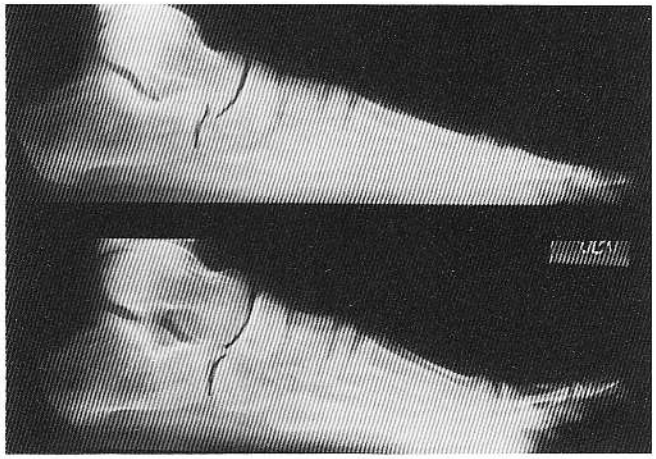

Figure 25C. (Top) In a pronated foot x-ray, the talonavicular joint "appears" much more anterior than the calcaneal cuboid joint, as the lateral silhouette of the talus becomes more prominent, this creates an anterior break in the cyma line. The lateral wall of the posterior subtalar joint facet rotates forward, occluding the sinus tarsi, causing a + Kirby sign. (Bottom) In a supinated foot x-ray, as the talus abducts, the talonavicular joint "appears" much more posterior than the calcaneal cuboid joint, as the talar silhouette becomes less longitudinal, this creates a posterior break in the cyma line. The lateral wall of the posterior subtalar joint rotates backward, uncovering the sinus tarsi, causing a more open and rounded sinus tarsi or "Bullet Hole."

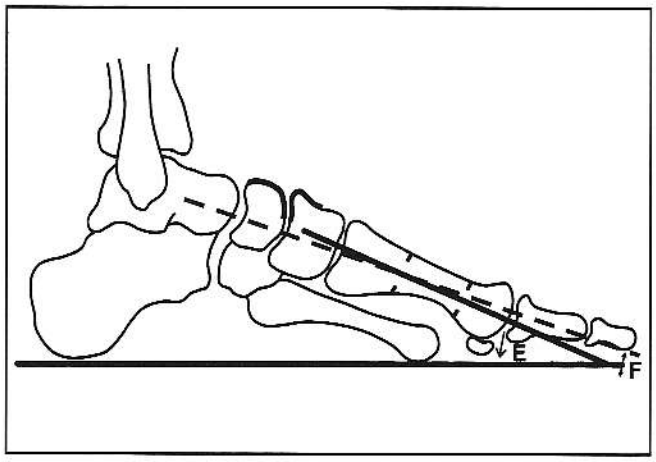

Figure 26A. The first metatarsal declination angle - this is the relationship between the bisection of the first metatarsal and the weight supporting surface (E). The lateral talo first metatarsal angle is measured between the bisection of the head and neck of the talus and the bisection of the 1st metatarsal (F).

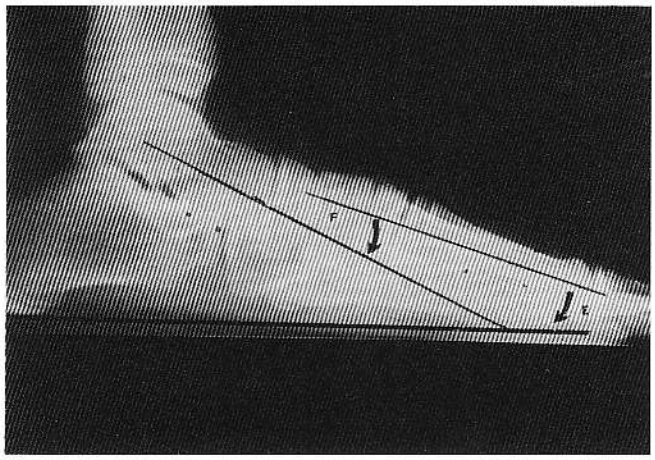

Figure 26B. Pronated foot x-ray. The first metatarsal declination angle reduces somewhat (E). The lateral first metatarsal angle increases in the positive direction as the talus significantly plantarflexes (F).

