Apparent Curvature of the Lateral First Metatarsal Shaft and Hallux Proximal Phalanx as a Surrogate for Frontal Plane Deformity in the Hallux Abducto Valgus Deformity

Todd Hasenstein, DPM
Eric T. Meyr
Andrew J. Meyr, DPM

INTRODUCTION

Hallux abducto valgus (HAV or the bunion deformity) is a commonly encountered patient complaint widely considered to be a triplanar deformity, with involvement of the transverse, sagittal and frontal planes (1-3). Despite this, most of the published literature has focused on clinical and radiographic evaluation in the transverse plane only, with relatively little information available regarding the frontal and sagittal planes (4-19). Further, those studies which have evaluated the frontal plane have relied on intra-operative findings and/or the sesamoid axial radiographic projection (8,10,13,20-23).

We have observed that it is common in clinical practice to associate increased frontal plane deformity with an increased relative "curvature" of the lateral first metatarsal shaft and/or lateral hallux proximal phalanx shaft on the dorsoplantar (DP) radiographic projection (24-26). In other words, as frontal plane deformity increases, the curvature of the lateral first metatarsal might appear to be radiographically more pronounced. However, we are unaware of any specific or quantitative assessment of this. Therefore, the objective of this investigation was to associate the lateral curvature of the first metatarsal and hallux proximal phalanx with frontal plane deformity in the HAV deformity.

MATERIALS AND METHODS

The radiographs of patients from the Temple University Foot and Ankle Institute were retrospectively reviewed for the present investigation. Included in the present study were consecutive patients who had undergone radiographic evaluation with at least a weight-bearing DP foot radiograph, a weight-bearing lateral foot radiograph, and a weight-bearing sesamoid axial radiograph prior to undergoing elective reconstruction of the first metatarsophalangeal joint for the HAV deformity. Radiographs were excluded with a history of previous foot or ankle surgery and/or evidence of osseous trauma. Institutional review board approval was obtained.

All anterior-posterior (AP) and lateral radiographs were taken with standard technique in the angle and base of gait, and performed by 1 of 2 radiologic technicians with a combined 50 years of clinical experience (27). The purpose of the angle and base of gait is to radiographically represent the structure of the foot during weight-bearing midstance. The angle of gait is defined as the degree of abduction or adduction of the foot from midline during gait, while the base of gait is defined as the distance between both heels during the gait cycle. At our facility, the patient is positioned into the angle and base of gait by the radiology technician following an observation of gait and stance.

Five measurements were recorded from each standard weight-bearing AP radiograph, and included the first intermetatarsal angle (IMA), hallux abductus angle (HAA), tibial sesamoid position (TSP), first metatarsal area (Met1_Area), and hallux proximal phalanx area (Phalanx_Area) (28). The DP radiograph was defined as the film placed in a horizontal position flat on the orthoposer with the tubehead angulated 15 degrees from vertical, directed posteriorly, and aimed at the second metatarsocuneiform joint. The first IMA was defined as the angular relationship between the bisectors of the first and second metatarsal shafts. Bisectors were determined by individually identifying the proximal and distal midpoints of the diaphyseal-metaphyseal junctions, and then forming a line connecting the 2 points. This was considered a continuous variable. The HAA was defined as the angular relationship between the bisectors of the first metatarsal and hallux proximal phalanx shafts. This was considered a continuous variable. The TSP was measured on a 7-point scale as described by Hardy and Clapham (12). This was considered a categorical variable.

The Met1_Area was defined as the area located between a line connecting the distal-lateral most first metatarsal head to the proximal-lateral most metatarsal base and the lateral aspect of the first metatarsal (Figure 1). The calculation of this area was completed following conversion of the radiographs to .pdf format and utilizing the measurement function of Adode Acrobat (Adobe Systems, information about area measurement function available at: https://helpx.adobe.com/acrobat/using/grids-guides-measurements-pdfs.html). This produced an area in units of mm^2. Our working assumption was that greater "curvature" of the metatarsal

