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Original Research

Quantitative Analysis of the Degree of Frontal Rotation Required to Anatomically Align the First Metatarsal Phalangeal Joint During Modified Tarsal-Metatarsal Arthrodesis Without Capsular Balancing

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ABSTRACT

The data from 35 consecutive patients with hallux valgus undergoing triplane arthrodesis at the first tarsal metatarsal joint were studied to determine the amount of first metatarsal frontal plane rotation (supination) needed to anatomically align the first metatarsal phalangeal joint on an anterior posterior radiograph without soft tissue balancing at the first metatarsal phalangeal joint. Radiographs were measured both pre- and postoperatively to assess the 1-2 intermetatarsal angle, hallux abductus angle, and tibial sesamoid position (TSP). The mean amount of varus (supination) rotation performed during correction was 22.1° ± 5.2° and the mean amount of intermetatarsal angle reduction achieved after completion of the procedure was 6.9° ± 3.0°. The TSP changed by a mean of 3.3° ± 1.2°. A series of univariate linear regression analyses was performed to analyze the relationship between the frontal plane rotation of the first metatarsal performed during the operation and the preoperative intermetatarsal angle, hallux abductus angle, and TSP. Greater preoperative TSP scores were associated with greater intraoperative varus (supination) rotation required for joint alignment. Direct observation of the alignment changes at the first metatarsal phalangeal joint after metatarsal rotation without distal procedures strengthened the notion that the frontal plane rotational position plays an important role in the bunion deformity.

The inconsistency in clinical outcomes when using popular metatarsal osteotomies with supplementary soft tissue balancing for hallux abducto valgus (HAV) correction prompted us to explore the role of frontal plane rotation of the first metatarsal as a component of operative treatment. Available investigations regarding bunion-affected feet have reported both the first metatarsal and the phalangeal components of the first metatarsal phalangeal joint (MTPJ) in a valgus (pronated) position (1–4). Studies reporting the observed frontal plane position of the first metatarsal include both qualitative and quantitative descriptions. Grode and McCarthy (1) and Eustace et al (2) commented on the directional description, with the terms *eversion* and *pronation* used to, respectively, describe the valgus frontal plane position of the first metatarsal. Scranton and Rutkowski (3) reported both with a preoperative mean metatarsal pronation value of 14.5°, and Mortier et al (4) reported a mean metatarsal pronation of 12.7°.

Recent reports describing the surgical manipulation of first metatarsal frontal plane position have reported data using a qualitative or directional description alone (5–9). The purpose of the present investigation was to report our results quantifying the amount of frontal plane rotation (supination) used to align the first MTPJ during a modified tarsal metatarsal arthrodesis without distal joint capsular work. We also report the associations between common preoperative radiographic HAV measurements and the degree of rotation imparted surgically in our patients.

Patients and Methods

The Des Moines University institutional review board granted exempt status to our retrospective review. A medical record review was conducted of 35 consecutive

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patients (34 females, 1 male) with symptomatic HAV for whom conservative treatment had failed. These patients had undergone a tarsal metatarsal arthrodesis modified to correct the frontal plane rotational component of the deformity from September 2012 to July 2014. Patients were excluded if previous first ray surgery had been performed. The criteria for inclusion in the study were as follows: (1) intraoperative measurement of the degree of frontal plane rotational correction and (2) pre- and postoperative anteroposterior radiographs available.

The surgical technique consisted of a dorsal incision made medial to the extensor hallucis longus tendon and lateral to the tibialis anterior tendon from the mid-first metatarsal shaft to the proximal aspect of the medial cuneiform. Direct dissection was carried to the level of the bone, with the periosteal tissue reflected as part of a full-thickness flap. A custom-designed protractor, used during tarsal metatarsal corrective fusion for the past several years by the senior author (P.D.) to guide correction, was used to perform the rotational measurements. The measurement device was placed to overlie the first tarsal metatarsal joint, and 3 pins were inserted through the device to capture an arbitrary zero point of rotation. The initial pin placement was reproduced in all patients, because the pins were placed in line through the device. Two pins were inserted into the cuneiform and one pin into the metatarsal shaft. After the pins were inserted, the device was removed, and the joint was appropriately resected to preserve the metatarsal length and correct the transverse aspect of the deformity. After transverse correction was complete, the first MTPJ joint was observed under a fluoroscopic anteroposterior view and manipulated by pushing the metatarsal pin to rotate the first metatarsal in a varus direction (supination) until the MTPJ was aligned both radiographically and clinically. Our observation criteria for joint alignment consisted of an assessment of aspects of the MTPJ that the published data have suggested are related to rotational position, including the distal metatarsal articular angle (10,11), the hallux abductus angle (HAA) (7), the prominence of the medial eminence (1), lateral rounding of the metatarsal head (12), and the tibial sesamoid position (TSP) (13–15) (Fig. 1).

After temporary fixation, the device was turned perpendicular to its initial position and placed on the pins in the medial cuneiform. These 2 pins served as a stable reference point of the original rotational position. The degree of supination used to reduce the first MTPJ was measured by comparing the position of the metatarsal pin after rotational correction to the scale built into the measurement device, and the data were recorded (Fig. 2). Final fixation was performed in this same position.

