The Journal of Foot & Ankle Surgery 57 (2018) 1140–1142

Contents lists available at ScienceDirect

The Journal of Foot & Ankle Surgery

journal homepage: www.jfas.org

Evaluation of the Mechanical Axis of the First Ray Before and After First Metatarsal-Phalangeal Joint Reconstructive Surgery

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ARTICLE INFO

Level of Clinical Evidence: 4

Keywords:
bunion
hallux valgus
metatarsophalangeal

ABSTRACT

LaPorta et al published a description of measurement of the mechanical axis of the first ray in an attempt to introduce center-of-rotation angulation principles into forefoot reconstructive surgery. They found significant differences in the measurement of the first intermetatarsal angle between groups of feet with and without hallux abducto valgus deformity, but they found no difference in the measurement of the M1-M2 mechanical axis angle between groups. The objectives of this study were to further investigate the proposed M1-M2 mechanical axis angle and to examine the effect of hallux abducto valgus corrective surgery on its measurement. We retrospectively evaluated weight-bearing dorsal-plantar projection radiographs taken in the angle and base of gait of 56 consecutive feet before and after first metatarsal-phalangeal joint corrective surgery. On each radiograph, we calculated the first intermetatarsal angle, the hallux abductus angle, the tibial sesamoid position, the M1-M2 mechanical axis angle, and the position of the sesamoids relative to the mechanical axis of the medial column. Statistically significant decreases were observed when comparing pre- versus post-operative measurement of the first intermetatarsal angle (−4.83°; $p < .001$), hallux abductus angle (−11.46°; $p < .001$), and tibial sesamoid position (−1.99 positional grade; $p < .001$). Statistically significant differences were also observed for the M1-M2 mechanical axis angle (−0.47°; $p = .007$) and the position of the sesamoids relative to the mechanical axis of the medial column (0.38 positional grade; $p < .001$), but it is unlikely that these results would be considered clinically significant given the differences of less than 1° and less than 1 positional grade, respectfully. The results of this investigation add to the body of knowledge and will hopefully lead to future investigations into the progression, evaluation, and treatment of the hallux abducto valgus deformity.

LaPorta et al. (1) published a description of the measurement of the mechanical axis of the first ray (MAFR) to introduce center-of-rotation angulation principles into forefoot reconstructive surgery (2–4). They specifically compared measurement of the MAFR to the traditional first intermetatarsal angle in separate groups of feet with and without hallux abducto valgus (HAV) deformity. Moreover, they initially defined the mechanical axis of the medial column as the line extending from the center of the talar head (Point E in Figs. 1 and 2) to the center of the base of the proximal phalanx of the hallux (Point A in Figs. 1 and 2). The M1-M2 mechanical axis angle is then the resultant angle between lines EA and EC in the Figures (with Point C representing the center of the second metatarsal-phalangeal joint) (1).

In feet without HAV deformity (i.e., Fig. 1), the authors found a mean value of 7.5° for the first intermetatarsal angle and 11.19° for the M1-M2 mechanical axis angle (1). They also observed that in normally aligned feet, line EA consistently passed through both point D (the dorsal lateral proximal corner of the medial cuneiform) and Point B (the center of the first metatarsal head). However, in feet with HAV deformity (i.e., Fig. 2), although the mean first intermetatarsal angle was observed to be 13.5°, the M1-M2 mechanical axis angle did not substantially change at a mean of 11.58°. They further observed that points B and D were not aligned with line EA in feet with HAV.

They took this finding to mean that the proximal phalanx and sesamoid apparatus remain in an unchanged position during the progression of HAV, and that the resultant deformity comes primarily from splaying of the first metatarsal medially. They also proposed that the degree of angular correction required during HAV reconstructive surgery can be predicted from the amount of displacement of points B and D from Line EA. However, they provided no direct evidence with respect to the progression of the HAV deformity and did not evaluate the effect of HAV surgical correction on the measurement of this angle. Therefore

Financial Disclosure: None
Conflict of Interest: None
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https://doi.org/10.1053/j.jfas.2018.05.009