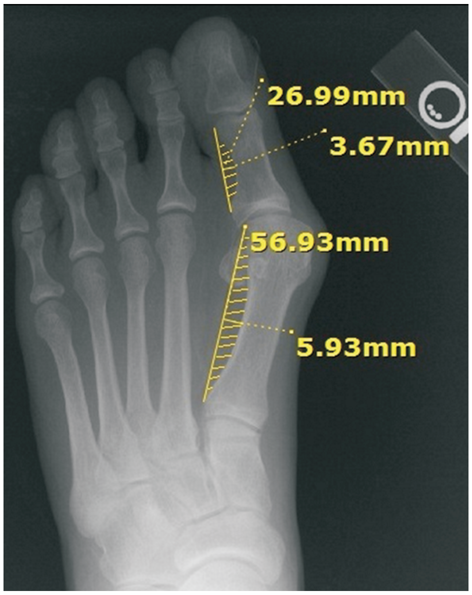

Figure 1. Definition of the Met1_Area.

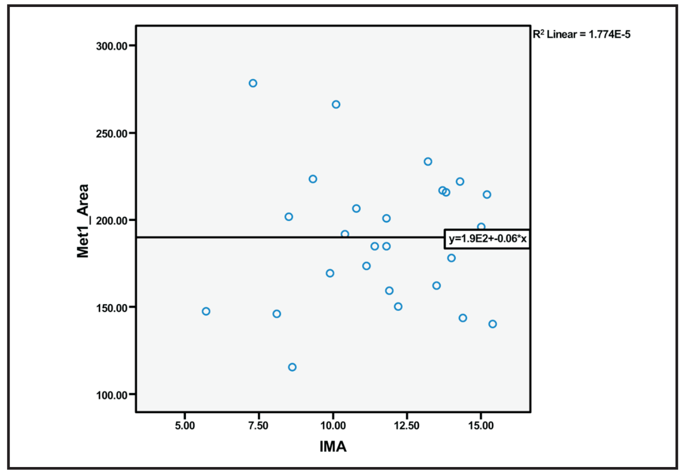

Figure 2. Relationship of the transverse plane IMA to the Met1_Area.

shaft would result in a greater area calculation. A similar process was utilized to determine the Phalanx_Area based on the distal-lateral most aspect of the hallux proximal phalanx head and proximal-lateral most aspect of the hallux proximal phalanx base.

One measurement was recorded from each standard weight-bearing lateral radiograph, and included the first metatarsal inclination angle (Inclin_1). The lateral radiograph was defined as the image receptor placed in an upright, vertical position in the orthoposer with the tube head angulated at 90 degrees from vertical, directed medially, and aimed at the lateral cuneiform/cuboid (27). The first metatarsal inclination angle was defined as the resultant angulation between the supporting surface and the longitudinal bisection of the first metatarsal (28). This was considered a continuous variable.

Two measurements were recorded from each standard weight-bearing sesamoid axial radiograph, and included the tibial sesamoid grade (SG) and sesamoid rotation angle (SRA). The sesamoid axial radiograph was defined as the image receptor placed in an upright, vertical position in the orthoposer with the tubehead angulated at 90 degrees from vertical, directed anteriorly, and aimed at the midline of the plantar foot (27). The foot is positioned in a sesamoid axial positioning device, which dorsiflexes the metatarsophalangeal joints and allows for visualization of the metatarsal-sesamoid articulation. The tibial sesamoid grade was defined as the position of the tibial sesamoid relative to the intersesamoid ridge, and categorized on the 4-point scale described by Yildirim et al (10). This was considered a categorical variable. The sesamoid rotation angle was measured as the angular relationship between the weight-bearing surface (positioning device) and a line connecting the most inferior aspect of the medial and lateral sesamoids as described by Kuwano et al (13). This was considered a continuous variable.

The radiographic measurements were performed by a single author (TH) and confirmed by a second author (AJM) using computerized digital software (Opal-RAD PACS, Viztek), which measured to a precision of 0.1°. The area measurements were performed by another author (ETM) and confirmed by a second author (AJM). After taking the radiographic measurements, the data were stored in a personal computer for subsequent statistical analysis. All statistical analyses were performed using Statistical Analysis Systems software, version 9.2 (SAS Institute) by one study author (AJM). Each parameter was graphically depicted against each other on a frequency scatter plot and analyzed with both a regression line and Pearson correlation coefficient to evaluate for relationships among the variables.

RESULTS

Measurements were performed on a total of 26 feet (14 right; 7 male). The subject mean ± SD age was 40.4 ± 15.3 years (range 18-63).

