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Review

Is Our Current Paradigm for Evaluation and Management of the Bunion Deformity Flawed? A Discussion of Procedure Philosophy Relative to Anatomy

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A R T I C L E I N F O

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A B S T R A C T

Of the >100 procedures that have been proposed to treat hallux valgus or the “bunion” deformity, most have focused on correction through metatarsal osteotomies at various levels combined with soft tissue balancing procedures at the first metatarsophalangeal joint. This paradigm of metatarsal osteotomy and soft tissue balancing has been so commonplace, any argument for a fundamental change to the approach becomes uncomfortable and seems unwarranted to most foot and ankle surgeons. However, the simple fact that so many procedures exist, with so many modifications of these procedures, can be interpreted as a failure of our basic paradigm of metatarsal osteotomy and soft tissue balancing. We have observed that failure to recognize frontal plane rotation of the first metatarsal and our willingness to ignore deformity correction principles and create osteotomies outside the center of rotation of angulation are factors that can result in inconsistent outcomes. Our current multiprocedural mindset drives the search for yet more procedures and modifications in an attempt to reduce the incidence of complications. We present an anatomic analysis of hallux abducto valgus and metatarsus primus adducto valgus and critically analyze some of the shortcomings of currently popular corrective procedures. We also review the available data regarding frontal plane rotation of the first metatarsal and propose a new paradigm that considers frontal plane rotation of the first metatarsal as a priority in choosing the most appropriate procedure for bunion correction.

The purpose of the present report was to review the publications regarding the frontal plane position of the first metatarsal, sesamoid alignment, and current paradigms of preoperative bunion evaluation and to illustrate our experience with the effect of frontal plane rotation on the first metatarsophalangeal joint (MTPJ) and sesamoid apparatus. The present analysis also allows comparison with popular metatarsal osteotomy procedures, highlighting what we believe are major shortcomings in the common paradigm for bunion correction. Our intent is to spark discussion, debate, and research that will ultimately lead to improved outcomes and reduced complications in bunion surgery.

Obtaining satisfactory alignment and achieving a lasting correction are 2 primary goals of any deformity correction procedure. The most common paradigm in bunion surgery relies on ≥1 metatarsal osteotomies to correct the intermetatarsal angle (IMA) and soft tissue balancing to align the first MTPJ. That >100 corrective options have been studied and recommended for hallux abducto valgus (HAV) correction indicates a deficiency in our thought process and our approach to bunion correction. We believe that successive or repeated minor modifications of metatarsal osteotomy surgical techniques do not represent innovation. Instead, the need for repeated minor modifications of this common technique indicates a flaw in the basis of both the understanding of the pathology and the technique used to correct it (i.e., a failure of the basic paradigm). The sheer number of procedure modifications proposed over many decades for sliding metatarsal osteotomies fits this reasoning of a failed paradigm. Innovation requires a change in the thought process and approach to the problem, rather than repeated modifications of an existing technique.

If one examines the multitude of metatarsal osteotomy designs, it is clear that the correction provided has been limited to the transverse or sagittal planes, regardless of the geometry of the cut, the fixation selected, or the associated soft tissue balancing. Examination of the published data reveals the clear and consistent presence of metatarsal

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frontal plane rotation associated with a bunion deformity. From these facts, it stands to reason that innovation must also include a frontal plane component of the metatarsal position in bunion deformity correction.

Just as with all complex problems, the best solution will address the primary etiology of the issue. In the case of a bunion, the primary etiology is the deformed anatomy or the level of deformity. The common and popular metatarsal osteotomy procedures do not address the true deformity, which is a triplanar deformity at the metatarsal cuneiform level. Instead these popular procedures have focused correction on a nondeformed metatarsal with the singular priority of reducing the IMA. Correction with a metatarsal osteotomy almost always requires significant additional attention to MTPJ realignment through soft tissue balancing, and, in some cases, additional osteotomies of the metatarsal and hallux. This paradigm of metatarsal osteotomy and soft tissue balancing has been so commonplace, any argument for a fundamental change to the approach becomes uncomfortable and seems unwarranted to most foot and ankle surgeons. However, from the published research and our experience, we propose a new paradigm for the management of bunion deformities that considers the complex multiplanar relationships of the first metatarsal, cuneiforms, and first MTPJ.

First, we must discuss the level of the deformity. The level of deformity in a bunion and, therefore, the choice of procedure for correction can be answered by a detailed analysis of the anatomy. This new thought process involves using the center of rotation of angulation concept described by Paley (1). Using this accepted deformity mapping concept, we find the level of deformity at the metatarsal cuneiform joint (Fig. 1). This level has consistently been noted by other surgeons (2–5). We also must recognize that frontal plane rotation of the first metatarsal will be present in a bunion deformity. This frontal plane component has a significant and dramatic effect on the alignment of the first MTPJ, including the sesamoids. The position of the metatarsal in a bunion deformity has been studied, and a consistent pronation or valgus position has been noted (6–12). Recent studies have observed the importance of reducing the valgus (pronated) frontal plane component of the metatarsal in the deformity and the effect this derotation can have on MTPJ and sesamoid alignment (10–12). These reports have presented the radiographic observations obtained from anteroposterior (AP) projections and confirmed the reduction in the hallux abductus angle (HAA), proximal articular set angle (PASA), tibial sesamoid position, and lateral roundness of the metatarsal head by incorporating supination or varus rotation of the first metatarsal. The most commonly accepted paradigm for correction of the sesamoid position relies on metatarsal and, to a lesser extent, hallux osteotomies to reposition the metatarsal head over stationary sesamoids in conjunction with capsular release and/or plication to reposition the sesamoids under the metatarsal head. This thought process treats the deformity as a uniplanar transverse plane deformity and ignores the existence of frontal plane metatarsal rotation.