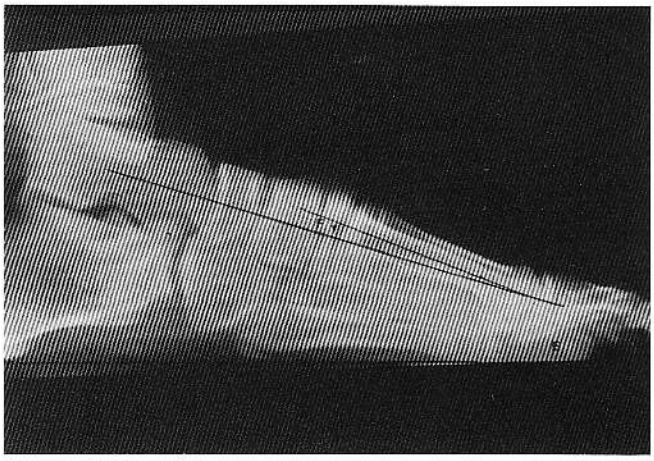

Figure 26C. Supinated foot x-ray. The first metatarsal declination angle increases somewhat (E). The lateral talar first metatarsal angle increases in the negative direction as the talus dorsiflexes significantly (F).

forward. As the talus adducts and dorsiflexes, the leading wall of the posterior facet of the talus rotates backwards, widening the entrance of the sinus tarsi. With significant supination, the sinus tarsi area can appear open and rounded. This is referred to as a "Bullet Hole" (sinus tarsi) (Fig. 25C).[5,7,12]

The First Metatarsal Declination Angle is an estimation of the plantar declination of the 1st metatarsal as measured between the bisection of the 1st metatarsal and the weight supporting surface, (as measured by the plantarmost aspect of the calcaneus and the 5th metatarsal head) (Fig. 26A).[3] This is a combined positional and structural angle. With pronation, this angle decreases to the end range of dorsiflexion available, and with supination, this angle increases to end range of plantar flexion, unless the tibialis anterior is active and dorsiflexing the first ray segment (Figs. 26B, 26C).[12]

The Lateral-Talo 1st Metatarsal Angle is the relationship between the 1st ray segment and the talus, as measured between the bisection of the 1st metatarsal and the bisection of the head and neck of the talus. This angle is a very important indicator of the first ray and forefoot stability (Fig. 26A).[5]

A negative talo 1st metatarsal angle (ie.plantar flexion of the 1st ray on the talonavicular segment), indicates stability of the 1st ray in the forefoot. There is often the dorsal prominence of the 1st metatarsal cuneiform area (Fig. 26B).

A positive talo 1st metatarsal angle (ie. dorsiflexion of the 1st ray on the talarnavicular segment) indicates instability of the 1st ray. There is often a concavity in the region of the 1st cuneiform navicular area termed a *Navicular Cuneiform Fault* (Fig. 26C). This is a combined structural and positional angle.

With pronation of the subtalar joint, the first ray dorsiflexes if motion is available at the first ray. The talar and the navicular segments plantarflex. With supination of the subtalar joint, the first ray plantarflexes to end range of motion available (unless the tibialis anterior is actively dorsiflexing the first ray segment). The talar and navicular segments dorsiflex.[4,5]

The Seiberg Index is the measurement of the sagittal plane relationship of the first metatarsal to the second metatarsal. The perpendicular distance from the dorsum of the second metatarsal shaft to the dorsum of the 1st metatarsal shaft, approximately 1.5 cm from its articular base is measured in millimeters. Next, the perpendicular distance from the dorsum of the second metatarsal shaft to the dorsum of the 1st metatarsal shaft at the 1st metatarsal neck level, just proximal to the head, is measured in millimeters. The proximal measurement is subtracted from the distal measurement to obtain the Seiberg Index (Fig. 27A).[15] This is primarily a structural angle, but may change somewhat with pronation and supination. A plantarflexed first ray can be a structural deformity or a functional positional state, in which the first metatarsal is plantar flexed more than the second metatarsal. The distance of the more proximal measurement is greater than the distal measurement. The difference is expressed as a negative number for the Seiberg Index (Fig. 27B).

