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Original Research

Prediction of angular correction following first metatarsal-phalangeal joint arthrodesis

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ABSTRACT

The literature has established that the first metatarsal-phalangeal joint arthrodesis procedure will provide some correction of the first intermetatarsal and hallux valgus angles. But while this has previously primarily been investigated as a simple association (i.e. comparison of pre-operative to post-operative values), the objective of this investigation was to consider angular change as a continuous variable and to specifically correlate it with pre-operative values. Radiographs from 100 consecutive first metatarsal-phalangeal joint arthrodeses meeting selection criteria were evaluated. A negative Pearson correlation coefficient was observed between the pre-operative first intermetatarsal angle and intraoperative change in the first intermetatarsal angle (Pearson -0.547; $p<0.001$). In other words, with progressively increased levels of pre-operative intermetatarsal angle deformity, one should expect greater intermetatarsal angle correction. The relationship is described by the equation $Y = 2.82 – 0.38X$ indicating that for every one degree of pre-operative intermetatarsal deformity over approximately 7 degrees, 0.38 degrees of post-operative correction might be expected. A negative Pearson correlation was observed between the pre-operative hallux valgus angle and the intraoperative change in the first hallux valgus angle (Pearson -0.806; $p<0.001$). In other words, with progressively increased levels of pre-operative hallux valgus angle deformity, one should expect greater hallux valgus correction. The relationship is described by the equation $Y = 5.5 – 0.63X$ indicating that for every one degree of pre-operative hallux valgus angle deformity over approximately 9 degrees, 0.63 degrees of hallux valgus angle post-operative correction might be expected. Results of this investigation demonstrate a statistical correlation between pre-operative radiographic deformity and intermetatarsal angle and hallux valgus angle post-operative correction, and might provide foot and ankle surgeons with a degree pre-operative prediction of expected angular correction following the procedure.

Introduction

The literature and clinical experience have established that the first metatarsal-phalangeal joint arthrodesis procedure will provide some correction of the first intermetatarsal angle and hallux valgus angle when performed for either the hallux rigidus or hallux valgus deformities [1-15]. Hallux valgus angle correction is relatively direct in that the surgeon effectively has the ability to position and fixate the hallux proximal phalanx in a preferred position on the first metatarsal head. First intermetatarsal angle correction is relatively indirect, and is assumed to result from the removal of retrograde buckling forces on the first metatarsal-phalangeal, first metatarsal-medial cuneiform and intercuneiform articulations, as well as realignment of intrinsic and extrinsic musculotendinous actions. This has previously primarily been investigated as a simple association (i.e. comparison of pre-operative to post-operative values in different groups) [1-10]. A few studies have performed more advanced comparisons with continuous variable analyses between varying radiographic and functional outcomes [11-14]. And we are aware of one study which performed a multivariate regression analysis and found that the preoperative first intermetatarsal angle was independently associated with correction [15]. We are unaware of any investigation which has attempted to predict post-operative correction based on pre-operative angular measurements.

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Therefore, the objective of this investigation was to similarly consider radiographic angular correction as a continuous variable, thereby allowing for derivation of correlation coefficients and linear regression equations. It is our hypothesis that the degree of post-operative angular correction can be predicted pre-operatively.

Methodology

Following IRB approval, radiographs from consecutive first metatarsal-phalangeal joint arthrodesis procedures performed at a single institution over a 2-year data collection period (1/1/2022-12/31/2023) meeting selection criteria were evaluated. Selection criteria were subjects between the age of 18-90 years, with available pre-operative weight-bearing dorsal-plantar projection radiographs, with available ≥4 week post-operative weight-bearing dorsal-plantar projection radiographs, and undergoing a primary first metatarsal-phalangeal joint arthrodesis without other concomitant procedures of the first ray or medial column. Procedures were performed by 4 different surgeons and utilized a variety of joint preparation and fixation techniques.

Recorded variables included the first intermetatarsal angle (IMA), hallux valgus angle (HVA), tibial sesamoid position (TSP), and hallux interphalangeus angle. The first IMA was defined as the angular relationship between the bisectors of the first and second metatarsal shafts [16,17]. The HVA was defined as the angular relationship between the bisectors of the first metatarsal and hallux proximal phalanx shafts [16,17]. The tibial sesamoid position was on a 7-point scale as described by Hardy and Clapham [16-18]. The hallux interphalangeus angle was defined as the angular relationship between the bisectors of the hallux proximal phalanx and hallux distal phalanx shafts [16,17]. Initial measurements were performed by one study author (SN) and confirmed by the senior author (AJM) utilizing computerized digital software (Opal-RAD PACS, Viztek, Garner, NC) measuring to a precision of 0.1°.

