The Multiplanar Effect of First Metatarsal Osteotomy on Sesamoid Position

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ABSTRACT

The standard classification system used to measure the sesamoids in the evaluation of hallux abductovalgus is a uniplanar description of a multiplanar deformity. Additionally, it cannot accurately describe a true measure of sesamoid positional change in the perioperative period because the first metatarsal is laterally transposed during corrective surgery. The intended emphasis of this investigation is to evaluate the sesamoid position in multiple planes relative to a stationary anatomical landmark following first metatarsal osteotomy for the surgical correction of hallux abductovalgus deformity. A retrospective radiographic review of 46 feet in 38 patients demonstrated statistically significant (P < .001) differences between preoperative and postoperative values for the first intermetatarsal angle, hallux abductus angle, sesamoid rotation angle, tibial sesamoid position, and tibial sesamoid grade. However, there was no significant difference in the sesamoid position in both the transverse (P = .07) and frontal (P = .29) planes when measured relative to the stationary second metatarsal. Based on the preceding results, the appropriate expected surgical outcome of hallux abductovalgus correction may be to relocate the first metatarsal on top of the relatively immobile sesamoids.

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The 7-point Hardy and Clapham classification system used to evaluate the sesamoids in relation to the first metatarsal in perioperative planning for hallux abductovalgus deformity takes into consideration 2 variables: (1) transverse plane tibial sesamoid position, and (2) transverse plane first metatarsal position (Figure 1) (1). Using this classification system, a number of studies have reported substantial changes in the tibial sesamoid position following surgical intervention for the repair of hallux abductovalgus (2–11). However, because one of these variables, the first metatarsal, is usually laterally transposed during surgical correction, this measurement may not accurately describe a change in the position of the tibial sesamoid. In fact, change in the position of the tibial sesamoid is more accurately measured relative to a stationary anatomical landmark. This concept was emphasized by Judge et al (12), who demonstrated no significant change in the transverse plane sesamoid position relative to the second metatarsal following surgical correction of hallux abductovalgus.

Further, hallux abductovalgus is widely regarded as a triplanar deformity with the sesamoids described as laterally displaced, or subluxated, into the first intermetatarsal space in the frontal and transverse planes (13–21). Some authors have even successfully quantified frontal plane radiographic sesamoid deviation (22, 23). However, because the tibial sesamoid position classification is a uniplanar measurement that only measures change in the transverse plane, standard radiographic quantification of the tibial sesamoid position does not provide the surgeon with a complete impression of the target anatomy. In an effort to better understand the tibial sesamoid position in regard to repair of hallux abductovalgus, we undertook a retrospective evaluation of radiographs to assess the sesamoid position in multiple planes relative to a stationary anatomical landmark, namely the second metatarsal, following bunionectomy involving first metatarsal osteotomy.

Patients and Methods

The radiographs of consecutive patients from the senior author’s (R.R.) practice were used for the purposes of this investigation. Inclusion criteria consisted of consecutive patients who underwent distal first metatarsal osteotomy for the correction of hallux abductovalgus deformity, with preoperative and postoperative anteroposterior (AP) and sesamoid axial radiographs, and a minimum radiographic follow-up of 8 weeks. All of the surgical procedures were performed by the senior author (R.R.), between January 2006 and June 2008, and consisted of chevron-type distal first metatarsal osteotomy with lateral transposition of the capital fragment and internal fixation with 1 or 2 interfragmental compression screws. A lateral release consisting of sequential sectioning of the deep transverse intermetatarsal ligament, conjoint tendon of the adductor hallucis, and ligamentous release of the fibular sesamoid was also performed in all cases. No direct medial capsule work was performed in any of the cases.
All of the radiographs were taken in the angle and base of gait, and made by the senior author (R.R.), who also made all of the radiographic measurements. The measurements were made using a handheld protractor and rule, with clear acetate laid over the radiographs, which were viewed on a typical wall-mounted light box. Four measurements were recorded from each standard weight-bearing anteroposterior (AP) radiograph, including the first intermetatarsal angle (IMA), hallux abductus angle (HAA), tibial sesamoid position (TSP), and the tibial sesamoid-second metatarsal distance (TS-MT2D). The first IMA was defined as the angular relationship between the bisectors of the first and second metatarsal shafts (24). The bisectors of the first and second metatarsals were determined by individually identifying the proximal and distal midpoints of the diaphyseal-metaphyseal junctions, and then forming a line connecting the 2 points (12). The HAA was defined as the angular relationship between the bisectors of the first metatarsal and hallux proximal phalanx shafts (24). The TSP was determined by placing the medial border of the tibial sesamoid to a perpendicular of the bisector of the second metatarsal (25). The TS-MT2D was determined by placing the medial border of the tibial sesamoid to a perpendicular of the bisector of the second metatarsal (25).