From our observations and the available data, we believe the tibial sesamoid position is at least partially an observation of metatarsal frontal plane rotation, rather than solely an observation of a deviated transverse plane metatarsal position (13–17). In reality, both frontal plane rotation and transverse plane deviation of the first metatarsal produce the anatomic components of the bunion deformity; therefore, the 2-dimensional radiographic findings are based on this 3-dimensional deformity.

From this anatomic analysis, we call into question the efficacy of metatarsal osteotomies coupled with soft tissue procedures to accurately, consistently, and permanently align the sesamoids when the pathologic frontal plane position is not addressed.

Valgus Position of Metatarsal

Frontal plane pronation or a valgus position of the hallux in a bunion deformity is readily accepted, clinically observable, and reflected in the term “hallux abducto valgus.” Less accepted in foot and ankle surgery, and less clinically observable, is the frontal plane position of the metatarsal in a bunion deformity. In 1980, Scranton and Rutkowski (6) reported a study in which they used sesamoid axial radiographs to observe the position of the metatarsal in a control group and a group with bunion deformities. Their study found that the feet with bunions had a mean 14.5° of metatarsal pronation, or

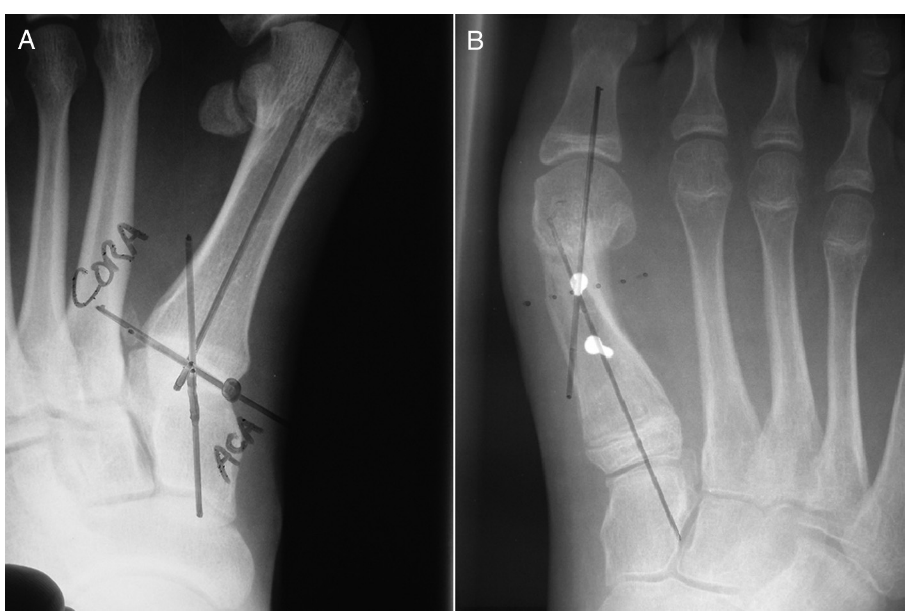

Fig. 1. (*A*) An anteroposterior radiograph of a foot with a bunion. The center of rotational angulation is identified at the point at which the anatomic axes cross and identifies the level of the deformity. (*B*) A radiograph of a foot that received a metatarsal osteotomy to correct a bunion deformity. The correction did not occur at the center of rotational angulation; rather, a secondary deformity was introduced into the metatarsal, creating an additional center of rotational angulation in a metatarsal with no previous deformity.

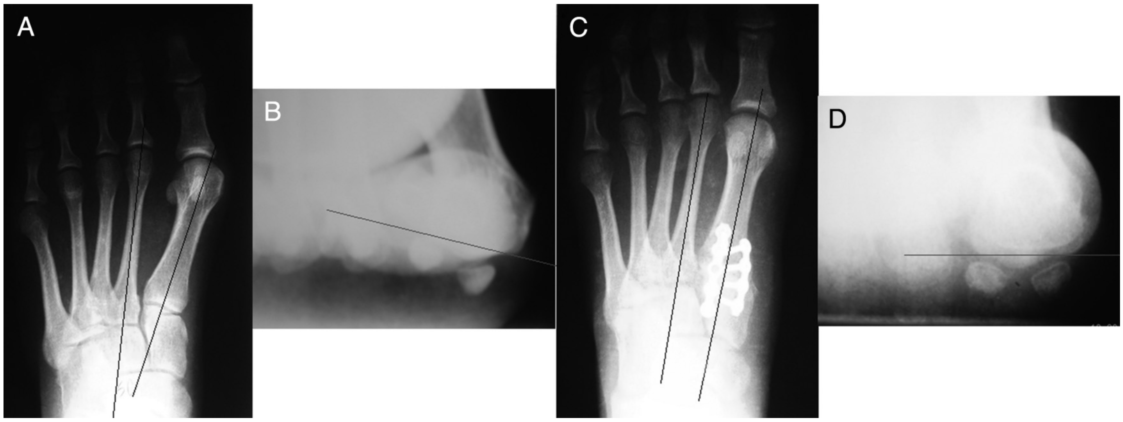

Fig. 2. (*A*) The transverse plane deviation of the metatarsal observed on an anteroposterior radiograph. (*B*) The frontal plane rotation of the metatarsal observed on a sesamoid axial radiograph. Both adduction of the metatarsal and the valgus (pronated) frontal plane rotation are anatomic components of a bunion. (*C* and *D*) Correction of the transverse plane and frontal plane aspect of the deformity, with resultant realignment of the sesamoids, without soft tissue balancing.

