Radiographic Assessment of Relationship between Medial Cuneiform Obliquity and Hallux Valgus

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Authors’ contributions

PFB and YQX contributed to the conception and design of the study; XYM, CL and XHM collected of the data; PFB and LQP analysesed, and interpretation of the data; PFB wrote the manuscript.; All authors read and approved the final manuscript.

Abstract

The research results are inconsistent that assessing whether the increased obliquity of the distal articular surface of the medial cuneiform leads to an increase in hallux valgus angle. Thus, this study investigated the relationship between distal medial cuneiform obliquity and hallux valgus by measuring various angles in weight-bearing anteroposterior radiographs of the foot. In total, 679 feet of 538 patients with the radiographs were included in the study. We measured radiographic parameters including hallux valgus angle, 1st-2nd intermetatarsal angle, metatarsus adductus angle, first metatarsus cuneiform angle, distal medial cuneiform angle, and first proximal metatarsal articular angle were measured. The surface morphology (flat or curved) of the first tarsometatarsal joint was also recorded. Our results analysis revealed a weak negative correlation between distal medial cuneiform angle and both hallux valgus angle and 1st-2nd intermetatarsal angle, contrary to our assumption. So we believe that distal medial cuneiform angle was relatively constant and it cannot be used as a characteristic angle for quantifying hallux valgus. first metatarsus cuneiform
angle was a characteristic indicator of hallux valgus and was positively correlated with its severity \( p < .000 \), indicating that it can be used to measure the size of hallux valgus. It can also be used as a reference factor for the first metatarsal osteotomy in clinical bunion orthopaedics. First tarsometatarsal joint morphology was unrelated to hallux valgus, whereas metatarsus adductus angle, and first proximal metatarsal articular angle should be considered in hallux valgus.

**Level of Clinical Evidence:** 3

**Keywords:** bunion, first tarsometatarsal joint, radiographic detection, weight-bearing anteroposterior X-ray film

While hallux valgus is a common disorder in orthopedics and foot and ankle surgery, its pathological changes are currently unclear. Recent studies have primarily focused on the metatarsals, phalanges, sesamoid, and dynamic systems (1-3). Although the medial cuneiform is directly attached to the first metatarsal as a component of the first ray, few studies have reported on the relationship between the medial cuneiform and hallux valgus. Obliquity of the big toe in primates gradually decreased as they evolved. In humans, the big toe is nearly parallel to the lateral toe; however, some obliquity remains at the distal end of the medial cuneiform (4). This obliquity may play a role in the development of hallux valgus in humans (5-7). Hatch (8) et al found an inverse relationship with DMCA and HAV severity. This obliquity also differed among races (9). However, studies assessing whether the increased obliquity of the distal articular surface of the medial cuneiform leads to an increase in hallux
valgus angle differ or are even completely contrary (8,10). The present retrospective study of the angle associated with obliquity of the distal medial cuneiform articular surface measured selected weight-bearing anteroposterior radiographs and investigated the relationship between distal medial cuneiform joint obliquity and hallux valgus.

**Patients and Methods**

*Research methods*

Using the medical record and computer archiving and transmission systems of the radiology department, we collected weight-bearing anteroposterior radiographs of the feet of patients with hallux valgus acquired in the radiology department of our hospital between January 2018 and February 2021. When the standard weight-bearing anteroposterior radiograph of a foot was taken, the patient stood on a receiving board, and the angle between the centerline of the tube and the line perpendicular to the ground was 15° (8), which was basically perpendicular to the dorsum of the foot; the radiographic appearance of the foot can change depending on whether the foot is in a supinated or pronated attitude (6,8); thus, all of our weight-bearing anteroposterior radiographs of the foot were taken when the ball had a 15° angle with the line perpendicular to the ground. The radiographs were read separately by two experienced orthopedic surgeons, and radiographs that did not meet the inclusion criteria were excluded. Disagreements were resolved through discussion. Continued disagreements were resolved by consultation with a senior foot
and ankle surgeon who made the final decision. The inclusion criteria were: 1) age \(\geq18\) years; and 2) diagnosis of hallux valgus and weight-bearing anteroposterior X-ray examination. The exclusion criteria were: 1) Congenital foot deformity (syndactyly, polydactyly, etc.), pes cavus, pes planus, and other foot deformities; 2) history of foot surgery; and 3) severe arthritis with unidentifiable joint space.