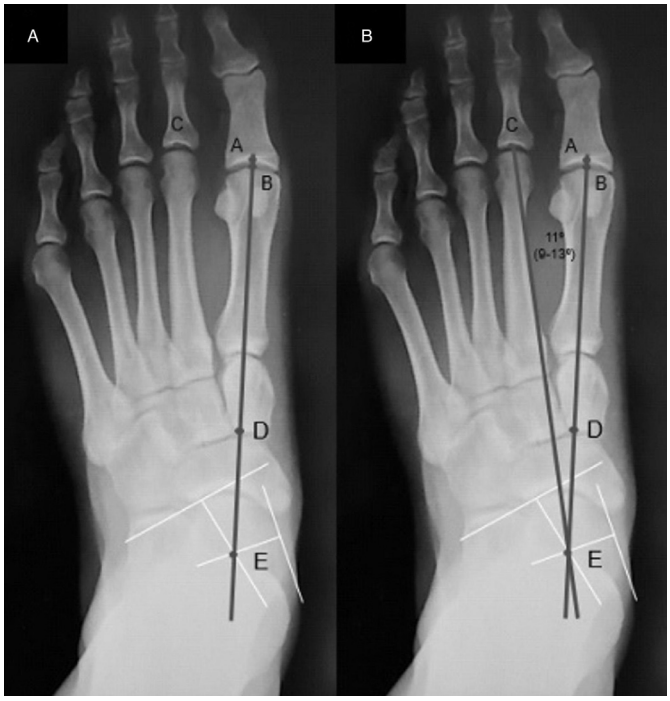

Fig. 1. Measurement of the M1-M2 mechanical axis angle in a rectus foot (Reproduced from Laporta et al [1]).

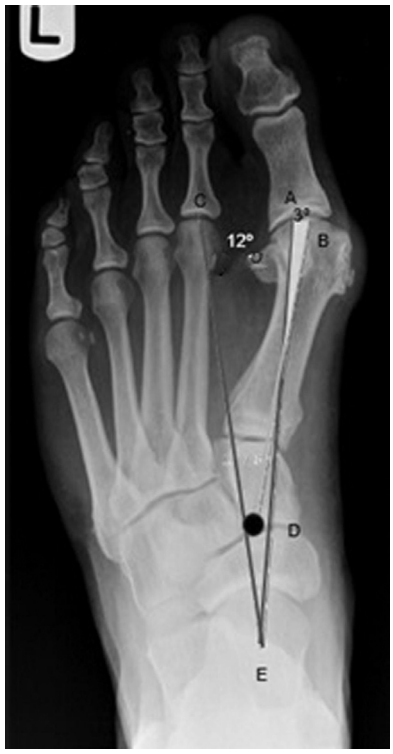

Fig. 2. Measurement of a foot with hallux abducto valgus deformity (Reproduced from Laporta et al [1]).

the objectives of this study were to further investigate the proposed M1-M2 mechanical axis angle and to examine the effect of HAV corrective surgery on its measurement.

Patients and Methods

After obtaining institutional review board approval, we retrospectively evaluated weight-bearing dorsal-plantar projection radiographs taken in the angle and base of gait of 56 consecutive feet before and after first metatarsal-phalangeal joint corrective surgery. On each radiograph, we calculated the first intermetatarsal angle (defined as the angular relationship between the bisectors of the first and second metatarsal shafts); the hallux abductus angle (defined as the angular relationship between the bisectors of the first metatarsal and hallux proximal phalanx shafts); the tibial sesamoid position (on a 7-point scale as described by Hardy and Clapham [5]); and the M1-M2 mechanical axis angle (as described by Laporta et al [1]). Initial measurements were performed by 2 authors (S.N. and B.D.) and confirmed by the senior author (A.J.M.).

We also attempted to describe the position of the sesamoids relative to the mechanical axis of the medial column (MAx; line EA on Figs. 1 and 2) on a 5-point scale: grade 1 (MAx completely medial to the tibial sesamoid); grade 2 (MAx within the tibial sesamoid); grade 3 (MAx between the tibial and fibular sesamoids); grade 4 (MAx within the fibular sesamoid); and grade 5 (MAx lateral to the fibular sesamoid).

All statistical analyses were performed by the corresponding author (A.J.M.) using Statistical Analysis Systems software, version 9.2 (SAS Institute, Cary, NC). Descriptive statistics are reported in terms of the mean, standard deviation, and range. Comparative statistical analysis was performed for preoperative versus postoperative measurements with a paired Student *t*-test. The level of statistical significant was set at a *p*-value = .05.