A Metatarsus Primus Elevatus (dorsiflexed 1st ray) can be a fixed structural deformity or a functional positional state in which the 1st metatarsal is elevated more than the 2nd metatarsal. The distance of the more proximal measurement is less than the distal measurement. The difference is expressed as a positive number for the Seiberg Index (Figs. 27C, 27D).

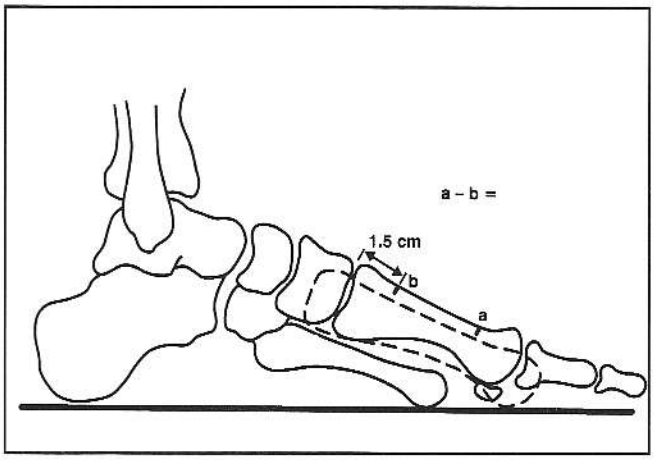

Figure 27A. Seiberg Index is a sagittal measurement of the relationship of the first metatarsal to the second metatarsal.The perpendicular distance from the dorsum of the second metatarsal to the dorsum of the first metatarsal shaft is measured at the first metatarsal neck and 1.5 cm from the first metatarsal base. The proximal measurement is subtracted from the distal measurement to give the Seiberg Index.

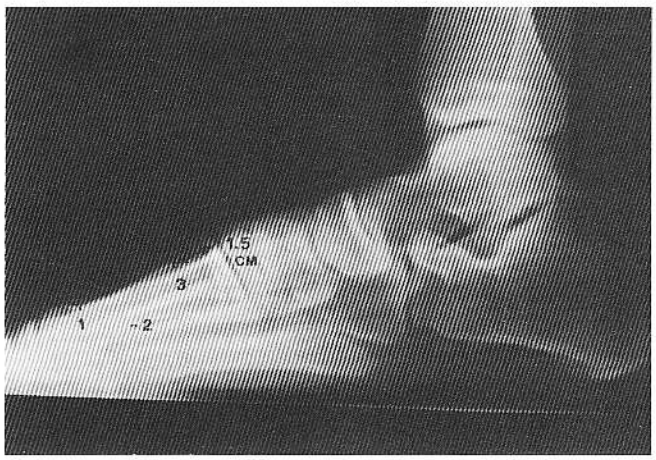

Figure 27B. With a plantar declinated first ray, the Seiberg Index is negative.

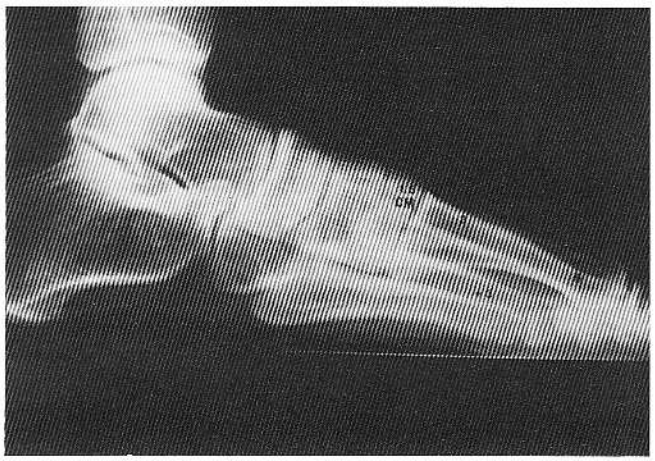

Figure 27C. With a metatarsus primus elevatus, the Seiberg Index is positive.