Data was stored in a password protected personal computer for subsequent statistical analysis by one study author (AJM) 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 pre- versus post-operative measurements with the paired student t-test. Bivariate Pearson correlation coefficients were calculated of the pre-operative intermetatarsal angle and hallux valgus angle measurements to their respective post-operative change. The statistical software generates a simple regression line on the graphical depiction of this bivariate analysis (frequency scatter plot) with an equation representing the slope of the line. Solving for "y=0″ of this equation defines the x-intercept point. The level of statistical significant was set at a p-value of 0.05.

Results

One hundred consecutive first metatarsal-phalangeal joint arthrodesis procedures were evaluated. Subject age was 61.04±8.60 years (41-85). Forty-five (45.0%) subjects were of male gender, and 57 (57.0%) procedures were performed on the right foot. Table 1 demonstrates results of the comparison of pre-operative to post-operative radiographic outcomes. Statistically significant improvements were noted in the first IMA (11.65±4.23 vs. 10.01±3.60; p<0.001), HVA (25.94±14.44 vs. 15.01±8.55; p<0.001), and TSP (4.33±3.42 vs. 3.42±1.88; p<0.001). No perioperative change was observed in the hallux interphalangeus angle (14.38±7.66 vs. 14.98±7.92; p=0.439).

A negative Pearson correlation coefficient was observed between the pre-operative first IMA and perioperative change in the first IMA (Pearson -0.547; p<0.001) (Fig. 1). In other words, with progressively increased levels of pre-operative IMA deformity, one might expect greater IMA correction. The relationship is described by the equation Y = 2.82 – 0.38X, indicating that for every one degree of pre-operative IMA deformity over approximately 7 degrees, 0.38 degrees of correction might be expected.

Table 1
Comparison of pre- and post-operative radiographic outcomes.

Radiographic outcome	Pre-operative IMA	Post-operative IMA	Statistical comparison
Intermetatarsal angle (mean ±standard deviation)	11.65±4.23	10.01±3.60	P<0.001*
Hallux valgus angle (mean ±standard deviation)	25.94±14.44	15.01±8.55	P<0.001*
Tibial sesamoid position (mean±standard deviation)	4.33±3.42	3.42±1.88	P<0.001*
Hallux interphalangeus angle (mean±standard deviation)	14.38±7.66	14.98±7.92	P=0.439

* Indicates statistical significance $p < 0.05$.

A negative Pearson correlation was observed between the pre-operative HVA and perioperative change in the first HVA (Pearson -0.806; p<0.001) (Fig. 2). In other words, with progressively increased levels of pre-operative HVA deformity, one might expect greater HVA correction. The relationship is described by the equation Y = 5.5 – 0.63X, indicating that for every one degree of pre-operative HVA deformity over approximately 9 degrees, 0.63 degrees of correction might be expected.

Discussion

As with any scientific investigation, critical readers are encouraged to review the study design and specific results in order to reach their own independent conclusions, while the following represents our conclusions based on the preceding results. We also never consider data to be definitive, but do think that these results might be worthy of interest and future investigation to foot and ankle surgeons.

First, results of this investigation demonstrate and confirm a statistical correlation beyond an association of first IMA and HVA correction following the first metatarsal-phalangeal joint arthrodesis. The observed statistically significant negative Pearson correlation coefficients indicate that the amount of angular correction achieved with the procedure is variable and dependent on the degree of pre-operative deformity. In other words, surgeons can expect greater amounts of angular correction with the procedure when greater pre-operative deformity is present. This might be intuitive and self-evident with respect to the HVA due to the direct correction achieved with the procedure, but a relatively unique finding with respect to the first intermetatarsal angle due to the indirect proposed mechanisms of angular correction.

Second, the equations associated with the bivariate analyses might allow for a reasonable degree of pre-operative prediction of angular correction with the procedure. For the first intermetatarsal angle, these results indicate that for every one degree of pre-operative IMA deformity over approximately 7 degrees, 0.38 degrees of correction might be expected following the procedure. And for the hallux valgus angle, these results indicate that for every one degree of pre-operative HVA deformity over approximately 9 degrees, 0.63 degrees of correction might be expected following the procedure. This might assist foot and ankle surgeons pre-operatively anticipate the need for performance of adjuvant procedures.