valgus position, and the normal feet had a mean 3.1° metatarsal valgus position. They concluded that the 3 structural deformities present in a bunion must be corrected: the abducted hallux, adducted metatarsal, and pronated or valgus metatarsal. Mortier et al (2) in 2012 also used sesamoid axial radiographs to observe the position of the metatarsal in a bunion deformity (Fig. 2). Their novel method of both patient positioning and measurement showed a mean 12.7° of metatarsal pronation in feet with bunion deformities. They concluded this rotation was due to metatarsal cuneiform instability rather than torsion of the metatarsal shaft and that valgus metatarsal rotation in bunion deformities is systematic. Grode and McCarthy (7) studied a similar view of the foot, but using cryomicrotomy rather than radiographs. They sectioned cadaveric feet in multiple planes and at multiple levels in varying degrees of bunion severity. Their observations included that, in a bunion, the position of the medial eminence or bump actually represents the dorsomedial surface of the head of the first metatarsal that is “brought into prominence by rotation through eversion” (Fig. 3). The frontal plane sections confirmed a metatarsal head in eversion, a term synonymous with both pronation and valgus in the published data.

Eustace et al (8) departed from the frontal plane view and instead devised a method to measure the pronation of the first metatarsal based on the observation of the location of the inferior proximal tuberosity of the first metatarsal base. The lateral translocation of the tuberosity that occurs with metatarsal pronation or a valgus position was established in a cadaveric study. Once quantified, it was applied to a clinical study of bunion and normal feet. They found that the degree of first metatarsal pronation has a linear relationship to the amount of medial deviation of the first metatarsal. They concluded that derotational surgical procedures should be explored further (8). The purpose of their report was observation of the position, not correction.

Correction of Rotation

Correction of the pronated or valgus metatarsal has existed in foot and ankle studies as far back as 1956. Mizuno et al (18) observed the frontal plane position of both the hallux and the metatarsal. They used the term “torsion” to describe the pronation position that the metatarsal assumes as it moves medially. They also proposed a derotational

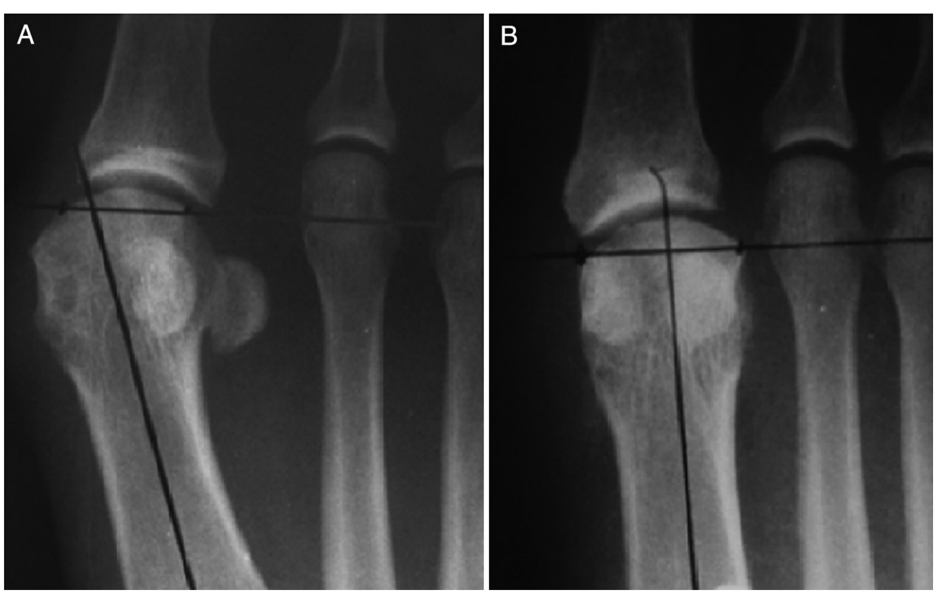

Fig. 3. (*A*) A preoperative weightbearing anteroposterior radiograph. (*B*) A postoperative weightbearing anteroposterior radiograph after first tarsal metatarsal arthrodesis with rotational correction in which no resection of the medial eminence occurred. Correction of the metatarsal's valgus (pronated) position reduces the prominence of the dorsomedial aspect of the metatarsal head.

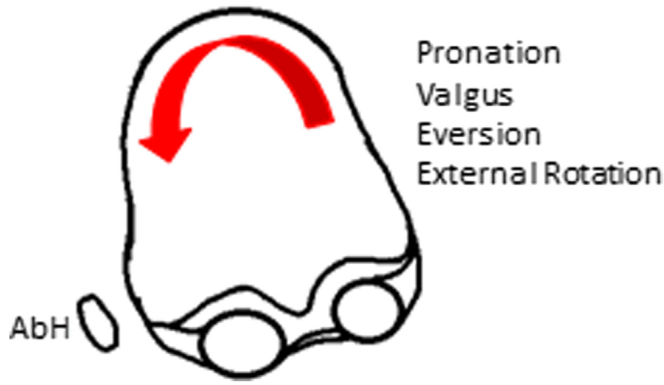

Fig. 4. Various terms have been used to describe the frontal plane position of the first metatarsal in a bunion deformity. Dayton et al (19) discussed the semantic stumbling blocks that can make communication difficult owing to the varied terminology in a report published in 2014. Pronation, eversion, external rotation, and valgus are used to describe the same position and are all correctly used to describe the same first metatarsal motion or position, dependent on training background and geographic convention. The direction of rotation associated with these terms is depicted. Supination, inversion, internal rotation, and varus are used to describe rotation in the opposite direction.