Relationship of the transverse plane to the curvature area

Figure 2 demonstrates the relationship of the transverse plane IMA to the Met1_Area. No substantial relationship was observed with a corresponding Pearson's correlation coefficient of -0.004 (P = 0.984). Figure 3 demonstrates the relationship of the transverse plane IMA to the Phalanx_Area. No substantial relationship was observed with a corresponding Pearson's correlation coefficient of -0.221 (P = 0.278). Figure 4 demonstrates the relationship of the transverse plane HAA to the Met1_Area. No substantial relationship was observed with a corresponding Pearson's correlation coefficient of -0.102 (P = 0.621).

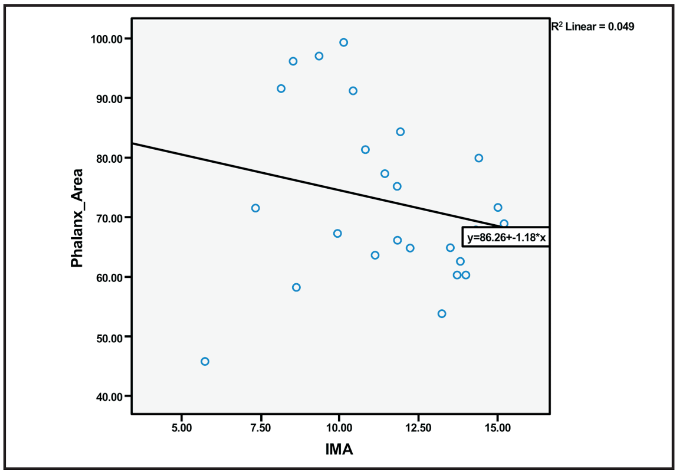

Figure 3. Relationship of the transverse plane IMA to the Phalanx_Area.

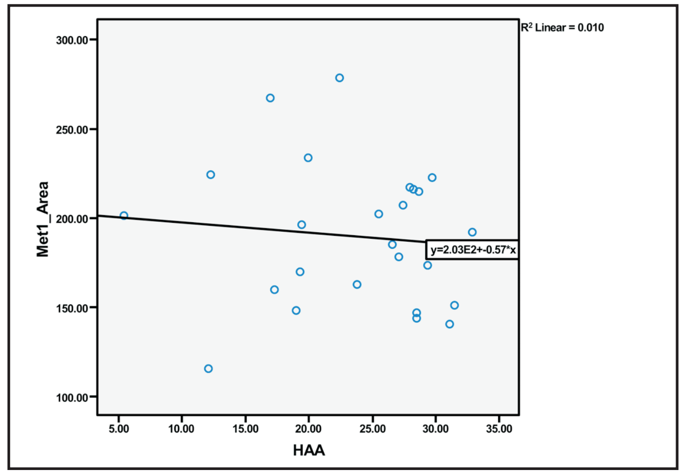

Figure 4. Relationship of the transverse plane HAA to the Met1_Area.

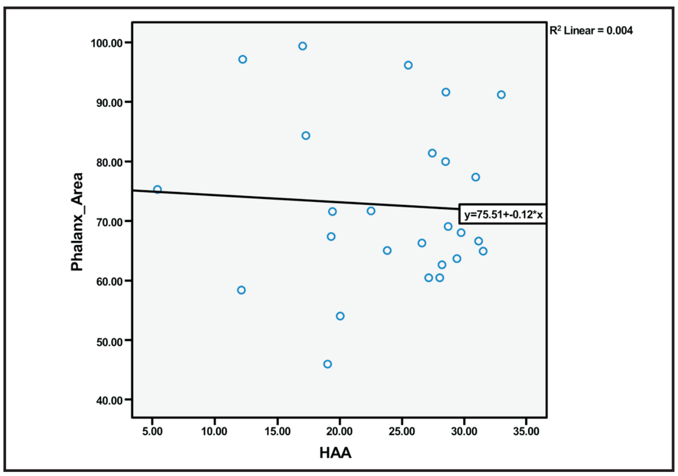

Figure 5. Relationship of the transverse plane HAA to the Phalanx_Area.