All scientific investigations have limitations, and this one has several important limitations to consider. First, results are derived from a limited amount of subjects and from a single institution, and therefore some degree of selection bias and sampling bias is expected. There might also be some statistical bias as the senior author was involved in all stages of data collection and analysis. Second, the procedures were performed for a variety of indications and not specifically for correction of the hallux valgus deformity. With that said, this relatively broad inclusion of procedures might be more consistent with clinical practice and have led to a more diverse and robust data set. And third, this is a

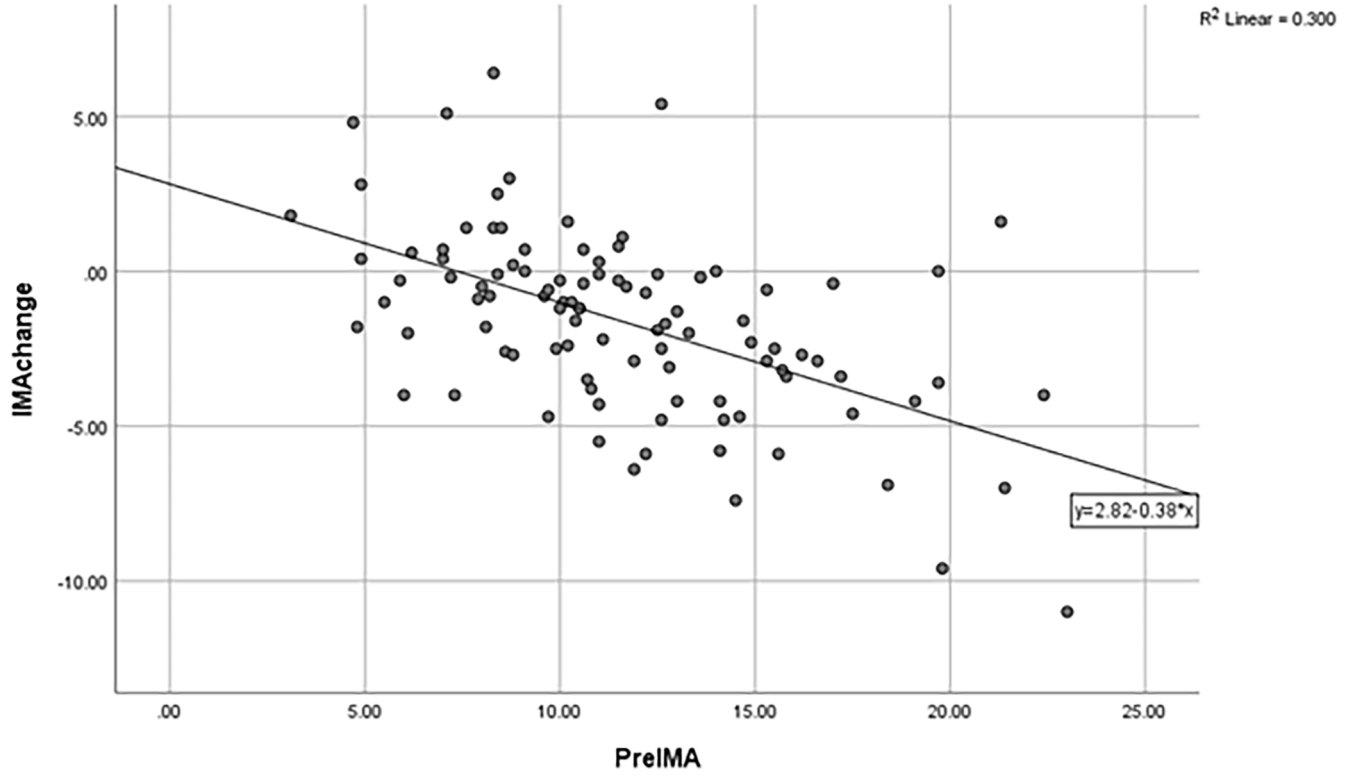

Fig. 1. Correlation analysis of the first intermetatarsal angle.
The relationship is described by the equation Y = 2.82 – 0.38X indicating that for every one degree of pre-operative intermetatarsal angle deformity over approximately 7 degrees, 0.38 degrees of post-operative correction might be expected.