osteotomy of the first metatarsal, termed a "detorsional osteotomy" in their report (18). The report by Mizuno et al (18) highlights a difficulty found in reading about the rotational position across the published data. This difficulty lies in the variety of terms used to describe the same pathologic position. One reason the studies by Mizuno et al (18) and others have been overlooked is that the terms used are either unfamiliar or have been defined differently by foot and ankle surgeons, depending on geography and training. We presented an analysis of anatomic nomenclature in 2014 (19) in an attempt to overcome this semantic stumbling block. In our report, the history of terminology was laid out, equivalent terms were described, and new nomenclature intended to add clarity was proposed. Regarding the metatarsal rotational position, one should read the terms "pronation," "valgus," "eversion," and "external rotation" as equivalent (Fig. 4). Likewise, the terms "supination," "varus," "inversion," and "internal rotation" are equivalent. The term "hallux abducto valgus" with metatarsus primus adducto valgus is used to describe the multiplane deviation of both the hallux and the metatarsal segments within the deformity. This term is also consistent with the known position of both the hallux and the metatarsal in a bunion.

Correction of the frontal plane valgus (pronation) aspect of a bunion deformity is still uncommon, although multiple reports have recently been published. In 2013, Dayton et al (10) reported a case series of 25 procedures in which rotational correction was incorporated as part of a modified Lapidus procedure. The addition of rotational correction to the Lapidus procedure resulted in a decrease of the IMA but also significant decreases in the HAA, PASA, and sesamoid position achieved without capsular balancing. Other studies have supported the findings from Dayton et al (10) on the effect of frontal plane rotation on the PASA. These studies showed that increasing the valgus frontal plane position (pronation) of the first metatarsal increases the measured distal metatarsal articular angle or PASA (20,21). In 2014, DiDomenico et al (11) described their procedural approach to multiplanar bunion correction using the hallux to drive derotation of the valgus metatarsal by way of ligamentotaxis. Because the hallux was moved in a supinated or varus direction, the metatarsal followed. This, in turn, aligned the metatarsal phalangeal joint, reducing the HAA, PASA, and sesamoid position. Neither DiDomenico et al (11) nor Dayton et al (10) included resection of the medial eminence in their procedures. In a study regarding the medial eminence, Thordarson and Krewer (22) observed that when

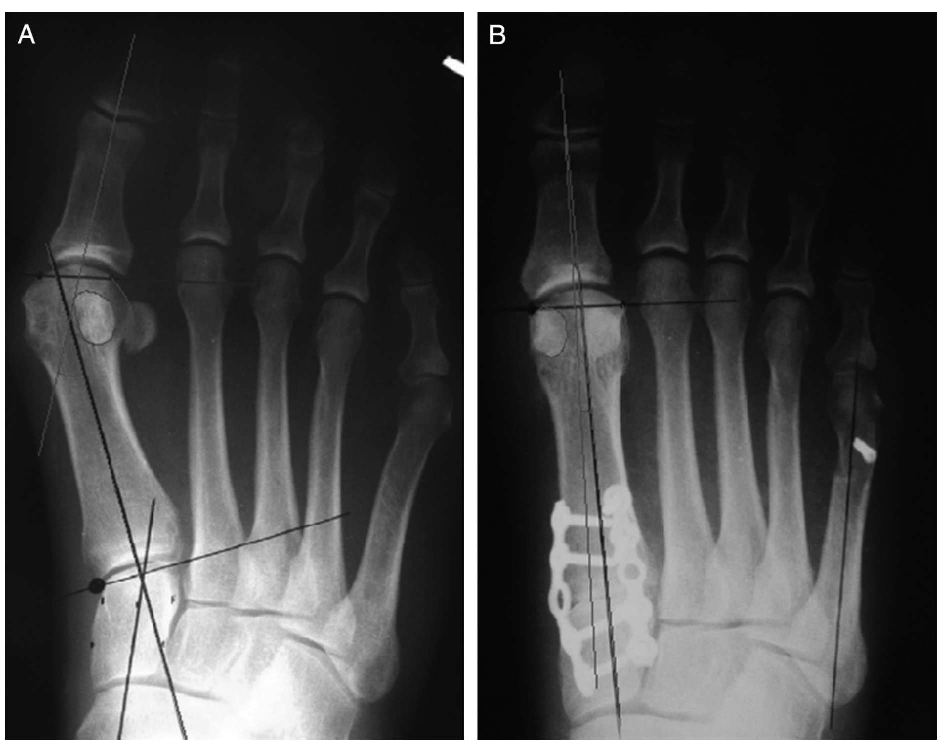

Fig. 5. (*A*) A preoperative anteroposterior weightbearing radiograph. Note the hallux abductus angle, sesamoid position, prominence of the medial eminence, and observable roundness of the lateral metatarsal head. (*B*) A modified Lapidus procedure with transverse plane correction and rotational correction performed at the center of rotational angulation. No deformity was identified within the metatarsal. Observe the change in joint alignment, sesamoid position, prominence of the medial eminence, and shape of the lateral metatarsal head. Capsular balancing was not performed to produce this result.