Fig. 1. The 7-point tibial sesamoid position classification. The 7-point Hardy and Clapham tibial sesamoid classification system consists of 2 variables: transverse plane first metatarsal position and transverse plane tibial sesamoid position.

Fig. 2. Tibial sesamoid-second metatarsal distance. The tibial sesamoid-second metatarsal distance is defined as the distance from the medial border of the tibial sesamoid to a perpendicular of the bisector of the second metatarsal. (Reprinted from Judge MS, LaPointe S, Yu GV, Shook JE, Taylor RP. The effect of hallux abducto valgus surgery on the sesamoid apparatus position. J Am Podiatr Med Assoc 89(11–12):551–559, 1999; with permission.)

Fig. 3. Sesamoid axial positioning device. This sesamoid axial positioning device was used for all axial radiographic projections.
was measured on a 7-point scale as described by Hardy and Clapham (1, 24). The TS-MT2D was measured as the distance from the midpoint of the medial border of the tibial sesamoid to a line perpendicular to the bisector of the second metatarsal, as described by Judge et al (Figure 2) (12).

Three measurements were recorded from each standard weight-bearing sesamoid axial radiograph, and all of these were made using the same positioning device (Figure 3). The sesamoid rotation angle (SRA) was measured as the angular relationship between the weight-bearing surface (substrate) and a line connecting the most inferior aspect of the medial and lateral sesamoids, as described by Kuwano et al (22) (Figure 4).

The tibial sesamoid grade (TSG) was measured as the position of the tibial sesamoid relative to the intersesamoidal ridge, and categorized on the 4-point scale described by Yildirim et al (23) (Figure 5). The axial tibial sesamoid-second metatarsal distance (axTS-MT2D) is a new measurement that we introduce and define as the distance between the midpoint of the medial aspect of the tibial sesamoid and a line perpendicular to the bisector of the second metatarsal shaft, as viewed in the axial projection (Figure 6).

After making the radiographic measurements, the data were stored in a personal computer for subsequent statistical analyses. The measurements were then statistically compared using paired Student t tests, and statistical significance was defined at the 5% (P ≤ .05) level.

Results

A total of 46 feet in 38 patients (33 female) were included in the analysis. Age ranged from 26 to 70 years with a mean of 42.6 ± 10.7 years. The postoperative duration of follow-up ranged from 8 to 52 weeks, with a mean of 23.3 ± 11.5 years. Table 1 depicts the mean preoperative and postoperative values for the radiographic variables, as well as the probability of the null hypothesis for comparison of the preoperative and postoperative measurements, and the mean difference between the values. Statistically significant (P < .001) differences were observed for all of the measurements that referenced the first metatarsal, including the first IMA, HAA, and TSP in the AP radiographic view, and the SRA and TSG in the axial view. Measurements that referenced the second metatarsal instead of the first, namely the TS-MT2D in the AP and axial views, were not statistically significant (P = .07 and P = .29, respectively).