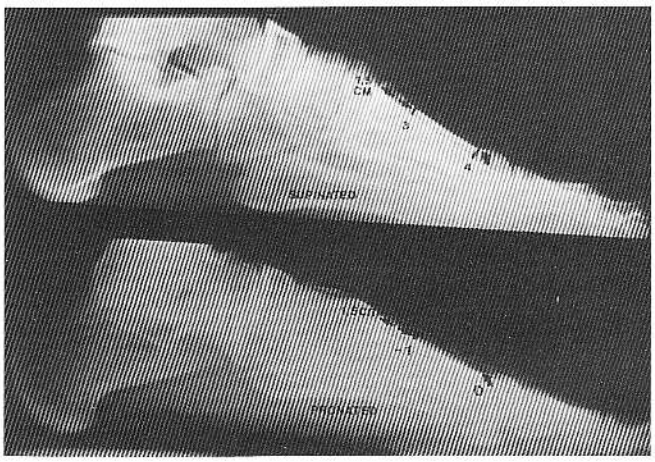

Figure 27D. The Seiberg Index changes very little with supination and pronation.

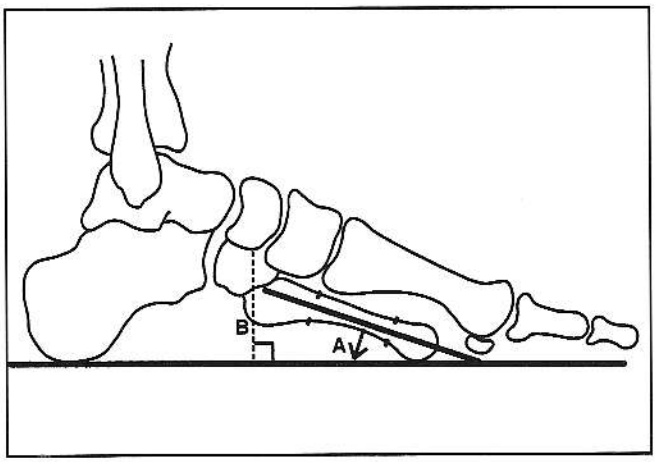

Figure 28A. Fifth metatarsal declination angle - The angle measures the relationship between the bisection of the fifth metatarsal and the weight bearing surface.

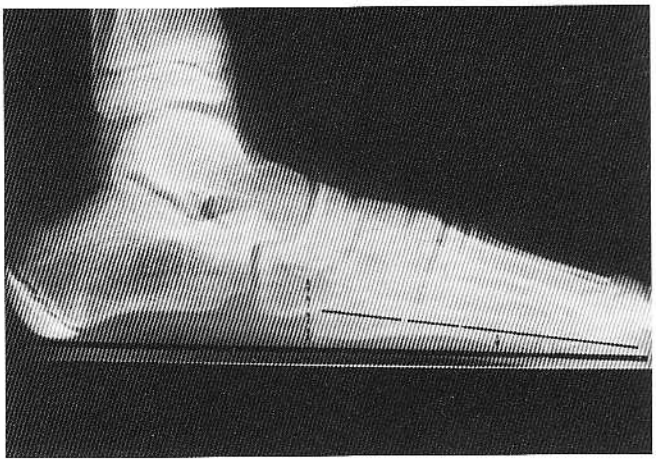

Figure 28B. Height of the navicular - This is higher in a pes cavus foot and lower in a pes planus foot.The fifth metatarsal declination angle increases with pronation (eversion of foot). The navicular lowers with pronation.

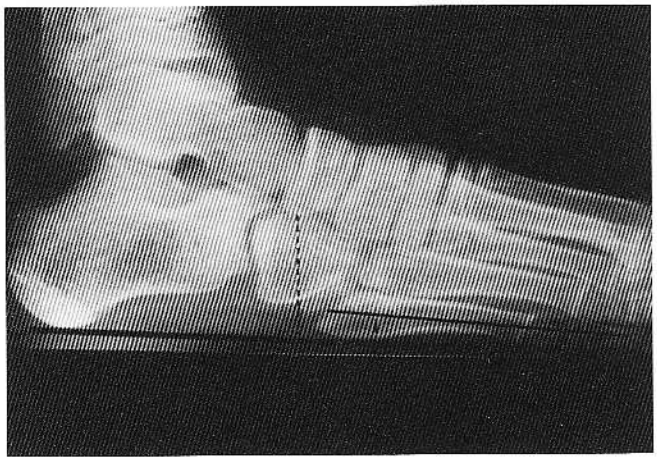

Figure 28C. The fifth metatarsal declination angle decreases with supination (inversion of foot). The navicular elevates with supination.