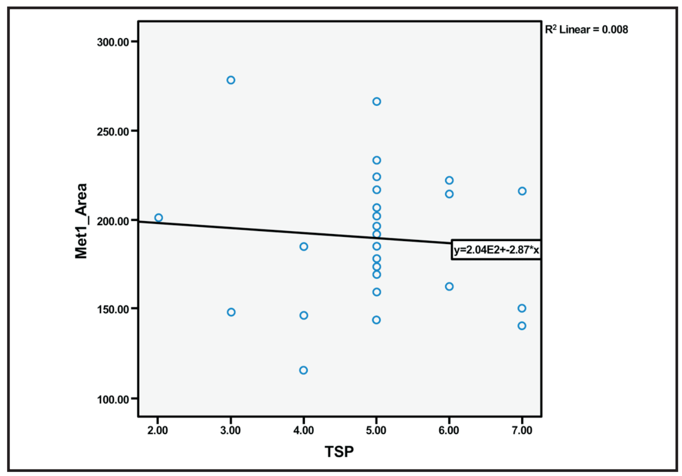

Figure 6. Relationship of the transverse plane TSP to the Met1_Area.

Figure 5 demonstrates the relationship of the transverse plane HAA to the Phalanx_Area. No substantial relationship was observed with a corresponding Pearson's correlation coefficient of -0.060 (P = 0.770).

Figure 6 demonstrates the relationship of the transverse plane TSP to the Met1_Area. No substantial relationship was observed with a corresponding Pearson's correlation coefficient of -0.087 (P = 0.673).

Figure 7 demonstrates the relationship of the transverse plane MSP to the Phalanx_Area. No substantial relationship was observed with a corresponding Pearson's correlation coefficient of -0.034 (P = 0.870).

Relationship of the frontal plane to the curvature area

Figure 8 demonstrates the relationship of the frontal plane TSG to the Met1_Area. No substantial relationship was observed with a corresponding Pearson's correlation coefficient of -0.193 (P = 0.344). Figure 9 demonstrates the relationship of the frontal plane TSG to the Phalanx_Area. No substantial relationship was observed with a corresponding Pearson's correlation coefficient of -0.345 (P = 0.084).

Figure 10 demonstrates the relationship of the frontal plane SRA to the Met1_Area. No substantial relationship was observed with a corresponding Pearson's correlation coefficient of 0.013 (P = 0.949). Figure 11 demonstrates the relationship of the frontal plane SRA to the Phalanx_Area. No substantial relationship was observed with a corresponding Pearson's correlation coefficient of -0.030 (P = 0.886).

Relationship of the sagittal plane to the curvature area

Figure 12 demonstrates the relationship of the sagittal plane Inclin_1 to the Met1_Area. No substantial relationship was observed with a corresponding Pearson's correlation coefficient of -0.182 (P = 0.374). Figure 13 demonstrates the relationship of the sagittal plane Inclin_1 to the Phalanx_Area. No substantial relationship was observed with a corresponding Pearson's correlation coefficient of -0.030 (P = 0.886).

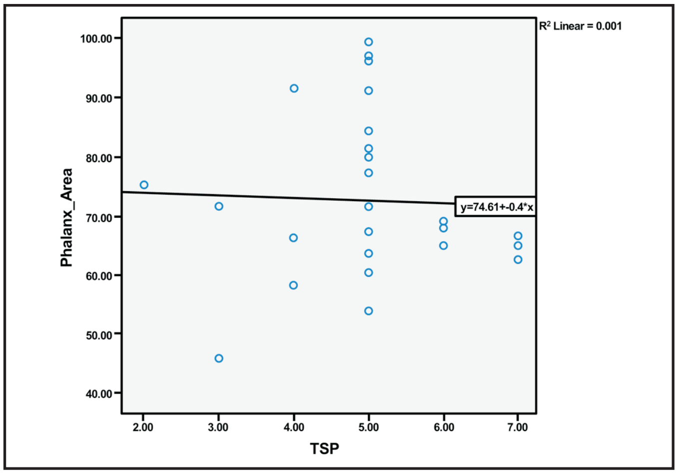

Figure 7. Relationship of the transverse plane MSP to the Phalanx_Area.

