Observed Changes in First Metatarsal and Medial Cuneiform Positions after First Metatarsophalangeal Joint Arthrodesis

Paul Dayton, DPM, MS, FACFAS1,2, Merrell Kauwe, BS3, John S.K. Kauwe, PhD4, Mindi Feilmeier, DPM, FACFAS5, Jordan Hirschi, BS3

1 UnityPoint Clinic, Trinity Regional Medical Center, Fort Dodge, IA
2 Adjunct Professor, Des Moines University College of Podiatric Medicine and Surgery, Des Moines, IA
3 Pediatric Medical Student, Des Moines University College of Podiatric Medicine and Surgery, Des Moines, IA
4 Department of Biology, Brigham Young University, Provo, UT
5 Assistant Professor, Des Moines University College of Podiatric Medicine and Surgery, Des Moines, IA

A R T I C L E   I N F O
Level of Clinical Evidence: 4
Keywords:
atavism
first ray
fusion
hallux valgus
motion
rotation

A B S T R A C T
The first intermetatarsal angle (IMA) is known to decrease after first metatarsophalangeal joint arthrodesis, although the exact mechanism by which this decrease occurs is not known. We measured the first IMA and obliquity of the medial cuneiform on anteroposterior weightbearing preoperative and postoperative radiographs in 86 feet and analyzed the statistical correlation between the IMA and the medial cuneiform angle. A change in the first IMA after first metatarsophalangeal joint fusion showed a strong positive correlation with a change in cuneiform obliquity (p < .0001). This finding was consistent in the direction and magnitude in each of 3 clinical subgroups: normal, p = .087; moderate deformity, p = .011; and severe deformity, p = .10. A comparison of the preoperative IMA and cuneiform obliquity revealed a trend toward a positive relationship but did not reach statistical significance (p = .08). The preoperative association between the IMA and medial cuneiform obliquity was not significant in any clinical subgroup, and the postoperative association between the IMA and cuneiform obliquity was not significant (p = .65). Clinical subgroup analysis showed no significant association between the IMA and the normal (p = .73) and moderately (p = .69) deformed feet, although the postoperative association between the IMA and cuneiform obliquity in the severely deformed group was significantly (p = .034) positive. A linear relationship between the reduction of the first IMA and medial cuneiform obliquity after metatarsophalangeal joint fusion was observed. Our findings suggest that frontal plane rotation influences cuneiform obliquity.

© 2014 by the American College of Foot and Ankle Surgeons. All rights reserved.

As early as 1882, reports had proposed that the primary level of a bunion deformity resided at the first metatarsocuneiform joint. Researchers have also proposed an association between hallux valgus and the shape of the first metatarsocuneiform joint (1,2). Procedures for the correction of bunion deformities at the first metatarsocuneiform joint were first referenced in 1911 (3) and were later advocated by Lapidus (4). In 1925, Truslow (5) suggested the term metatarsus primus varus to describe the deformity, highlighting the deviation of the first metatarsal medially as the primary concern and not the hallux deviating laterally. A review of these reports suggested that the terminology metatarsus primus varus did not refer to the frontal plane motion, such as it sometimes does today; rather, it meant a first metatarsal that deviated toward the midline of the body (5). This dual interpretation of the term metatarsus primus varus has led to ambiguity when discussing the components of a bunion deformity.

Morton (6) and Lapidus (4) agreed that the evolutionary history of Homo sapiens gave rise to the bunion deformity and cited primate feet with an oblique medial cuneiform and first metatarsal interface as a potential evolutionary cause of hallux valgus deformity. Lapidus (4) compared developing human feet with those of other primates and showed similar cuneiform obliquity in different species. He also noted that the obliquity decreased as a human fetus developed (4); however, in the adult primate, it remained. This “atavistic” or ancestral-type cuneiform with its oblique articulation has been purported to be a predisposing feature to the development of bunion deformity (4,6). Various measurements of this angulation have been made, although no accepted standard has been reported. Several investigators have measured this obliquity in association with bunion deformities, each using different parameters (4–8). Despite descriptions of an
association between an oblique or atavistic cuneiform and a bunion deformity, we have no proof of the exact role that medial cuneiform obliquity plays in the cause or development of the deformity.