Results

Results are displayed in Table. Statistically significant decreases were observed when comparing pre- versus post-operative measurement of the first intermetatarsal angle (−4.83°; $p < .001$), hallux abductus angle (−11.46°; $p < .001$), and tibial sesamoid position (−1.99 positional grade; $p < .001$). Statistically significant differences were also observed for the M1-M2 mechanical axis angle (−0.47°; $p = .007$), and MAx sesamoid grade (0.38 positional grade; $p < .001$), but it is unlikely that these results would be considered clinically significant given the differences of less than 1° and less than 1 positional grade, respectively.

We observed mean ± standard deviation (range) measurements of 10.79 ± 1.04° (8.1–13.1°) for the preoperative M1-M2 mechanical axis angle, and we found this to be similar to the descriptive statistics provided by LaPorta et al (1) for the measurement of this angle in feet with HAV: 11.58 ± 1.0° (6–22°). We also subjectively observed that the standard deviations and ranges for the M1-M2 mechanical axis angle and MAx sesamoid grade in our cohort were relatively more precise than the standard deviations and ranges for the first intermetatarsal angle and tibial sesamoid position, respectively.

Discussion

As with any scientific investigation, critical readers are encouraged to review the study design and results and reach their own conclusions. However, the following represents our conclusions based on the preceding specific results. As scientists, we never consider data to be definitive but do think that these results are worthy of attention and future investigation. First, these results seem to confirm the normative measurements of the initial work of LaPorta et al (1). Our mean preoperative measurements for the M1-M2 mechanical axis angle were within 1° of their mean measurements in a group of patients with first metatarsal-phalangeal joint pathology.

Second, these results seem to support their hypothesis that the M1-M2 mechanical axis angle does not change with the progression and course of the HAV deformity. They did not find substantial difference in measurements of this angle between 2 groups of feet with and without HAV deformity, and we did not observe clinically significant differences in measurements of this angle in a single group of feet before and after first metatarsal-phalangeal joint reconstructive surgery.

Table
Outcome measure descriptive and comparative statistics

Radiographic Parameter	Pre-Operative Measurement (n = 56 feet)	Post-Operative Measurement (n = 56 feet)	Statistical Comparison (Paired Student *t*-test)
First intermetatarsal angle (degrees)	11.58 ± 3.79(2.2–22.7)	6.75 ± 2.91(2.2–18.9	$p < .001$*
Hallux abductus angle (degrees)	23.86 ± 7.76 (8.7–36.4)	12.40 ± 6.27 (0.1–26.1)	$p < .001$*
Tibial sesamoid position (position)	4.47 ± 1.67 (1–7)	2.48 ± 1.11 (1–5)	$p < .001$*
M1-M2 mechanical axis angle (degrees)	10.79 ± 1.04 (8.1–13.1)	10.32 ± 1.11 (8.0–13.9)	$p = .007$*
Mechanical axis of the medial column-sesamoid relationship (position)	2.45 ± 0.50 (2–3)	2.83 ± 0.42 (2–4)	$p < .001$*

* $p < .05$ indicates statistical significance

Third and finally, these results seem to support their hypothesis that the base of the proximal phalanx and sesamoid apparatus remain in a relatively unchanged position during the progression of the HAV deformity. Here we provide original data of the relationship of the mechanical axis of the medial column to the sesamoid apparatus. In the preoperative group of patients with first metatarsal-phalangeal joint deformity and no history of surgery, the mechanical axis of the medial column was always found either between the 2 sesamoids or within the tibial sesamoid. This relationship did not substantially change after the first metatarsal-phalangeal joint reconstructive surgery.

All scientific investigations have limitations, and this study had several important ones to consider. First, data were collected from a single institution, using a limited number of patients, and the results might not be representative of our entire institution or other institutions. Second, this is a study of radiographic outcomes and does not provide any measure of patient clincal outcome or function. It is also not a longitudinal study and therefore does not provide direct evidence of the progression of the HAV deformity.

In conclusion, the results of this investigation add to the body of knowledge and will hopefully lead to future investigations into the progression, evaluation, and treatment of the hallux abducto valgus deformity.

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