Patient age, sex, left and right foot measurements, and other data were collected from all samples meeting the inclusion criteria. CAD 12.2.0.1 software was used to measure various angles of all radiographs, including hallux valgus angle (HVA), 1st-2nd intermetatarsal angle (IMA), metatarsus adductus angle (MAA), first metatarsus cuneiform angle (MCA), distal medial cuneiform angle (DMCA), and proximal metatarsal articular angle (PMAA) of the first metatarsal (Figure 1). In addition, the surface morphology (flat or curved) of the first tarsometatarsal (TMT) joint was recorded (Figure 2). After the measurements were taken, all samples were classified according to the HVA magnitude, with the normal and hallux valgus group including patients with HVAs of <15 degrees and \(\geq15\) degrees, respectively. The hallux valgus group was further subdivided into mild-moderate (HVA: 15–35 degrees) and severe (HVA >35 degrees) subgroups.

Currently, no uniform measurement standard exists for distal medial cuneiform obliquity. Thus, we used the method described by Hatch et al. (8). The distal medial cuneiform angle (DMCA), measured as the angle between the line connecting the midpoint of the distal joint orientation line of the medial cuneiform and the midpoint of the proximal joint orientation line and the line perpendicular to the distal joint
orientation line, was used to represent the obliquity of the distal medial cuneiform. The first proximal metatarsal articular angle (PMAA), measured as the angle between the line perpendicular to the joint orientation line of the proximal first metatarsal and the anatomical axis of the first metatarsal, was used to represent the obliquity of the proximal first metatarsal (Figure 1).

Statistics

All patient information and imaging features were summarized and analyzed using the Statistical Package for Social Sciences for Windows, version 19.0 (IBM SPSS Statistics, Chicago, IL). Measurement data conforming to the normal distribution were expressed as means ± standard deviation, and independent samples t-test and one-way analysis of variance (ANOVA) were used for comparisons between groups. Count data were expressed as proportions and χ2 tests were used for comparisons between groups. Correlation and multiple linear regression analyses were used to assess the correlations and dependence between indicators. Differences with p < .05 were considered statistically significant.

Results

This study included 538 patients (679 feet) ranging in age between 18 and 82 years and with an average age of 36 years who met the inclusion criteria (222 males, 41%). After grouping, the normal group included 155 patients (168 feet, 100 male patients [65%]), while the hallux valgus group included 383 patients (511 feet, 131
Measurement of PMAA revealed three relationships between the anatomical axis of the first metatarsal and the line perpendicular to the articular surface. First, the anatomical axis of the metatarsal was located inside the line perpendicular to the articular surface (tibial side), which we defined as the "adducted metatarsal". Second, the anatomical axis of the metatarsal was located outside the line perpendicular to the articular surface (fibular), which we defined as "abducted metatarsal". Finally, the two lines did not intersect, which we defined as "neutral metatarsal", with a PMAA angle of 0 degrees (Figure 3). In the normal, mild-moderate, and severe hallux valgus groups, the proportions of "adducted" metatarsals were 24%, 41%, and 68%, respectively (Table 2, Figure 4).

Except for DMCA and adducted metatarsal PMAA, the normal and hallux valgus groups showed significant differences ($p < .05$) (Table 1). Most patients with hallux valgus (363/511, 71%) showed mild-moderate hallux valgus (average HVA: $23.93 \pm 6.31$ degrees), while the remaining patients (148/511, 29%) showed severe hallux valgus (average HVA: $44.17 \pm 8.48$ degrees) (Table 2). Patients with severe hallux valgus had larger IMA and MCA than those in patients with mild-moderate hallux valgus ($p < .05$), whereas the DMCA was smaller than in those with mild-moderate hallux valgus ($p < .05$). The adducted metatarsal PMAA was larger in the severe hallux valgus group than in the mild-moderate hallux valgus group ($p < .05$), while abducted metatarsal PMAA in the severe hallux valgus group was significantly smaller than in the mild-moderate hallux valgus group ($p < .05$). Curved TMT
morphology was observed four times more often than flat regardless of the magnitude of the hallux valgus angle (Table 1, Table 2, Figure 5); however, this difference was not statistically significant ($p = .075$).