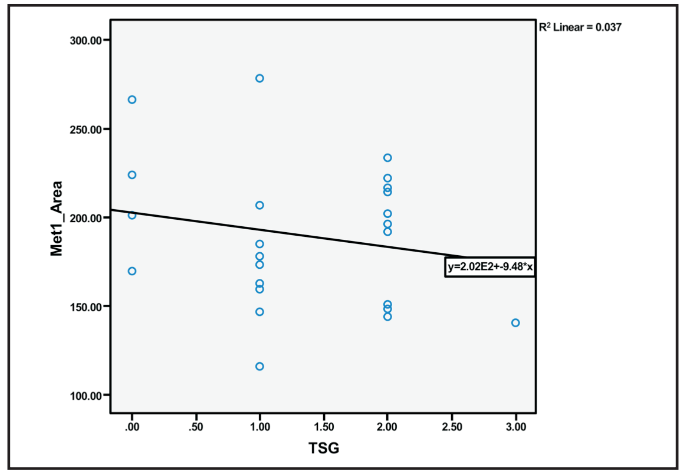

Figure 8. Relationship of the frontal plane TSG to the Met1_Area.

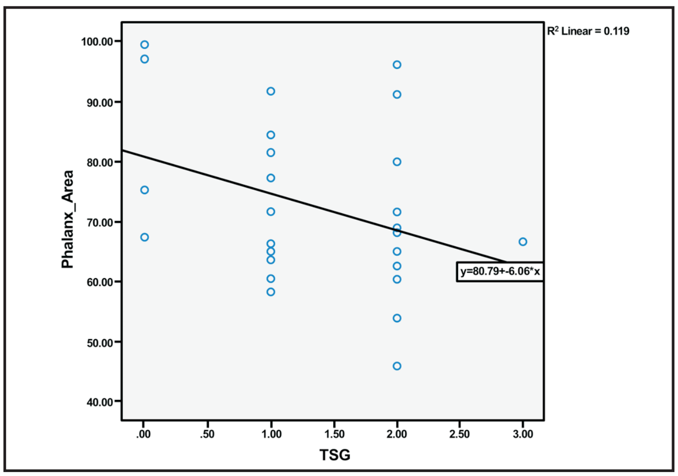

Figure 9. Relationship of the frontal plane TSG to the Phalanx_Area.

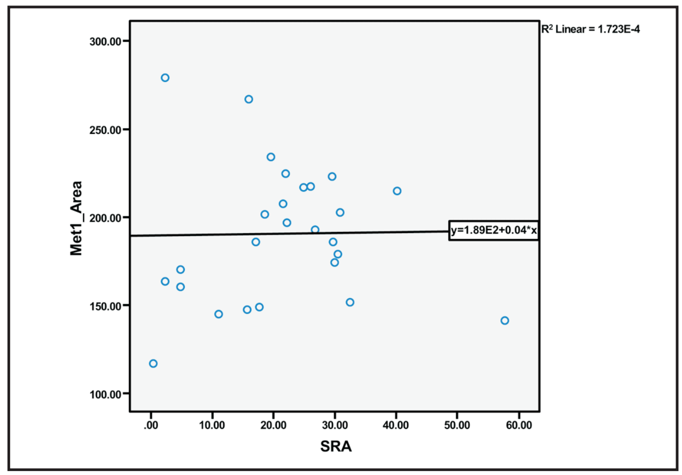

Figure 10. Relationship of the frontal plane SRA to the Met1_Area.

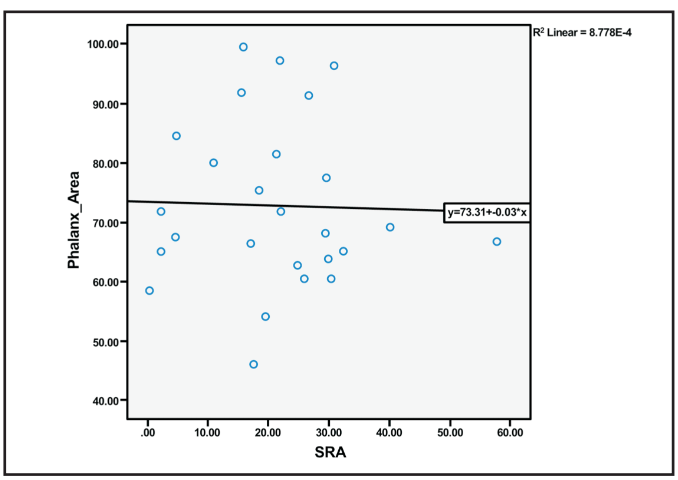

Figure 11. Relationship of the frontal plane SRA to the Phalanx_Area.