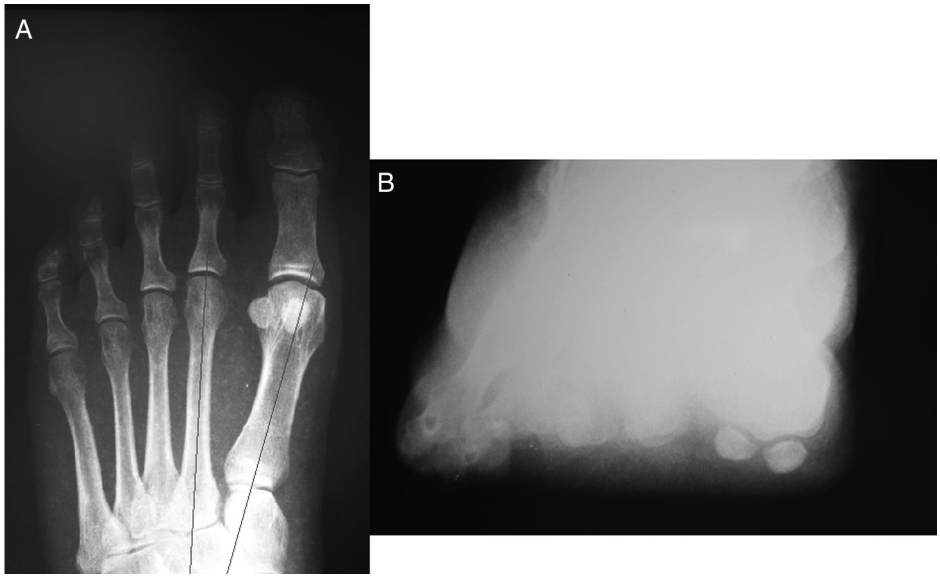

Fig. 6. (*A*) Weightbearing anteroposterior radiograph showing a tibial sesamoid position of 5. (*B*) Sesamoid axial radiograph showing the sesamoids in correct anatomic position residing in their articular grooves on either side of the median crista. The sesamoid position on the anteroposterior radiograph is not indicative of the true sesamoid position owing to the altered perception that the valgus (pronated) metatarsal rotation imparts.

comparing bunion and normal feet, no statistically significant difference was present at the eminence. They concluded that if the goal of bunion surgery is to reconstruct the normal anatomy, medial eminence resection does little to help (22).

In 2013, Okuda et al (12) described a proximal abduction supination osteotomy of the first metatarsal. Again, the term "supination," as part of the crescentic osteotomy they performed, is synonymous with the terms "varus" and "inversion." They found rotational correction produced a significant effect on the distal joint, including the HAA and the sesamoid position. They also pointed out the changes in the appearance of the lateral aspect of the metatarsal head that occur when valgus rotation is addressed. In a foot with a bunion, the lateral and plantar aspect of the metatarsal head creates a rounded appearance as the metatarsal assumes a valgus (pronated) position. With their procedure, this roundness is decreased. Previous studies by Okuda et al (23,24) showed that this lateral round sign and incomplete reduction of the sesamoids are associated with the risk of recurrence (Fig. 5).

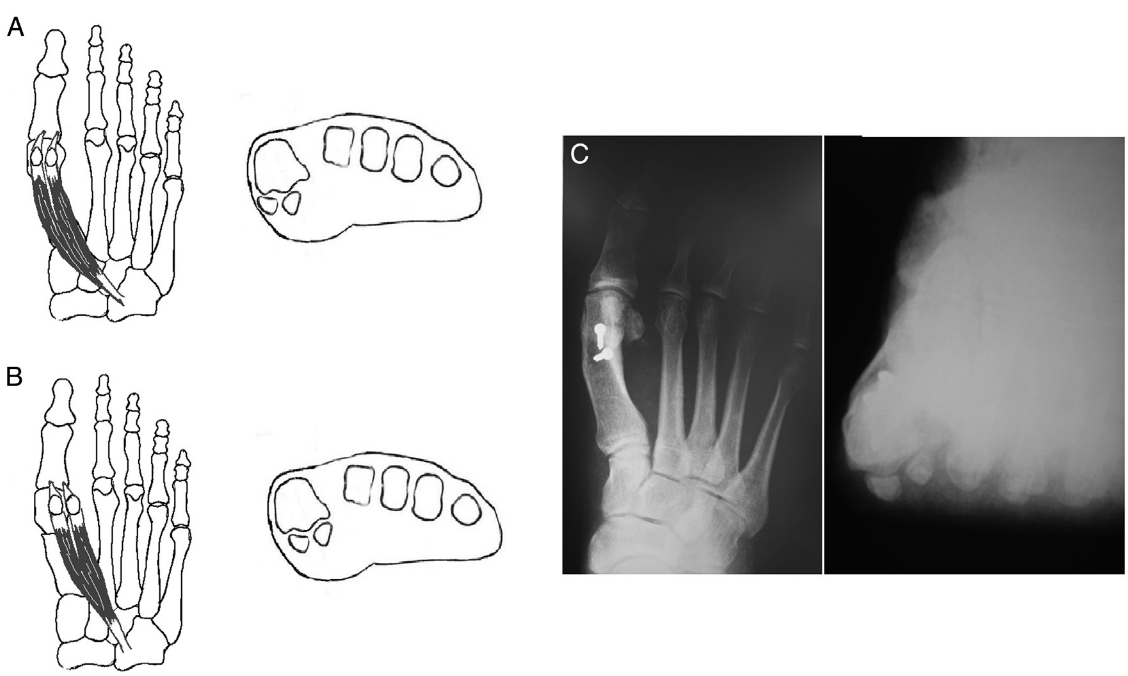

Fig. 7. (*A*) A depiction of medial iatrogenic sesamoid subluxation after soft lateral release and capsular plication. The sesamoids will appear corrected on anteroposterior (AP) radiographs. (*B*) A depiction of the short flexor tendons resuming their linear pull and bringing the sesamoids back into their anatomic position under a pronated or valgus metatarsal head. This gives the AP radiograph an appearance of subluxation owing to the pronated metatarsal head. (*C*) A chevron osteotomy with AP and sesamoid axial radiographs obtained 4 years after the procedure. The appearance of sesamoid subluxation on the AP radiograph is not indicative of the true sesamoid position when axial radiographs are assessed.