The 5th Metatarsal Declination Angle is an estimation of the plantar declination of the 5th metatarsal as measured between the bisection of the 5th metatarsal and the weight-supporting surface. The weight-supporting surface is measured by the plantarmost aspect of the calcaneus and the 5th metatarsal (Fig. 28A). This is a combined structural and positional angle. With pronation, this angle increases as weight is shifted more to the medial column (eversion of the forefoot) (Fig. 28B). With supination, this angle decreases as the foot is rolled more onto the lateral column (inversion of the forefoot) (Fig. 28C).[12]

The Height of the Navicular is an estimation of the height of the arch by measuring the distance of the plantarmost aspect of the navicular from the weight-supporting surface. This is higher in a pes cavus foot and lower in a pes planus foot (Fig. 28A).

The height decreases with the eversion of the midfoot with excessive midtarsal pronation (Fig 28B). The height increases with the inversion of the midfoot with supination (Fig. 28C).[12] Subluxations exaggerate these findings.

REFERENCES

1. Hlavac HF: Differences in x-ray findings with varied positioning of the foot. *J Am Podiatry Assoc* 57(10):185, 1971.
2. Gamble FO, Yale I: *Clinical Foot Roentgenology* Baltimore, Md; Williams & Wilkins:1966.
3. Sgarlato T: X-ray evaluation. In Sgarlato T, ed. *Compendium of Podiatric Biomechanics* San Francisco, California College of Podiatric Medicine:1971.
4. Engel E, Erlick N, Krems I: A simplified metatarsus adductus angle *J Am Podiatry Assoc* 73(12):620, 1983.
5. Green D, Sgarlato T, Wittenberg M: clinical biomechanical evaluation of the foot - a preliminary radiocinemagraphic study, *J Am Podiatric Assoc* 65(8):732, 1975.
6. Weissman S: *Radiology of the Foot* Baltimore, Md:William and Wilkins:1983.
7. DiGiovanni J, Smith SD: Normal Biomechanics of the adult rearfoot - a radiographic analysis, *J Am Podiatry Assoc* 66(11): 812, 1976.
8. Yu G, DiNapoli R: surgical management of hallux abducto valgus with concomitant metatarsus adductus In McGlamry ED, ed. *Reconstructive Surgery of the Foot and Leg - Update 89* Tucker, Ga; Podiatry Institute Publishing:1989.
9. LaPorta G, Melillo T, Olinsky D: X-ray Evaluation of Hallux Abductovalgus Deformity, *J Am Podiatry Assoc* 64(8):544, 1974.
10. McGlamry ED: Hallucal Sesamoids, *J Am Podiatry Assoc* 55:693, 1965.
11. Yu G, Judge M, Taylor R: hallux valgus surgery and the sesamoid apparatus In Vickers NS, ed *Reconstructive Surgery of the Foot and Leg - Update '97* Tucker, Ga; Podiatry Institute Publishing:1997.
12. Green, D.R. et al: "The Naked Foot in Motion (Radiocinematography)" - Movie, Podiatry Institute, Tucker, GA, 1973.
13. Whitney A, Green, D: "Pseudo Equinus", JAPA 72: 365, 1982.
14. Mahan K, McGlamry Ed, Green D: "Pes Planovalgus Deformity" in *Comprehensive Textbook of Foot Surgery* Vol I, 1st Edition, Ed by McGlamry Ed, Williams and Wilkens, Baltimore, 1987
15. Smith T, Pitts T, Green D: "Pes Cavus" in *Comprehensive Textbook of Foot Surgery*, Vol I, 2nd Edition, Ed. by McGlamry Ed, Banks A, Downey M, Williams and Wilkens, Baltimore, 1992.

ADDITIONAL REFERENCES

Green D, Smith T: "Pes Cavus Classifications: A Simplified Approach," *Reconstructive Surgery of the Foot and Leg - Update '94*, Ed by Camasta C, Vickers NS, Ruch J, The Podiatry Institute, Tucker, GA, 1994.

Seiberg M, Felson S, Colson J, et al: Closing Base Wedge Osteotomy versus Austin Bunionectomy for Metatarsus Primus Adductus, *JAPA* 84.11: 548, 1994.