The term hallux valgus has also been used to describe the bunion deformity. This terminology was first introduced by Carl Hueter in 1870 (9) and was used to describe a deformity in which the hallux had moved away from the midline of the body. This term is widely used today in describing a bunion deformity and its use implies that the primary deformity resides at the metatarsophalangeal joint (MTPJ). Despite its widespread use and implied understanding, the term hallux valgus fails to fully characterize the 3 planar components of a bunion. Munuera et al (10) found that an abducted hallux preceded an increase in the intermetatarsal angle (1-2 IMA), leading to the conclusion that hallux valgus precedes a medially deviated first metatarsal. Snijders et al (11) used a biomechanical study to measure the force vectors and noted that the motions produced while walking caused the hallux to deviate laterally. They concluded that this force increased the 1-2 IMA. Thus, the hallux valgus caused deviation of the first metatarsal. This relationship was reinforced by reports that showed a reduction in the 1-2 IMA after first MTPJ fusion (12–14). Although not often discussed, frontal plane rotation has also been thought to be a component of hallux abducto valgus and metatarsus primus adductus and has been shown to be a part of the pathologic development of bunion deformities (15–17). Additionally, rotation has been shown to have an influence on the radiographic appearance of medial cuneiform obliquity (7). Furthermore, valgus metatarsal rotation has been shown to be an element in the correction of a bunion deformity (18).

Thus, it is clear that a variety of terms and concepts have been used to describe the bunion deformity but that no consensus has been reached regarding the etiology and progression of the deformity. The aim of the present investigation was to quantify the medial cuneiform obliquity before and after first MTPJ fusion. We hypothesized that if the oblique cuneiform were a predisposing factor in the development of a bunion deformity, its atavistic appearance would remain constant as the first IMA decreased after first MTPJ fusion owing to the forces of the hallux acting on the nonrigid first ray. These forces are relieved by MTPJ release and realignment, such that spontaneous frontal plane derotation of the first ray occurs, along with a reduction of the first IMA, thereby altering the radiographic appearance of the obliquity of the cuneiform.

Patients and Methods

A nonconsecutive sample of radiographic records that included only those patients who had undergone first MTPJ fusion for correction of pathologic features of the first ray were retrieved from the database of the senior author’s (P.D.) practice. The radiographs pertained to patients who had undergone first MTPJ fusion between June 2008 and June 2012 and were identified by searching the electronic records for procedure code 28750. These radiographs were reviewed, and the final cases for inclusion were selected only by the completeness of the radiographic records and evidence of isolated first MTPJ fusion. No clinical selection criteria such as patient health, preoperative complaint, surgical indications, or operative outcome were considered. The Des Moines University institutional review board approved the records review.

The senior author (P.D.) performed the measurements for the first IMA and the medial cuneiform angle. Measurement of the first IMA was consistent with that described by Gerbert (19). The obliquity of the first cuneiform bone was defined by drawing 3 lines: line A, formed by taking the most proximal medial point of the medial cuneiform and drawing a line connecting it with the most distal medial point of the medial cuneiform; line B, formed by drawing a line connecting the medial and lateral points at which the cuneiform articulates with the first metatarsal, which serves as the 2nd arm of the angle measuring the obliquity of the first cuneiform; and line C, formed by drawing a line perpendicular to line A, serving as the 2nd arm of the angle (Fig. 1).

The full data set was analyzed using linear regression to evaluate the relationship between (1) the preoperative first IMA and preoperative cuneiform obliquity, (2) the postoperative IMA and postoperative cuneiform obliquity, and (3) the preoperative to postoperative change in the IMA and cuneiform obliquity. The data were then stratified into 3 groups of preoperative IMA values according to the following radiographic definitions: normal, represented by an IMA of 0° to 10°; moderate, represented by an IMA of greater than 10° to 15°; and severe, represented by an IMA of greater than 15°. These strata were selected because they represented clinically significant differences in the hallux valgus deformity. The stratified data were then analyzed using linear regression as described to investigate the differences in these relationships among clinically relevant preoperative IMA classes. The statistical analyses were performed by J.S.K.K. using IBM SPSS Statistics for Windows, Version 19.0, data analysis software (IBM, Armonk, NY), and statistical significance was defined at the 5% (p ≤ .05) level.