Fig. 8. (*A* and *B*) Two cases in which chevron osteotomies were performed. Note the preoperative sesamoid deviation indicative of metatarsal pronation or valgus rotation. Early postoperative films show the sesamoid position under the metatarsal head. Because it is not possible to purposefully address valgus (pronation) rotation in the transverse plane with a sliding osteotomy, either iatrogenic subluxation by lateral release with medial capsular placation or spontaneous derotation has altered the observed sesamoid position. During the course of each case, the sesamoids returned to their anatomic position owing to the linear pull of the plantar soft tissues and the everted (pronated) first metatarsal. The return of the sesamoids under the metatarsal head re-establishes the appearance of subluxation on the AP radiographs and results in a risk of bunion recurrence. Note the increase in the true intermetatarsal angle from immediately postoperatively to the final follow-up radiograph, which likely resulted from the lateral deviation of the soft tissues pulling the hallux into valgus and exerting a medial force on the first metatarsal, resulting in a recurrence of the high IMA. In the second case, a sesamoid axial radiograph was obtained during the follow-up period. The axial image shows a residual frontal plane pronation or valgus position present.

AP Radiograph Deficiency

A correlation exists between the degree of the displacement of the sesamoid bones observed on AP radiographs and the severity of the bunion deformity (25,26). Discussion of this correlation often includes that a constant position of the sesamoids exists in relationship to the second metatarsal (27–30) and the proximal phalanx to the second metatarsal (3). The constant relationship of the sesamoid position in the transverse plane lends itself to a proposed process in which the first metatarsal deviates medially off a stable and stationary sesamoid apparatus that is tethered in place by ligamentous and tendon attachments. However, the appearance of the sesamoids on the AP radiograph is not indicative of their actual position in relation to the median crista and the bisection of the metatarsal shaft through the median crista. Frontal plane rotation of the first metatarsal alters what will be seen on the AP radiographic projection (Fig. 6).

The pronated or valgus position of the metatarsal gives the appearance that the metatarsal head has migrated off the sesamoid complex and that the fibular sesamoid resides in the interspace. Inman (14) used a combination of models and radiographs to show that in a valgus or pronated metatarsal, the sesamoids appear to deviate laterally on an AP radiograph. However, a comparison of the sesamoid axial radiographs with their AP counterparts showed the sesamoids are still found in their anatomic positions (in their grooves and separated by the median crista), despite their appearance of lateral translocation. Boberg and Judge (15) made the same observation in a report on bunion correction without interspace release. In most cases they reviewed, the preoperative AP radiographs showed apparent deviation of the sesamoids, although the sesamoid axial radiographs failed to confirm the sesamoid displacement. One explanation offered is that the apparent subluxation of the sesamoids results from an oblique rotation of the metatarsal head, much the same as a lateral oblique radiograph shifts the perspective, making the structures appear more laterally than is the case. They also called into question the use of AP radiographic sesamoid measurement as a tool of bunion assessment.

Talbot and Saltzman (16) came to the same conclusion regarding the use of AP radiographs to evaluate sesamoid subluxation. They found that the sesamoid position, as estimated from the AP radiographs, did not correlate with the actual sesamoid position when viewed using a *tangential view,* a term synonymous with *sesamoid axial.* The difference between the observations could not be accounted for by a change in MTPJ positioning when obtaining the sesamoid axial view. Because of the valgus (pronated) position of the metatarsal, the AP radiograph-based measurement models are not valid in assessing true sesamoid position. These studies have been

Fig. 9. (*A* and *B*) A Lapidus procedure was performed by 1 of us (P.D.) in which the valgus or pronated position of the metatarsal was addressed. Note the change in the sesamoid position and the lateral roundness of the metatarsal head, both indicative of a valgus metatarsal position and both risk factors for bunion recurrence.

corroborated by a cadaveric study by Dayton et al (13), in which the first tarsal metatarsal joint was freed and the metatarsal was placed in various degrees of inversion and eversion. With eversion (pronation) of the metatarsal, there was the appearance of lateral displacement of the sesamoids on the AP radiograph. With inversion (supination), the apparent position was corrected. The metatarsal did not move off the sesamoid apparatus; rather, rotation altered what could be observed on the AP radiographs.

Knowing the difficulty in assessing the sesamoid position from an AP radiograph, Kuwano et al (31) devised a measurement used to observe the sesamoid position on tangential or axial radiographs. Not only did they find a correlation with the degree of HAV and the valgus (pronated) position of the sesamoid apparatus, they also found that the AP assessment of sesamoid subluxation was inadequate to assess the true sesamoid position (31). These results also corroborate the observations from Dayton et al (13), DiDomenico et al (11), and Okuda (12) that varus (supination) rotation imparts correction of the sesamoid position on AP radiographs when the frontal plane valgus (pronated) position of the metatarsal is addressed.

Deficiency of Metatarsal Osteotomies

If the pronated or valgus metatarsal is the primary reason for the perceived deviation of the sesamoids, what really occurs with transverse plane translational osteotomies that produce alignment of the sesamoids immediately after the procedure? In the case of a sliding osteotomy that corrects the IMA but cannot produce varus (supination) rotation to correct the frontal plane position of the metatarsal in a bunion, we hypothesize that iatrogenic subluxation of the sesamoids medial to the median crista has created the perception that the sesamoids are correctly positioned under the metatarsal on the AP radiograph. This occurs after the lateral release and during the medial capsular plication. An additional explanation is that in some cases a degree of frontal plane correction occurs spontaneously when retrograde buckling forces of the hallux acting on the metatarsal are relieved. If the appearance of the sesamoid correction was iatrogenic medial subluxation, the position on the AP radiograph would not be maintained over time. The sesamoids would appear corrected on the postoperative film solely because of the lateral soft tissue release and medial soft tissue plication. Considering this circumstance, during the ensuing months, the sesamoids would begin to return their anatomic position in the sesamoidal grooves, which are still rotated in a valgus (pronated) orientation. This lateral drift, which is, in reality, a resumption of the normal position, results from the plantar soft tissues, including the short flexor tendons, resuming their linear orientation after joint motion resumes, thereby pulling the sesamoids back to their anatomic location under the metatarsal, which is laterally rotated (Fig. 6). This position relative to an everted metatarsal would mean a displaced appearance of sesamoids on the AP radiograph. Although immediately postoperatively, the sesamoid position would be predictable and within control of the surgeon using soft tissue balancing, long-term maintenance of this position would not be predictable nor under control of the surgeon, because the pathologic position of the metatarsal, causing the appearance of subluxation, has not been addressed. This would also produce deforming forces from the hallux proximal to the metatarsal, because of the lateral position of the sesamoids and tendons, as described by Mortier et al (2) and can result in recurrence of both the HAV and increased IMA (Fig. 7).