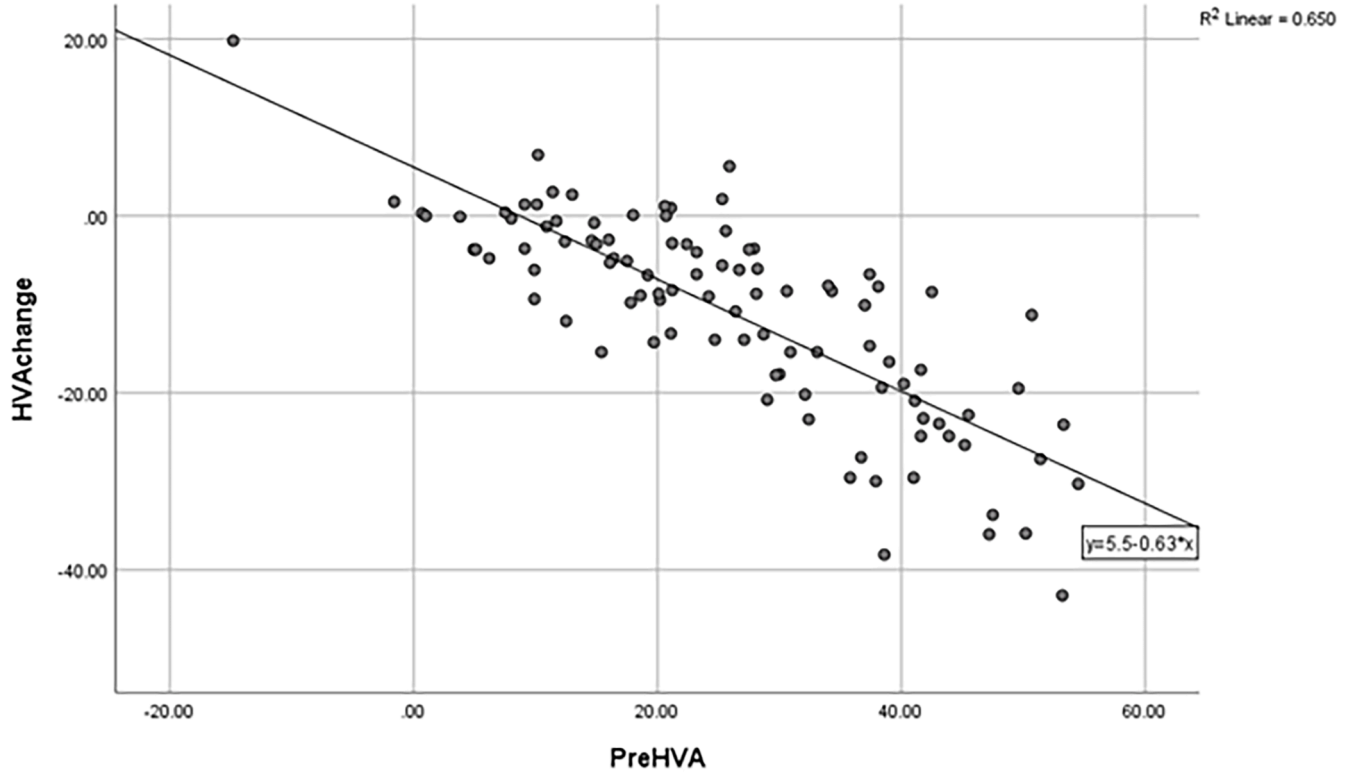

Fig. 2. Correlation analysis of the hallux valgus angle.
The relationship is described by the equation Y = 5.5 – 0.63X indicating that for every one degree of pre-operative hallux valgus angle deformity over approximately 9 degrees, 0.63 degrees of post-operative correction might be expected.

study of radiographic outcomes and not patient-reported or functional outcome measures.

In conclusion, results of this investigation demonstrate a statistical correlation between intermetatarsal angle and hallux valgus angle correction following first metatarsal-phalangeal joint arthrodesis, however, other factors are likely contributing to this relationship beyond what is studied here. They might also provide foot and ankle surgeons with a modest degree of prediction for expected angular correction following the procedure based on pre-operative deformity.

Declaration of competing interest

Meyr is a JFAS section editor and on the ACFAS Board of Directors executive committee.