Correlation analysis showed that all measured angles were correlated with HVA ($p < .05$) (Table 3). IMA showed a strong positive correlation with HVA ($r = 0.518$), MAA and MCA both showed weak positive correlations with HVA ($r = 0.143, 0.399$), and DMCA showed a weak negative correlation with HVA ($r = -0.120$). In addition, MAA and MCA exhibited weak correlations with IMA ($r = -0.157, 0.453$) ($p < .05$), while we observed no correlation between DMCA and IMA ($p = .163$) (Table 4).

A multiple linear regression model was constructed to analyze the factors influencing HVA. The model was statistically significant ($R^2 = 0.636$ and $p < .05$). The results showed that age, MAA, MCA, and DMCA influenced HVA ($p < .05$). MAA and DMCA had a negative effect on HVA; that is, larger MAA and DMCA values resulted in smaller HVA values. Meanwhile, age and MCA had positive effects on HVA; that is, larger age and MCA values resulted in larger HVA values (Table 5). A multiple linear regression model was also constructed to analyze the factors influencing IMA. The model was statistically significant ($R^2 = 0.483$ and $p < .05$). The results showed that age, MAA, MCA, and DMCA influenced IMA ($p < .05$). MAA and DMCA had negative effects on IMA; that is, larger MAA and DMCA values resulted in smaller IMA values. Age and MCA had positive effects on IMA; that is, larger age and MCA values resulted in larger IMA values (Table 6).
Discussion

Since Morton (12) described obliquity of the medial cuneiform bone, many studies have focused on the relationship of this obliquity to hallux valgus. However, the findings are not uniform. We hypothesized that increased obliquity of the distal articular surface of the medial cuneiform causes an increased hallux valgus angle and performed studies to test this hypothesis. MAA is closely associated with hallux valgus. The definition of hallux valgus includes HVA and IMA (11,13). Our measurements showed a larger MAA in the hallux valgus group compared to that in the normal group (Table 1). However, the MAA did not differ significantly between the mild-moderate and severe hallux valgus groups. Moreover, regression analysis showed that MAA was not directly correlated with HVA but was directly and negatively correlated with IMA (Tables 2 and 3), indicating that MAA did not reflect the severity of hallux valgus. However, patients with greater metatarsus adductus had a relatively smaller IMA, which must be considered during surgical correction.

The two articular surfaces of the TMT can be classified into five different anatomical shapes; namely, continuous, bilobed, separated, "kidney-shaped", and "7-shaped" (14). Based on the number of articular surfaces, these can be classified as unifacet, bifacet, or trifacet (15). The continuous and kidney-shaped types are unifacet; the bilobed and separated types are bifacet; and the 7-shaped type is trifacet. Regardless of the anatomical shape or the number of articular surfaces, TMT morphology on weight-bearing anteroposterior radiography exists primarily in two
forms, flat and curved (16). In the overall sample, among only the male or female patients, or even within the normal group and within each hallux valgus subgroup, the ratio of flat and curved forms was generally 1:4 (Table 1, Table 2, Figure 5), indicating that TMT morphology in imaging was unrelated to sex or the presence or absence of hallux valgus. Overall, the curved morphology accounted for most cases; however, Dykyj et al. (5) reported a higher proportion of the curved morphology in women than in men, which may be related to sample size and calculations of selected groups between studies. The categorization of joints as having flat or curved anatomical morphologies on imaging requires further study.

Increased MCA leads directly to increased IMA. Increased MCA also increases the probability of hallux valgus; thus, Erduran et al. suggested a proportional relationship between MCA and hallux valgus (17). In our study, the MCA of the hallux valgus group was significantly larger than that of the normal group (Table 1). As HVA increased, the MCA also gradually increased (Table 2). In the regression analysis, MCA was positively correlated with both HVA and IMA (Tables 2 and 3), exhibiting a particularly strong positive correlation with IMA ($r = 0.692$). This suggested that MCA was a characteristic indicator of hallux valgus and was positively correlated with its severity, indicating that it can be used to measure the size of hallux valgus. It can also be used as a reference factor for the first metatarsal osteotomy in clinical bunion orthopaedics.

