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

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ABSTRACT

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.

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

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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 tarsometatarsal joint (TMTJ) was assessed using 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 first 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 second 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% ($p \leq .05$) 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

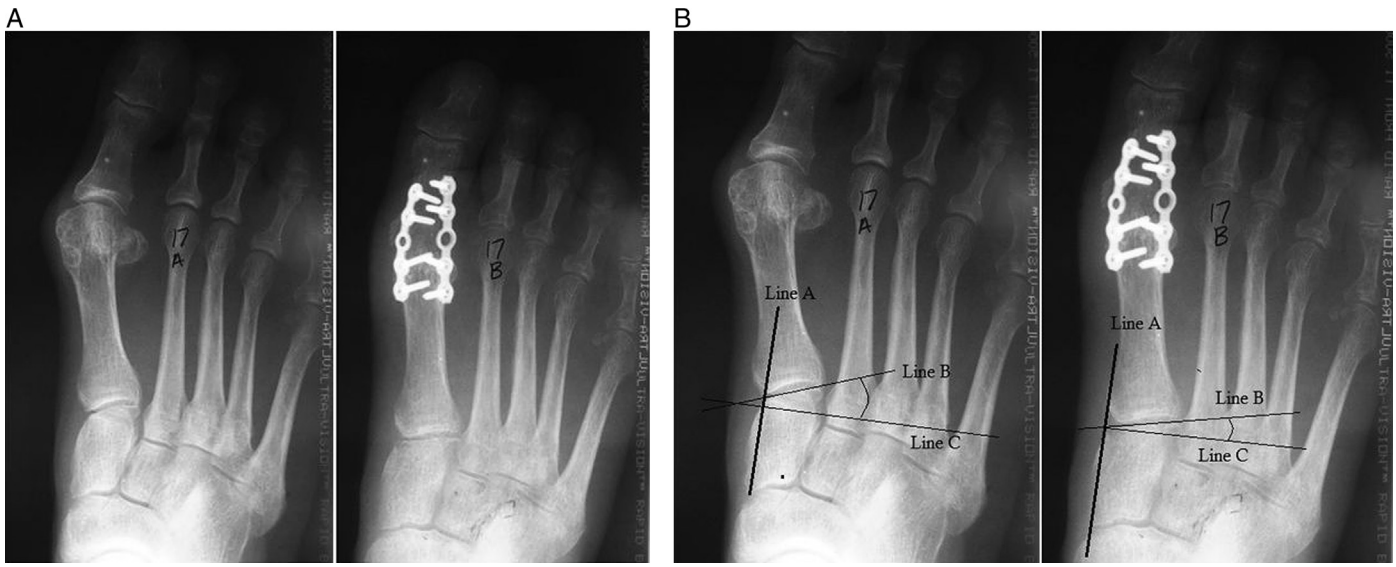

Fig. 1. Metatarsophalangeal joint fusion. Preoperative and postoperative views. (*A*) Preoperative and postoperative anteroposterior radiograph of foot with hallux valgus and metatarsus primus varus. (*B*) Preoperative and postoperative anteroposterior radiographs with lines drawn for measurement of cuneiform obliquity. Line A connects the most proximal medial and most distal medial points of the medial cuneiform. Line B connects the lateral and medial points of the first metatarsal medial cuneiform articulation. Line C is perpendicular to Line A. The angle measured is between Lines A and C.