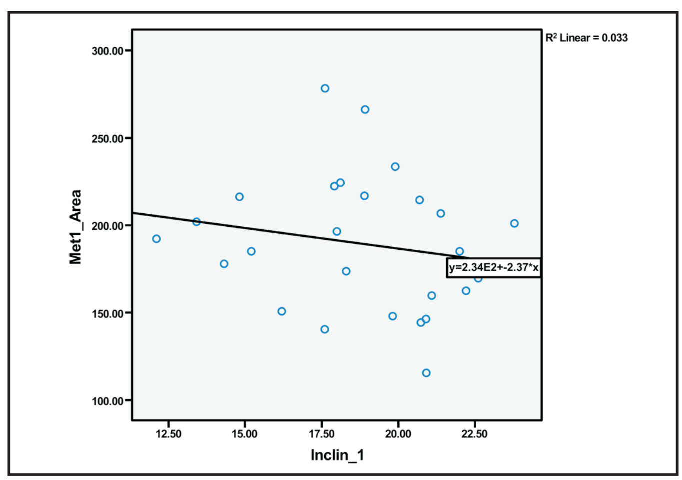

Figure 12. Relationship of the sagittal plane Inclin_1 to the Met1_Area.

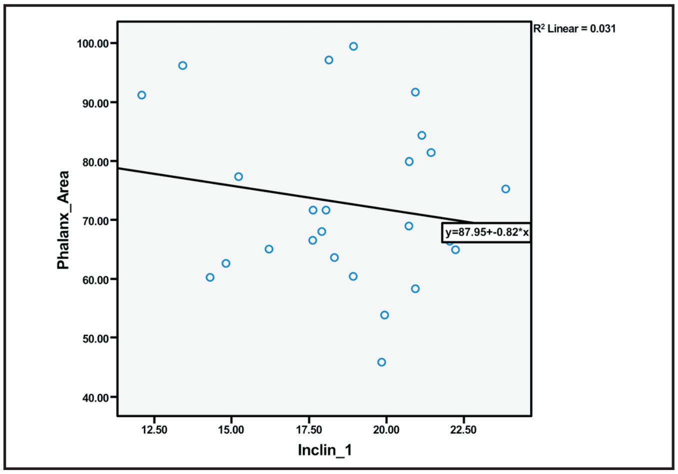

Figure 13. Relationship of the sagittal plane Inclin_1 to the Phalanx_Area.

DISCUSSION

The results of the present investigation have provided a quantitative comparison of commonly performed angular radiographic measurements of the HAV deformity in relation to the curvature on the lateral aspect of the first metatarsal shaft and hallux proximal phalanx. As with any scientific investigation, critical readers are encouraged to review the study design and results in order to reach their own conclusions. The following represents our conclusions based on the preceding results, and as scientists, we also never consider data to be definitive but do think that these results are worthy of attention and future investigation.

We primarily conclude that these results provide objective evidence that does not support use of the relative curvature of the lateral aspects of the first metatarsal and hallux proximal phalanx as surrogates for frontal plane deformity in HAV. We did not observe significant nor clinical substantial relationships between this curvature and measurements of frontal plane deformity, nor any relationship between this measurement with transverse or sagittal plane parameters. We take these findings to mean that evaluation of frontal plane deformity warrants independent evaluation and analysis, instead of simply inferring the presence or absence of deformity from other views.

The present study has several important limitations. Data were collected from a single institution, using a limited number of patients, and therefore these results might not be representative of our entire institution or other institutions. There may also be some disagreement among foot and ankle surgeons with respect to the specific radiographic measurements that we included in this investigation. We did not evaluate all possible radiographic measures that can be used in the evaluation of the HAV deformity, and there might be some disagreement with respect to the exact definition and measurement of these angles. Another limitation of any radiographic study is the variability of the positioning and projection of the radiographs, particularly when multiple radiographic technicians are involved. We also utilized a single evaluator, which could be considered both a limitation and a strength. The area measurements presented here are also a unique calculation. We are unaware of any previous attempt to objectively quantify osseous curvature. It is possible that our measurement is invalid and/or unreliable.

In conclusion, the results of this study provide objective quantitative data against use of the lateral curvature of the first metatarsal and hallux proximal phalanx as a surrogate for frontal plane deformity in the HAV deformity.

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