The few studies on medial cuneiform obliquity have not applied uniform standards for the nomenclature of the associated angles (7, 8, 14, 16, 18). Vyas et al. (7)
used the medial cortical tangent of the medial cuneiform and a line tangent to the distal articular surface to represent medial cuneiform obliquity; this angle was found to be unrelated to hallux valgus in cases of adolescent hallux valgus. We used the DMCA to represent medial cuneiform obliquity; our measurements of 168 normal and 511 hallux valgus feet showed DMCAs of $21.65 \pm 7.93$ degrees and $21.86 \pm 7.67$ degrees, respectively. The difference between the two was small and not statistically significant, indicating that the obliquity of the distal articular surface of the medial cuneiform was relatively constant regardless of the presence of hallux valgus; thus, its role in the development of hallux valgus is limited. Comparison of the hallux valgus subgroups showed a difference of approximately 2 degrees in the moderate-severe hallux valgus group compared to the mild-moderate hallux valgus group, with no significant differences between any of the other groups (Table 2). Regression analysis also revealed a weak negative correlation between DMCA and both HVA and IMA, contrary to our assumption that larger DMCA would lead to a larger IMA. This finding is consistent with that of Hatch et al. (8), who also used DMCA to represent medial cuneiform obliquity. Thus, DMCA is relatively constant and is not a characteristic indicator to quantify hallux valgus.

The obliquity of the distal articular surface of the medial cuneiform is considered an atavistic trait, (4) or a primary factor, while the obliquity of the proximal articular surface of the first metatarsal is believed to be an adaptive change(19). Therefore, we speculate that the medial cuneiform should show adaptive abduction of the first metatarsal to ensure that the first ray is "parallel" or "close to" the second ray due to
the obliquity of the distal articular surface of the medial cuneiform. An anatomical study of the first metatarsal in 77 cadaveric feet found an average abduction obliquity of 3.42 degrees from the base of the first metatarsal (9); this obliquity varied among races. Two studies by Hyer et al. (9, 20) also reported that the obliquity of the basal surface of the first metatarsal was related to the presence of a fibular intermetatarsal facet joint. When such an intermetatarsal facet joint was present, the obliquity is 4.63 degrees; otherwise, the obliquity was 2.92 degrees. Thus, the authors proposed that the increased obliquity of the articular surface at the base of the first metatarsal was associated with the intermetatarsal facet joint at the base of the first metatarsal. This result confirmed our conjecture; however, our measurements showed that the first metatarsal not only showed abduction but also an adducted morphology. Rotation of the first metatarsal affects its radiographic morphology and measurement of proximal joint obliquity (6); thus, we do not consider this "adduction" and "abduction" to be anatomical adduction and abduction per se but rather the appearance of the pronation and supination of the first ray on X-ray. When the first metatarsal is pronated, the intermetatarsal facet joint and the insertion of the peroneus longus tendon move to the fibular side, in which imaging of the articular surface indicates "adduction". Conversely, in hallux valgus without first metatarsal pronation, PMAA is one of the factors of hallux valgus formation, in which decreased PMAA increases the possibility of metatarsal supination. In other words, in the absence of pronation, imaging of the articular surface indicates "abduction".

Our measurements showed average PMAAs of the abducted metatarsal of 7.3
degrees and 5.85 degrees in the normal and hallux valgus groups, respectively (Table 1). In addition, the hallux valgus subgroup comparison showed that the PMAA of the abducted metatarsal also decreased as HVA increased (Table 2). This finding indicated that there was no statistical difference in the PMAA of the adducted metatarsal between the normal and hallux valgus groups; however, we observed a significant difference of approximately 1.7 degrees between the hallux valgus subgroups, which may be because the amount of hallux pronation directly affected the projected angle of the first metatarsal PMAA on the radiograph. In addition, metatarsal adduction accounted for 24% in the normal group in our study, much lower than metatarsal abduction, which accounted for 71%. In contrast, these values were nearly equal in the hallux valgus group. This indicated that there were fewer cases of hallux pronation in the normal group, while the proportion of cases with hallux pronation was higher in the hallux valgus group. In the normal, mild-moderate hallux valgus, and severe hallux valgus groups, the proportions of "adducted" metatarsals were 24%, 41%, and 68%, respectively, further confirming our conjecture (Table 2, Figure 4). Thus, we concluded that PMAA was associated with the size of hallux valgus and was a characteristic index of hallux valgus; however, there was some degree of hallux pronation in hallux valgus that affected the projected shape and accurate measurement of PMAA. In addition, as this angle has a narrow range, it cannot be used as a characteristic index to quantify hallux valgus and is not a guide for surgery.