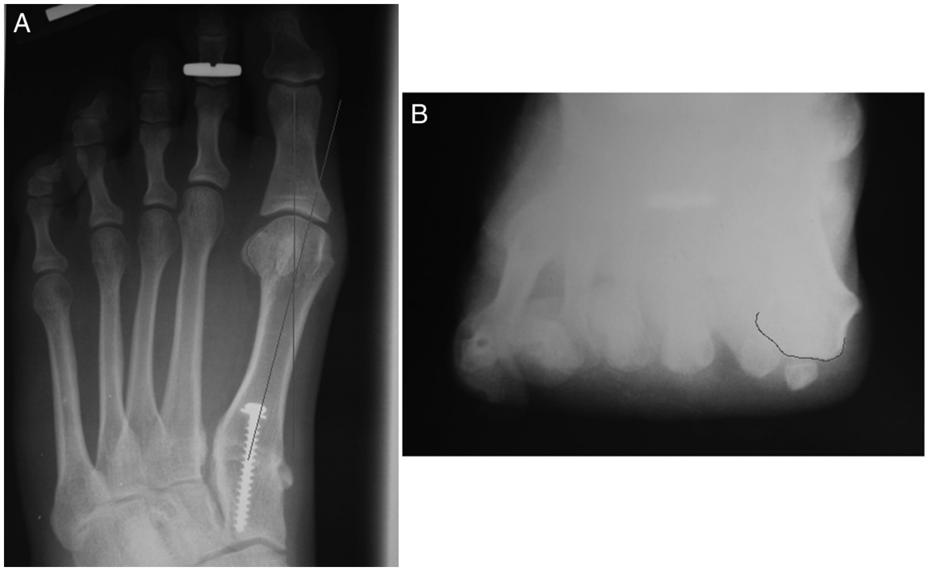

Fig. 10. (*A* and *B*) A Lapidus procedure performed by 1 of us (P.D.) before recognition of the valgus position of the metatarsal in a bunion deformity. The valgus frontal plane position was not corrected. Note that the sesamoid position on the anteroposterior and axial radiographs does not match. The metatarsophalangeal joint is still everted or pronated and not in anatomic alignment despite the intermetatarsal angle correction.

We must also address the convention of the measurement technique of the IMA and the potential inaccuracies that this convention imparts. The current convention for measuring IMA is an angular comparison of the mid-diaphysis line of the first and second metatarsals before the procedure. This is changed after the procedure to measuring the point at the center of the first MTPJ and the center of the metatarsal cuneiform joint (32). The recommended technique for postoperative measurement is a measurement of the mechanical axis of the first ray segment and is not equivalent to the anatomic axis or true IMA. This practice, which is conventional in our current paradigm, should be abandoned for the simple reason that it produces misleading conclusions regarding the true correction provided by metatarsal corrective procedures. If one analyzes the true IMA in many cases of metatarsal osteotomy, using strict deformity correction principles, the true IMA could actually increase when the convention of measuring the mechanical axis shows a decrease (Fig. 8). This practice represents an unacceptable condition of observational bias.

A description of frontal plane rotational changes after biplane procedures has been reported. A decrease in the retrograde buckling force that can occur with biplane correction could cause some spontaneous changes in the frontal plane position of the metatarsal. This could result from first metatarsal cuneiform joint frontal plane instability and motion (2). Boberg and Judge (15) observed this in their cases of chevron osteotomies. As mentioned previously, they observed that preoperative AP radiographs did not match their sesamoid axial counterparts when observing the sesamoid position resulting from frontal plane rotation. They also noted that the