References

[1] Dayton P, Feilmeier M, Hunziker B, Nielsen T, Reimer RA. Reduction of the intermetatarsal angle after first metatarsal phalangeal joint arthrodesis: a systematic review. J Foot Ankle Surg 2014;53(5):620–3.

[2] Sung W, Kluesner AJ, Irrgang J, Burns P, Wukich DK. Radiographic outcomes following primary arthrodesis of the first metatarsophalangeal joint in hallux abductovalgus deformity. J Foot Ankle Surg 2010;49(5):446–51.

[3] Cronin JJ, Limbers JP, Kutty S, Stephens MM. Intermetatarsal angle after first metatarsophalangeal joint arthrodesis for hallux valgus. Foot Ankle Int 2006;27(2):104–9.

[4] von Deimling C, Tondelli T, Brunner S, Andronic O, Graf AD. Achieving high union rates after first metatarsophalangeal joint arthrodesis: Radiographic outcomes and technical pitfalls. World J Orthop 2023;14(6):436–42.

[5] Roth W, Hoch C, Gross CE, Scott DJ. First metatarsophalangeal arthrodesis outcomes for hallux rigidus versus hallux valgus. Foot Ankle Surg 2023;29(1):50–5.

[6] Cravey KS, Barron IM, Atway SA, Anthony ML, Monson EK. Intermetatarsal angle and hallux abductus angle reduction after first metatarsophalangeal joint arthrodesis in mild, moderate, and severe hallux valgus. J Am Podiatr Med Assoc 2021;111(2):Article_3.

[7] McKean RM, Bergin PF, Watson G, Mehta SK, Tarquinio TA. Radiographic Evaluation of Intermetatarsal Angle Correction Following First MTP Joint Arthrodesis for Severe Hallux Valgus. Foot Ankle Int 2016;37(11):1183–6.

[8] Dusch T, Guareschi A, Moore A, Hoch C, Gross CE, in Scott DJChanges. Radiographic Alignment Following Metatarsophalangeal Fusion, Distal Metatarsal Osteotomy, and Lapidus. Foot Ankle Spec. 2023 Oct 16:19386400231203114.

[9] Dayton P, Lopiccolo J, Kiley J. Reduction of the intermetatarsal angle after first metatarsophalangeal joint arthrodesis in patients with moderate and severe metatarsus primus adductus. J Foot Ankle Surg 2002;41(5):316–9.

[10] Costa MT, Neto D, Kojima FH, Ferreira RC. Evaluation of the intermetatarsal angle after the arthrodesis of the first metatarsaophalangeal joint for treatment of the hallux valgus. Rev Bras Ortop 2015;47(3):363–7.

[11] Hoveidaei AH, Roshanshad A, Vosoughi AR. Clinical and radiological outcomes after arthrodesis of the first metatarsophalangeal joint. Int Orthop 2021;45(3):711–9.

[12] Dalat F, Cottalorda F, Fessy MH, Besse JL. Does arthrodesis of the first metatarsophalangeal joint correct the intermetatarsal M1M2 angle? Analysis of a continuous series of 208 arthrodeses fixed with plates. Orthop Traumatol Surg Res 2015;101(6):709–14.

[13] Pydah SK, Toh EM, Sirikonda SP, Walker CR. Intermetatarsal angular change following fusion of the first metatarsophalangeal joint. Foot Ankle Int 2009;30(5):415–8.

[14] Dayton P, Kauwe M, Kauwe JS, Feilmeier M, Hirschi J. Observed changes in first metatarsal and medial cuneiform positions after first metatarsophalangeal joint arthrodesis. J Foot Ankle Surg 2014;53(1):32–5.

[15] DE Cock L, Wuite S, Vleugels WJ, Burssens A, Matricali GA. Which parameters predict correction of the intermetatarsal angle after first metatarsophalangeal fusion? Acta Orthop Belg 2023;89(3):507–14.

[16] Baron RL, Strugielski CF, Christman RA. Positioning techniques and terminology. In: Christman RA, editor. Foot and Ankle Radiology. St. Louis, Missouri: Churchill Livingstone; 2003. p. 44–73.

[17] Sanner WH. Foot segmental relationships and bone morphology. In: Christman RA, editor. Foot and Ankle Radiology. St. Louis, MO: Churchill Livingstone; 2003. p. 272–300.

[18] Hardy RH, Clapham JC. Observations on hallux valgus. J Bone Joint Surg Br 1951;33-B(3):376–91.