The present retrospective study also has some limitations. First, while the
sample size was large, biases in sample selection and angle measurements were possible. In addition, the study was conducted using two-dimensional images and did not consider changes in three-dimensional space, a weight-bearing CT would be very helpful to compare the adduction/abduction findings of the first metatarsal. If at some point it could be done it would help practitioners in assessing frontal plane. Finally, although all samples in this study were taken according to the standard weight-bearing anteroposterior X-ray film, it was not possible to avoid that all samples had normal projection angles, which could also have an impact on the measurements.

In conclusion, the distal obliquity of the medial cuneiform was relatively constant, and the average DMCA angle is 21 degree; MCA but not DMCA can be used as a characteristic angle to quantify hallux valgus and as a reference angle to determine the plan during bunion surgery; TMT morphology showed little relationship to hallux valgus; and MAA, PMAA should be considered in hallux valgus.

References


### Table 1  Patient and condition characteristics for normal subjects and those with hallux valgus (N = 679 feet in 538 patients)

<table>
<thead>
<tr>
<th>Measure or Characteristic</th>
<th>Normal (n=168 feet in 154 patients)</th>
<th>Hallux valgus (n=511 feet in 403 patients)</th>
<th>p*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>37.56 ±14.85</td>
<td>39.06±16.19</td>
<td>0.061</td>
</tr>
<tr>
<td>Sex (male) n (%)</td>
<td>100 (65)</td>
<td>131 (33)</td>
<td>0.000</td>
</tr>
<tr>
<td>HVA</td>
<td>9.90±3.45</td>
<td>29.79±11.55</td>
<td>0.000</td>
</tr>
<tr>
<td>IMA</td>
<td>8.65±2.34</td>
<td>12.22±3.71</td>
<td>0.000</td>
</tr>
<tr>
<td>MAA</td>
<td>13.94±5.79</td>
<td>15.73±5.70</td>
<td>0.000</td>
</tr>
<tr>
<td>MCA</td>
<td>17.52±4.69</td>
<td>22.08±4.39</td>
<td>0.000</td>
</tr>
<tr>
<td>DMCA</td>
<td>21.65±7.93</td>
<td>21.86±7.67</td>
<td>0.760</td>
</tr>
<tr>
<td>TMT shape (curved) n (%)</td>
<td>136 (81)</td>
<td>399 (78)</td>
<td>0.246</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Measure or Characteristic</th>
<th>n (%)</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>PMAA abduction</td>
<td>119</td>
<td>7.30±4.07</td>
</tr>
<tr>
<td>PMAA adductus</td>
<td>40 (24)</td>
<td>5.53±4.78</td>
</tr>
<tr>
<td>PMAA (71)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PMAA (47)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PMAA 250 (62)</td>
<td>250</td>
<td>6.20±4.04</td>
</tr>
</tbody>
</table>

*Note: SD = Standard Deviation, p* = p-value
Abbreviations: HVA, hallux valgus angle; IMA, intermetatarsal angle; MAA, Metatarsus adductus angle; MCA, metatarsus cuneiform angle; DMCA, distal medial cuneiform angle; PMAA, proximal metatarsal articular angle; TMT, first tarsometatarsal

*All P values were adjusted using Holm – Bonferroni correction for multiple comparisons.

Table 2   Post Hoc comparisons by hallux valgus group (N = 679 feet in 538 patients)
Abbreviations: HVA, hallux valgus angle; IMA, intermetatarsal angle; MAA, Metatarsus adductus angle; MCA, metatarsus cuneiform angle; DMCA, distal medial cuneiform angle; PMAA, proximal metatarsal articular angle; TMT, first tarsometatarsal

All p values were adjusted using Holm-Bonferroni correction for multiple comparisons.

*p based on comparisons between subjects with normal and mild-moderate HV.

