The Effect of Rotation on Radiologic Measurement of DMAA and IMA angles: Novel Radiologic Validation

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Disclosures

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Hallux valgus is a common foot condition in adults, representing a spectrum of abnormalities involving the joints of the first ray that result in a three-dimensional deformity.

The routine workup of hallux valgus includes specific measurements made on a standard 15° anterior-posterior (AP) weight bearing foot radiograph, one of which is the distal metatarsal articular angle (DMAA). This measurement (normal defined as <15°) is used to determine first metatarsophalangeal (MP) joint congruity, assist in surgical indication and planning, and assess correction of deformity postoperatively.

The ideal radiographic measurement and classification system should be reproducible and should not be sensitive to other changes in the patient's anatomy (e.g. rotation) which may decrease the accuracy of the measurement.

Although the DMAA is routinely used, it may not represent the most accurate and reproducible method for measuring the degree of deformity in patients with hallux valgus. Robinson et al. demonstrated in a cadaveric study that the DMAA significantly varies with axial rotation and inclination.

Measurement of this angle in one radiographic plane may preclude its utility in assessing the rotational component of this three-dimensional deformity. Previous studies have not measured this angle in situ with a validated measuring tool to assess its accuracy.
Eight feet were harvested from four cadavers (four left and four right matched as pairs) from the Department of Anatomy and Cell Biology at our institution.

All specimens were visually inspected to assess for any prior surgical interventions to the foot and if no surgical scars or obvious deformity were noted, the foot was harvested at the level of the tibiotalar joint.

Specimen dissection was performed utilizing a dorsal approach so as to maintain the soft tissue anatomy and bony alignment in situ. The diaphysis of the first metatarsal and the first metatarsophalangeal (MP) joint were dissected away from surrounding tissues. The MP joint capsule was incised circumferentially.

Each foot was fixed with a cylindrical bolt passed transversely through the talus. The bolt was placed both perpendicular to the long axis of the metatarsal, as well as parallel to the plane of simulated weight-bearing of the foot. The bolt was then fixed to a custom radiographic analysis tool, allowing for dorsal rotation through the axis of the bolt.
A radiolucent rotation guide was digitally designed using CAD software (SolidWorks, Dassault Systèmes, Waltham, Massachusetts) and the final guide was fabricated from polyethylene using a multi-axis scanning and milling machine (MDX-20, Roland DGA Corporation, Irvine, California). The rotation guide was designed to allow adjust for an arc of axial rotation at fixed, 15-degree increments (Figure 1). This guide was fixed dorsomedially to the first metatarsal diaphysis with two Kirschner wires.

Figure 1. CAD diagram of radiolucent measurement jig. Both components were manufactured from ultra-high molecular weight polyethylene (UHMWPE).
Methods

• Radiologic evaluation was performed using fluoroscopy. Initial AP X-rays were taken at 15° caudad, consistent with accepted practice. The foot was then dorsiflexed 90 degrees and a longitudinal X-ray was obtained to verify the initial rotation between the two Kirschner wires.

• A transverse, diaphyseal osteotomy of the first metatarsal was performed. The distal fragment was internally rotated 15 degrees and an AP image was obtained.

• The specimen was dorsiflexed 90 degrees and a longitudinal X-ray was obtained for measurement of axial rotation. This was repeated for 30, 45, and 60 degrees of internal rotation of the distal fragment. This procedure was repeated identically for each specimen.

• Images were saved to the picture archiving and communication system (PACS) at our institution. The intermetatarsal (IMA), hallux valgus (HVA), and distal metatarsal articular angles were measured using the initial AP image of the foot. The intermetatarsal and distal metatarsal articular angles were measured using the AP X-ray at 15, 30, 45, and 60 degrees of axial rotation. The angle of rotation was verified using the longitudinal X-ray at 0, 15, 30, 45, and 60 degrees of axial rotation.
Results

• Accuracy of the radiolucent rotation guide was assessed by comparison to in-situ measured Kirschner wire angles on axial fluoroscopy. Analysis showed strongly positive correlation between the guide angles and the in situ measured angles, with a Pearson correlation of 0.968 (p < 0.001). This confirmed accuracy of the guide to control rotation at 15-degree increments (Figure 2).

• The IMA and DMAA were measured on every AP image. The IMA measured prior to osteotomy was compared to the IMA measured on subsequent images post-osteotomy. IMA remained stable for each AP image despite rotation of the distal segment, with a mean difference of less than 2.5 degrees.

• By contrast, the DMAA was not constant and deviated substantially even with the smallest degree of rotation (7.5 degrees deviation with 15 degrees of rotation at osteotomy) and increased to a maximum deviation of 12.5 degrees at the greatest amount of rotation (60 degrees at osteotomy).

• Overall, the DMAA differed significantly from baseline (p < 0.05) as distal segment rotation increased, which was not observed with the IMA (Figure 3). There was no significant trend in the direction of variance across specimens, as the DMAA did not increase or decrease in a predictable manner with changing rotation of the distal segment.
Figure 2. Validation of the radiolucent measuring jig. Vertical error bars represent the 95% confidence interval of the mean measurement.

Figure 3. Results of measurement of the DMAA and IMA. Difference from baseline is the difference of the measured angle (either IMA or DMAA) from the true angle, thus a smaller deviation from baseline represents the more accurate measure. Vertical error bars represent the 95% confidence interval of the mean angle. Groups as defined by their rotation at osteomy angle marked with an asterisk (*) demonstrate a significant difference between the DMAA and IMA for that specific amount of rotation at the osteotomy site.
Routine use of the DMAA in the clinical evaluation of hallux valgus, whether pre-, intra-, or post-operatively, may be precluded by rotational deformity of the first ray. Failure to assess the degree of deformity may result in improper surgical indication and decreased patient outcomes postoperatively. In this study we showed that measurement of the DMAA varies significantly with rotation of the distal first metatarsal. Accordingly, we recommend caution when utilizing the DMAA to assess first MP joint congruency, as it may unreliably and inaccurately estimate the three-dimensional deformity often encountered in pathologic hallux valgus. The IMA may be a more accurate way to assess the severity of hallux valgus which is less sensitive to first ray rotational deformities.
References


