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Original Research

Hallux Valgus Evaluation on MRI: Can Measurements Validated on Radiographs Be Used?

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ABSTRACT

Hallux valgus (HV) is a common deformity of the great toe affecting >23% of adults in the United States. The severity of the deformity is traditionally analyzed using radiographs to determine measurements such as the HV and intermetatarsal angles. We sought to determine the relationship between the radiographic and magnetic resonance imaging (MRI) measurements because this is not yet known. Two of us analyzed a series of 56 consecutive patients who had had radiographs and MRI performed on the same foot between April 27, 2015 and March 9, 2016 and who satisfied all other inclusion and exclusion criteria (age 18 to 100 years, no history of recent foot trauma, and no metal hardware in the foot). We found excellent interreader reliability (intraclass correlation 0.89 to 0.96) and intermodality agreement (intraclass correlation 0.83 to 0.91). The HV angle measured 15.0° ± 8.8° on the MRI scans and 13.8° ± 8.7° on the radiographs (mean difference –1.15° ± 3.89°), and the intermetatarsal angle was 9.0° ± 3.1° on the MRI scans and 8.8° ± 2.9° on the radiographs (mean difference –0.22° ± 2.10°). The HV measurements were reliable on both radiographs and MRI for the range of values tested. Small intermodality statistically significant differences in HV angle measurements were found; however, these might not be enough to be clinically significant.

Hallux valgus (HV), also known as a bunion, is a relatively common condition in the United States, affecting approximately 25% of adults aged 18 to 65 years and 36% of adults aged >65 years (1). The pathoanatomy is defined by medial deviation of the first metatarsal, lateral deviation of the hallux, and a prominent metatarsal head (2). This deformity is associated with an aching pain in the metatarsal head that can be sharply painful during ambulation and with shoe wear. It is also associated with a variety of painful and potentially disabling sequelae, including bursitis, cartilage degeneration, and nerve entrapment (3–5).

In addition to the history and physical examination findings, a variety of radiologic findings are used to assess the severity of HV. These include the HV angle (HVA) and the intermetatarsal angle (IMA), among many others (6). The HVA and IMA have been shown to correlate best with the magnitude of deformity (7). Although the angles have been well studied on radiographs, the magnetic resonance imaging (MRI) correlates of HV have not been described. MRI of the forefoot and midfoot has been increasingly used for the diagnosis of plantar plate tears, collateral ligament injuries, and cartilage assessment (8). This poses the question of whether radiographs would be necessary if the physician already planned to order an MRI scan. It is not known whether similar measurements used on the reference standard weightbearing radiographs can be used on non-weightbearing MRI scans for the diagnosis of HV and to classify its severity. If the measurements using MRI scans proved reliable, it might be unnecessary in certain cases to order radiographs and subject the patient to radiation.

The primary goal of the present study was to assess the mean differences in the HVA and IMA when comparing radiographs and MRI scans in the same patient to determine whether similar measurements could be used reliably with MRI as are used on radiographs. A secondary goal was to establish the interreader reliability. We hypothesized that similar measurements could be used on MRI for the assessment, diagnosis, and grading of HV.

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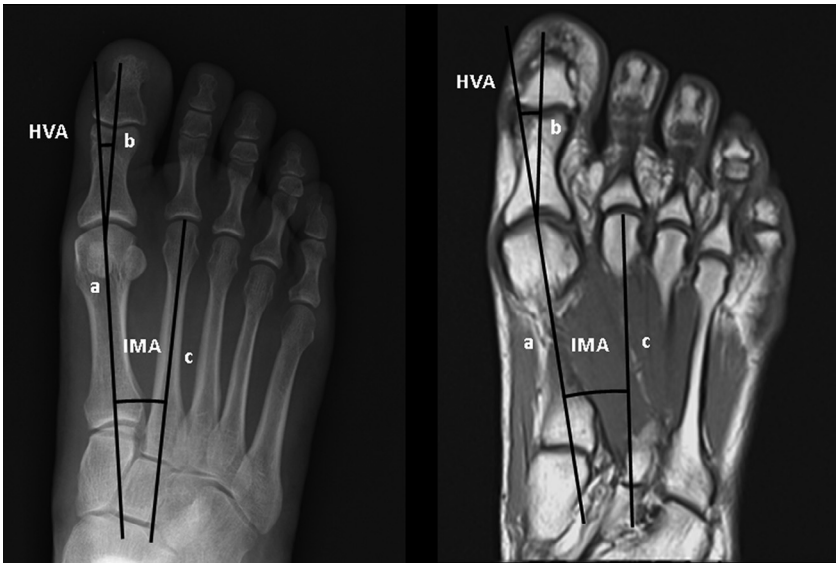

Fig. 1. Measurement of hallux valgus angle (HVA) and intermetatarsal angle (IMA) on a radiograph and magnetic resonance image. *Line a* passes through the midpoint of the first metatarsal head and base, *line b* passes through the midpoint of the head and base of the first proximal phalanx, and *line c* passes through the midpoint of the second metatarsal head and base. The HVA measures the acute angle between *lines a and b*, and the IMA measures the acute angle between *lines a and c*.