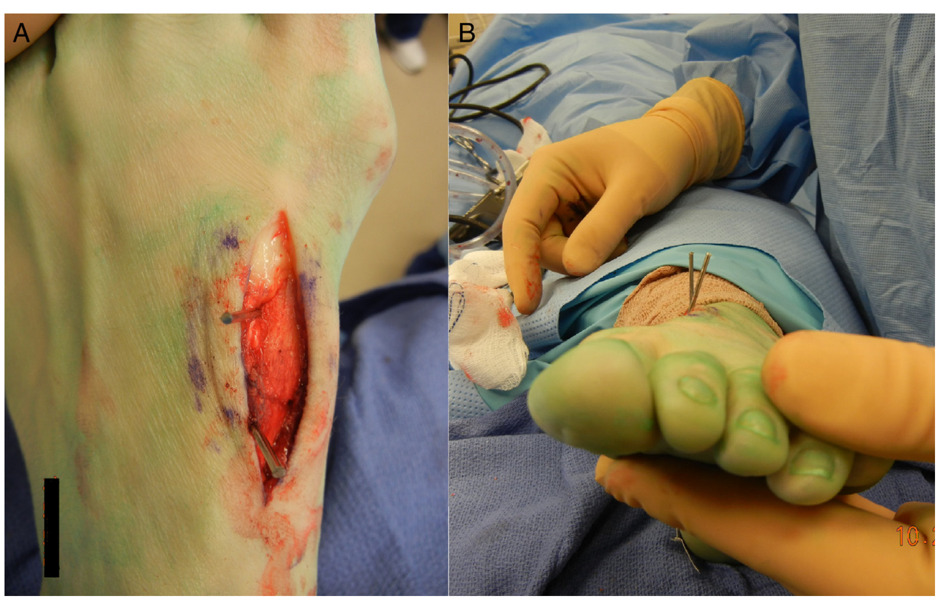

Fig. 11. (*A* and *B*) Two images of a foot that underwent rotational correction as part of a modified Lapidus procedure. The pins seen were placed in line before joint preparation. A varus or supination rotation was imparted to correct the valgus or pronated position of the metatarsal. The resultant orientation of the pins after rotational correction, with the distal pin internally rotated in relation to the proximal pin after varus or supination rotation of the metatarsal to correct the frontal plane position.

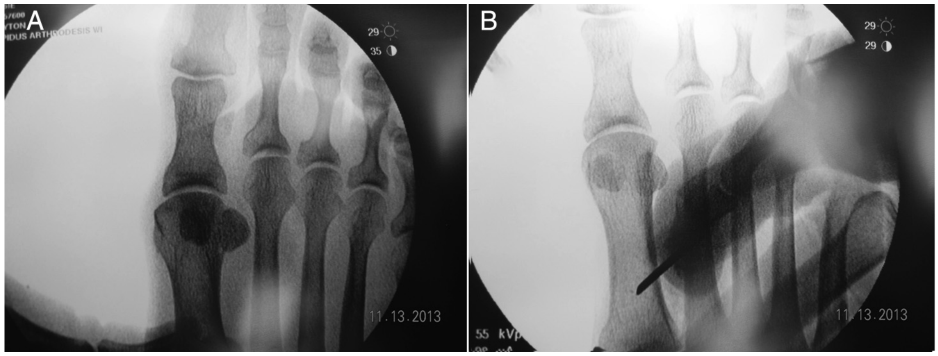

Fig. 12. (*A*) Intraoperative fluoroscopic view with the first metatarsal manipulated into valgus using Kirschner wires, such as shown in Fig. 8, to manipulate the frontal plane position. (*B*) View showing the first metatarsal manipulated in a varus direction with the sesamoid position, the lateral roundness of the metatarsal head, and the hallux abductus angle reduced.

sesamoid to second metatarsal position decreased after their procedure. This is in contrast to other published reports of a constant second metatarsal sesamoid position on AP radiographs. One explanation they offered was that the rotational position of the metatarsal head was altered with their sliding osteotomy and that the change in the distance between the fibular sesamoid and the second metatarsal head was "a rotational radiographic effect rather than a transverse plane deviation" (15). Reliance on this spontaneous frontal plane correction due to retrograde relief is not only unpredictable in the degree of rotational correction obtained, but it is also unpredictable regarding the maintenance of the correction obtained. It is not designed to reduce the frontal plane aspect of the deformity. It cannot correct it permanently, because the apex of rotational instability is the first metatarsal cuneiform joint (2).

Fig. 13. (*A*) Preoperative anteroposterior and sesamoid axial radiographs. (*B*) Postoperative anteroposterior and sesamoid axial radiographs taken 5 months after the procedure. The intermetatarsal angle and sesamoid position were maintained using a first tarsal metatarsal arthrodesis.

Corrections of the valgus (pronated) position of the metatarsal with osteotomies or arthrodesis that impart frontal plane mobility allow the surgeon ultimate flexibility in obtaining complete and consistent deformity correction. The surgeon must be aware of the rotational position of the metatarsal and understand the intraoperative assessment to observe anatomic alignment to "put these ideas into practice." Without knowledge of both the rotational position and the assessment of rotational correction, consistent alignment of the MTPJ during a Lapidus procedure was difficult for us to obtain. At times, the joint was aligned with the sesamoids reduced (Fig. 9). In other cases, IMA correction was achieved, but alignment of the MTPJ was not anatomic owing to failure to address metatarsal rotation (Fig. 10). To assess intraoperative MTPJ alignment, it is helpful to place Kirschner wires in line on each side of the first tarsal metatarsal joint. After the joint is freed and the cartilage and subchondral bone are resected in a manner that corrects the transverse and sagittal plane deformities, the pins will remain the reference point for the direction of rotation and aid in manipulation of rotational correction (Fig. 11).

Under fluoroscopy, the MTPJ can be visualized. When the sesamoids are aligned and the lateral round sign has decreased, one can be confident the MTPJ is in anatomic alignment (Fig. 12). With a first tarsal metatarsal arthrodesis, all components of the deformity can be reduced, giving the surgeon complete control of positioning, including the transverse, sagittal, and frontal plane. Frontal plane rotation aligns both the sesamoids and the sesamoidal grooves, and the potential deforming force vectors are aligned. This represents true triplane anatomic correction (Fig. 13).

In conclusion, HAV with metatarsus primus adducto valgus is a triplane deformity. The frontal plane component of this complex deformity has often been overlooked. With the commonly used sliding osteotomies, complete reduction of the sesamoids is not possible, because the frontal plane rotation cannot be addressed. The sesamoid position perceived on AP radiographs does not reflect the true position of the sesamoids in relation to the median crista and the articular grooves. We must strive to perform procedures that allow the surgeon complete control over both the degree and the maintenance of all planes of the deformity, including the frontal plane and, thereby, the ability to anatomically align the joint and retain that alignment over time without multiple procedures.

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