Results

Of the 107 potentially eligible sets of radiographs, 86 met our inclusion criteria and were included in the analyses. The mean values and standard deviations for the measurements in our 86 samples are presented in the Table. The change in the IMA showed a strong
An analysis of the clinical subgroups of the association was not significant in any of the clinical subgroups. We failed to detect a statistically significant association between the postoperative IMA and postoperative cuneiform obliquity ($p = .08$; Fig. 3). The postoperative IMA and preoperative cuneiform obliquity association was not significant in any of the clinical subgroups. We believe it is likely that the change in cuneiform obliquity is caused by a change in the foot position because no surgical manipulation of the joints proximal to the first metatarsophalangeal joint was undertaken in the patients. We analyzed radiographically, the changes we observed did not appear to have resulted from the intrinsic shape of the cuneiform but, instead, appeared to have resulted from positional differences in the relative projection of the anteroposterior radiographs. As noted, we believe the changes in cuneiform obliquity and changes in the first IMA are not explained by spontaneous transverse and frontal plane rotation of the first ray, which occurs after the distal deforming forces have been relieved (and the first MTPJ fused). It has been shown that movement of the first ray occurs in all 3 cardinal planes of the foot, including the frontal plane, and this rotation affects the radiographic appearance of hallux abducto valgus deformities. The effect of positional changes in the first ray on the perceived atavism of the cuneiform was noted in 2002 when Sanicola et al. (7) found that dorsiflexion, plantarflexion, inversion, and eversion of the first ray all changed the apparent obliquity. Ebisui (15) noted correlation of metatarsal frontal plane rotation and the radiographic appearance of feet with hallux valgus and stated that this rotation might be an important part of the pathomechanics of a bunion deformity. Although conflicting reports exist regarding the direction of motion of reduction that is normally expected. Thus, release of the deforming forces induced by the laterally deviated hallux pushing the first metatarsal medially seems to allow spontaneous movement of the first ray in both the transverse and frontal planes. There could also be sagittal plane motion; however, we had no reference for measurement of this in our study.
the first ray in normal feet and in those with bunion deformities, 
frontal plane eversion of the first ray has been consistently reported 
(14,16,17,19). Scranton and Rutkowski (16) showed an average of 14.5° 
of eversion of the first ray in deformed feet and a 3.1° average of 
everson in normal feet. Recently, Dayton et al (18) showed that 
metatarsal eversion was a component of hallux abducto valgus and 
metatarsus primus adductus and that rotational correction of meta-
tarsal eversion at the TMTJ is an important component of anatomic 
reduction of hallux abducto valgus deformity. 

Additional analysis of the data from our clinical series showed a 
linear relationship between preoperative IMA and preoperative 
medial cuneiform angle; however, in our series, this association did 
not reach statistical significance. This finding was also observed in our 
3 clinical subgroups (IMA of 0°–10°, 11°–15°, >15°). It is unclear why 
the changes in the preoperative and postoperative angles showed 
strong linear correlations, but the preoperative association did not 
reach statistical significance. Our study was not able to significantly 
confirm statistically the hypothesis that cuneiform obliquity and an 
increased IMA occur concurrently before first MTPJ fusion. This might 
have been because our data set lacked a sufficient number of foot 
radiographs with either a low or high first IMA (type 2 statistical 
error). Alternatively, a larger sample of normal and abnormal feet 
might have been needed to clarify the exact relationship between 
hallux abducto valgus and cuneiform obliquity. An interesting study 
would be to quantify the relationship between cuneiform obliquity 
(atavism) and hallux abducto valgus, which has been commonly 
stated as fact but has had minimal supporting data. We hypothesized 
that the preoperative cuneiform angle is related to some other factor 
beyond the actual cuneiform shape (i.e., atavism). This might be 
related to a combination of frontal, sagittal, or transverse plane mo-
tion of the first ray, including motion of the medial cuneiform. 

In addition to the type 2 statistical error, other limitations of this 
observational investigation included possible inconsistencies in the 
study population, because we selected nonconsecutive primary first 
MTPJ fusions from a single practice setting. Since we were not testing 
a therapeutic or diagnostic intervention and simply observing a 
potential association we feel that use of non-consecutive patients 
would be to quantify the relationship between cuneiform obliquity 
and hallux abducto valgus, which has been commonly 

References

1. LeBoucq H. Le developpement du premier merararsien et de son articulation 
4. Lapidus PW. The operative correction of metatarsus primus varus in hallux valgus. 
1925. 
6. Morton DJ. Metatarsus atavicus: the identification of a distinctive type of foot 
7. Sanicola SM, Arnold TB, Osher L. Is the radiographic appearance of the hallucal 
tarsometatarsal joint representative of its true anatomical structure? J Am Podiatr 
8. Tanaka Y, Takakura Y, Kuma T, Samoto N, Tamai S. Radiographic analysis of hallux 
10. Munuera PV, Dominequez G, Polo J, Rebollo J. Medial deviation of the first meta-
11. Snojders CJ, Snijder JL, Philppiens MM. Biomechanics of hallux valgus and spread 
metatarsophalangeal joint arthrodesis for hallux valgus. Foot Ankle Int 27:104– 
109, 2006. 
13. Mann RA, Katcherian DA. Relationship of metatarsophalangeal joint fusion on the 
metatarsophalangeal joint arthrodesis in patients with moderate and severe 
15. Ebisu JM. The first ray axis and the first metatarsophalangeal joint: an anatomical 
17. Grode SE, McCarthy DJ. The anatomical implications of hallux abducto valgus: a 
18. Dayton P, Feilmeier M, Kauwe M, Hirsch J. Relationship of frontal plane rotation of 
first metatarsal to proximal articular set angle and hallux alignment in patients 
undergoing tarsometatarsal arthrodesis for hallux abducto valgus: a case series 