The pre- and postoperative radiographs were measured by 1 of us (M.K.) to assess the 1-2 intermetatarsal angle (IMA), HAA, and TSP. The measurements were consistent with those described by Hardy and Clapham (15), with the TSP measured on a scale of 1 to 7. All analyses were conducted by 1 of us (R.R.) using SPSS, version 22 (IBM Corp., Armonk, NY). First, a series of paired t tests were conducted to examine the differences in pre- and postoperative angle measurements. Next, a series of univariate linear regression analyses was conducted to examine the effects of the preoperative IMA, HAA, and TSP on the postoperative varus rotation. All beta (β) values reported are unstandardized. Statistical significance was set at the 5% level ($p \leq .05$).

Results

Of the 35 patients identified, 34 (36 feet), with a mean follow-up period of 5 (range 3 to 12, median 5) months, met our inclusion criteria. One (2.9%) patient did not have the amount of rotation imparted recorded in the medical record due to the measurement device being unavailable at the time of their surgery. Additionally, the HAA value of 1 (2.9%) patient was not included in the statistical analysis because a phalangeal osteotomy had also been performed. This did not affect the rotational measurement; therefore, that patient was not excluded from our study.

Complete descriptive statistics are listed in the Table. The mean change in the IMA following the procedure was 6.97° (SD = 3.04°), $p < .001$; mean change in HAA was 13.61 (SD = 6.46), $p < .001$; mean change in TSP was 3.33 (SD = 1.22), $p < .001$ positions respectively. In sum, all angles were significantly reduced from pre to post measurements. The average degree of rotation imparted to the first metatarsal to obtain MTPJ and sesamoid alignment was 22.1° ± 5.15°. We conducted a series of hierarchical linear regression analyses. The effects of the preoperative IMA and HAA on operative varus rotation were not significant ($p > .2$). The effect of the preoperative TSP on varus rotation was statistically significant ($\beta = 1.28$, standard error = 0.61, $p = .043$). Specifically, greater preoperative TSP scores were associated with greater intraoperative varus rotation required for joint alignment.

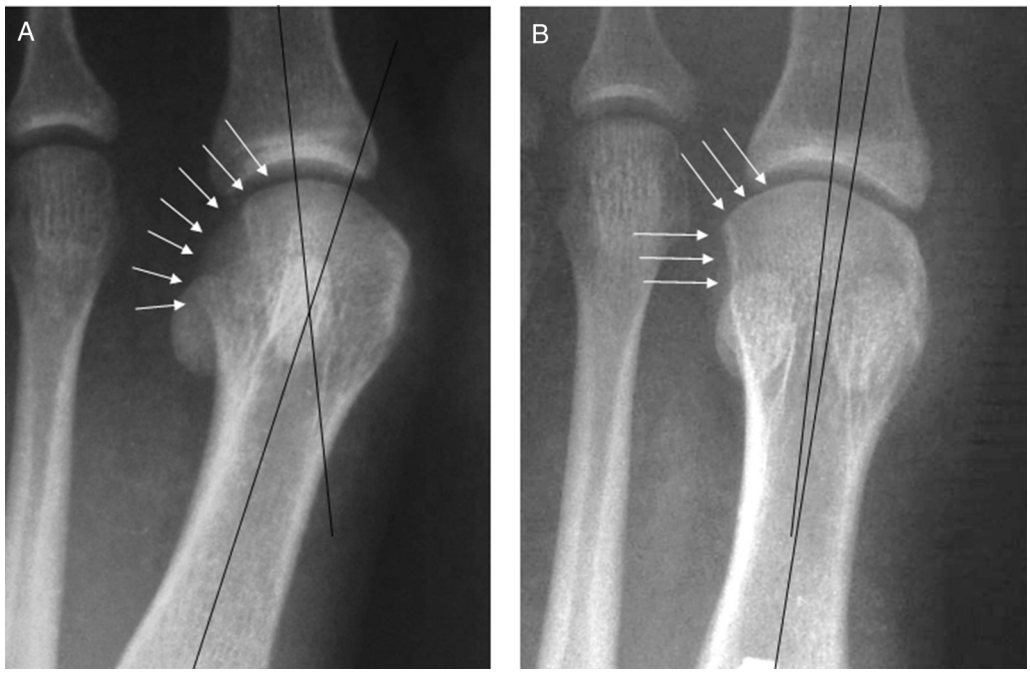

Fig. 1. (*A* and *B*) Aspects of the first metatarsal phalangeal joint that the published data show to be indicative of the frontal plane rotational position, including the prominence of a medial eminence, lateral deviation of the tibial sesamoid, lateral shape of the metatarsal head, and proximal articular set angle. These changes can be observed on these pre- and postoperative anteroposterior radiographs (*A* and *B* respectively) after Lapidus arthrodesis with varus rotation (supination) of the metatarsal without capsular balancing. *Arrows* indicate the change in the lateral roundness of the first metatarsal head. With metatarsal pronation, the lateral plantar aspect of the metatarsal becomes more prominent; the rounding is reduced with supination. This sign is both an indicator of rotational position and a predictor of recurrence (12). Note the change in the prominence of the medial eminence without medial resection and the sesamoid position after rotational correction without capsular balancing. These collective changes to the metatarsal phalangeal joint can be used to assess the joint position intraoperatively.