**p based on comparisons between subjects with mild-moderate and severe HV.

***p based on comparisons between normal subjects and those with severe HV.

Table 3 Correlations between radiographic measurements and HVA (N = 679 feet in 538 patients)
Table 4  Correlations between radiographic measurements and IMA (N = 679 feet in 538 patients)

<table>
<thead>
<tr>
<th>Measure</th>
<th>Correlation Coefficient (r)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAA</td>
<td>-0.157</td>
<td>0.000</td>
</tr>
<tr>
<td>MCA</td>
<td>0.453</td>
<td>0.000</td>
</tr>
<tr>
<td>DMCA</td>
<td>-0.062</td>
<td>0.163</td>
</tr>
</tbody>
</table>

Abbreviations: HVA, hallux valgus angle; IMA, intermetatarsal angle; MAA, Metatarsus adductus angle; MCA, metatarsus cuneiform angle; DMCA, distal medial cuneiform angle; TMT, first tarsometatarsal; CI, confidence interval

Table 5  Multivariable linear regression of HVA and age, MAA, MCA, and DMCA (N = 679 feet in 538 patients)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Partial regression</th>
<th>Standard</th>
<th>Standardized regression</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCA</td>
<td>0.399</td>
<td>0.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DMCA</td>
<td>-0.120</td>
<td>0.007</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: HVA, hallux valgus angle; IMA, intermetatarsal angle; MAA, Metatarsus adductus angle; MCA, metatarsus cuneiform angle; DMCA, distal medial cuneiform angle; TMT, first tarsometatarsal; CI, confidence interval
<table>
<thead>
<tr>
<th>Variable</th>
<th>Partial regression coefficient (Constant)</th>
<th>Error</th>
<th>Standard error</th>
<th>Standardized regression coefficient</th>
<th>t</th>
<th>p</th>
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</thead>
<tbody>
<tr>
<td>(Constant)</td>
<td>-2.988</td>
<td>1.419</td>
<td>-2.106</td>
<td>0.036</td>
<td>9.103</td>
<td>0.000</td>
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<tr>
<td>Age</td>
<td>0.394</td>
<td>0.017</td>
<td>0.579</td>
<td>22.737</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>MAA</td>
<td>-0.056</td>
<td>0.064</td>
<td>-0.024</td>
<td>-0.886</td>
<td>0.376</td>
<td></td>
</tr>
<tr>
<td>MCA</td>
<td>1.105</td>
<td>0.083</td>
<td>0.405</td>
<td>13.353</td>
<td>0.000</td>
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</tr>
<tr>
<td>DMCA</td>
<td>-0.325</td>
<td>0.046</td>
<td>-0.189</td>
<td>-7.060</td>
<td>0.000</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: MAA, Metatarsus adductus angle; MCA, metatarsus cuneiform angle; DMCA, distal medial cuneiform angle

Table 6  Multivariable linear regression of IMA and age, MAA, MCA, and DMCA (N = 679 feet in 538 patients)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Partial regression coefficient</th>
<th>Standard error</th>
<th>Standardized regression coefficient</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Constant)</td>
<td>4.336</td>
<td>0.476</td>
<td>9.103</td>
<td>0.000</td>
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<tr>
<td>Age</td>
<td>0.045</td>
<td>0.006</td>
<td>0.233</td>
<td>7.682</td>
<td>0.000</td>
</tr>
<tr>
<td>MAA</td>
<td>-0.245</td>
<td>0.021</td>
<td>-0.377</td>
<td>-11.501</td>
<td>0.000</td>
</tr>
<tr>
<td>MCA</td>
<td>0.532</td>
<td>0.028</td>
<td>0.692</td>
<td>19.152</td>
<td>0.000</td>
</tr>
<tr>
<td>DMCA</td>
<td>-0.084</td>
<td>0.015</td>
<td>-0.173</td>
<td>-5.427</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Abbreviations: MAA, Metatarsus adductus angle; MCA, metatarsus cuneiform angle; DMCA, distal medial cuneiform angle
Figures

**Fig. 1** Measurements of hallux valgus (HV), including hallux valgus angle (HVA), intermetatarsal angle (IMA), metatarsus adductus angle (MAA), metatarsus cuneiform angle (MCA), distal medial cuneiform angle (DMCA), proximal metatarsal articular angle (PMAA)
Fig. 2  First tarsometatarsal joint shapes (A curved, B flat)
Fig. 3  Morphologies of the first metatarsal (A adductus, B abduction)
Fig. 4  Percentages of the first metatarsal morphology graded as abduction, adductus, or neutral according to the weight-bearing radiographs (N = 679 feet in 538 patients)
Fig. 5  Percentages of first tarsometatarsal joint shapes graded as flat or curve-shaped from weight-bearing radiographs of the feet  (N = 679 feet in 538 patients)