Patients and Methods

The institutional review board approved our retrospective study, and informed consent was waived. We used Primordial® software (San Mateo, CA) to retrospectively query our patient database and found 90 consecutive patients who had undergone MRI of the forefoot and midfoot between April 27, 2015 and March 9, 2016. Our inclusion criteria were age 18 to 100 years and weightbearing radiographs (anteroposterior and lateral) and non-weightbearing MRI scans of the same foot available, with both studies generated within 3 months. The exclusion criteria included recent foot trauma or orthopedic hardware (n = 19) and poor image quality (n = 15). The final sample was 56 patients who met the inclusion and exclusion criteria.

For every patient, the HVA and IMA were measured by 2 of us (N.H., L.Z.) on weightbearing radiographs and non-weightbearing MRI scans for a total of 4 angles using Philips Intellispace® PACS software (Best, The Netherlands). The HVA is defined as the angle formed by the axis of the first metatarsal and the axis of the first proximal phalanx (Fig. 1). The IMA is defined as the angle formed by the axis of the first metatarsal and the axis of the second metatarsal (Fig. 1). The longitudinal axis (midline) was determined by connecting the centers of the bones as described by Miller (9).

To ensure the quality of our data and provide a benchmark for the reproducibility of each measurement, 2 of us (N.H., medical student; L.Z., radiologist with 8 years' experience) independently measured each angle on the radiographs and MRI scans in a separate setting. The readers were trained on an initial set of 6 cases from the sample under the direction of another senior radiologist (A.C.) with 20 years of radiology experience.

The mean ± standard deviation were calculated for all variables. A 3-way mixed model was used to calculate the intraclass correlation coefficient, with 95% bootstrap confidence intervals (CIs) between readers and between the imaging modalities for HVA and IMA. Student's *t* test was used to compare the 2 mean values, and a *p* value of < .05 was considered statistically significant. The mean differences between these values were calculated, and Bland-Altman plots were generated to quantify the magnitude and significance of any reported differences. We used both readers' measurements to determine the mean HVA and IMA for each imaging modality.

Results

The mean age of the study group was 54.2 ± 15.4 years. The mean body mass index was 28.7 ± 7.1 kg/m^2, and 71.4% (40 of 56) were females. Of the 56 patients, 30 (53.6%) had undergone imaging of the left foot and 26 (46.4%) of the right foot (Table 1).

The interreader reliability for the HVA was 0.96 (95% CI 0.94 to 0.98) and for the IMA was 0.89 (95% CI 0.8 to 0.95). The intermodality agreement (between the radiographs and MRI) using the same method was 0.91 (95% CI 0.89 to 0.93) for the HVA and 0.83 (95% CI 0.7 to 0.91) for the IMA (Table 2).

The mean angles and standard deviations for each reader for each imaging modality are reported in Table 3. The mean difference between the radiographs and MRI for the HVA was –1.15° ± 3.89° ($p = .03$). The mean difference between the radiographs and MRI for the IMA was –0.22° ± 2.10° ($p = .43$). This represented a small, but statistically significant, difference ($p < .05$) between the 2 imaging modalities for measuring the HVA but no significant difference for measuring the IMA. Bland-Altman plots (Figs. 2 and 3) were also generated, with 91% (51 of 56) of our data points within 2 standard deviations of the mean difference for the IMA and HVA (Table 4).

Table 1
Study cohort characteristics (N = 56 patients)

Characteristic	n (%)
Sex	
Male	16 (28.6)
Female	40 (71.4)
Foot	
Left	30 (53.6)
Right	26 (46.4)
BMI (kg/m^2)	28.7 ± 7.0
BMI group	
Normal or underweight (<25 kg/m^2)	19 (33.9)
Overweight (25 to 30 kg/m^2)	15 (26.8)
Obese (>30 kg/m^2)	20 (35.7)
NA	2 (3.6)
Age (y)	54.2 ± 15.4
<65	41 (73.2)
>65	15 (26.8)

Abbreviations: BMI, body mass index; NA, not applicable.

Table 2
Intraclass correlation coefficients

Angle	Reader 1 Versus Reader 2	Radiograph Versus MRI
HVA	0.96 (95% CI 0.94 to 0.98)	0.91 (95% CI 0.89 to 0.93)
IMA	0.89 (95% CI 0.8 to 0.95)	0.83 (95% CI 0.7 to 0.91)

Abbreviations: CI, confidence interval; HVA, hallux valgus angle; IMA, intermetatarsal angle; MRI, magnetic resonance imaging.