Discussion

Part of the impetus for this investigation was to add to our understanding of the relationship between the position of the tibial sesamoid and correction of hallux abductovalgus. Our findings were consistent with those of Judge et al (12), who noted no difference between the preoperative and postoperative position of the tibial sesamoid relative to the second metatarsal in the transverse plane. Additionally, we found no difference in the postoperative sesamoid position in the frontal plane, when the measurement referenced the second metatarsal. These findings indicate mobility of the first metatarsal relative to stable sesamoids, in association with lateral translocation of the capital fragment of the first metatarsal in bunion surgery. In essence, repair of the structural component of hallux abductovalgus entails relocation of the relatively mobile first metatarsal over the relatively immobile sesamoids. One might even say that the Hardy and Clapham classification system (1) is actually more a measure of first metatarsal position, rather than sesamoid position.

As with most scientific investigations, our findings raise more questions than they answer. The aforementioned difference in
perspective makes clear the importance of consistency in regard to making and measuring radiographs. In particular, we feel that it is important to consider the anatomical plane of the radiographic measurement, as well as the anatomical reference to which the tibial sesamoid is measured. For example, in this study, the transverse and frontal plane sesamoid positions were defined as the absolute distances between the tibial sesamoid and second metatarsal, but the true sesamoid position in these planes appears to be more complicated to ascertain and define. These measurements do not take into account rotational changes like those seen with the sesamoid rotation angle. Although the distance between the tibial sesamoid and the second metatarsal did not change in the frontal plane, the angular relationship between the sesamoids and another stationary landmark, the weight-bearing surface, as measured by the SRA, did statistically significantly change ($P < .001$). In other words, the sesamoid position did not change in the frontal plane when measured relative to the stationary second metatarsal, but the sesamoid position did change in the frontal plane when measured relative to the stationary weight-bearing surface. It is unclear at the present time if there is a stationary reference landmark to which all measurements can be made in order to accurately assess positional change.

It is also interesting to consider that a lateral first metatarsophalangeal joint (MTPJ) release was performed in all of the cases included in the analyses. One might hypothesize that the sesamoids would be expected to “move” more in the setting of a lateral release versus a hallux abductovalgus corrective procedure that does not include a lateral release. The results of this investigation did not demonstrate statistically significant differences in measurements related to the tibial sesamoid position relative to the second metatarsal after a lateral joint release had been performed. We feel that further work is required to determine exactly what clinical and functional effect the lateral release has on the apparent sesamoid position and hallux abductovalgus surgical correction. Based on the results of this investigation, the lateral release may be of most benefit when it influences the soft tissue structures maintaining the sesamoids relative to the first metatarsal in the frontal plane, or when it affects the soft tissue structures maintaining the first metatarsal relative to the second metatarsal in the transverse plane. Following this thought process, the lateral release may not be of benefit when it releases the soft tissue structures maintaining the sesamoids relative to the second metatarsal in the transverse plane.

Like all retrospective cohort studies, our investigation involved several methodological shortcomings that could have biased the results. We are fully aware of the potential limitations associated with using radiographic measurements to determine anatomical position and structural alignment, and although the surgeon made the measurements, we felt that using standard foot radiographs and manual outcomes measures, as well as established definitions of the outcomes of interest, probably increased the generalizability or our findings. Additionally, it can be difficult to reliably obtain a true first metatarsal bisection following first metatarsal osteotomy, despite our attempt to use rigid measurement technique performed by a single assessor. Moreover, the effect of medial first MTPJ capsule work was not specifically examined in this study, and future investigations will be required to determine its role in regard to changes in the apparent sesamoid position. Along this same line, we did not determine what effect, if any, change in the apparent sesamoid position has on functional outcomes and subjective clinical satisfaction. Because of this, we make no claims as to the potential influence that realignment of the sesamoids may have on patient satisfaction with their bunionectomy. Finally, we used Student $t$ test for our analyses, even though we assessed 46 feet in 38 patients and a nonparametric null hypothesis test may have been more appropriate.

In conclusion, our review of radiographs showed statistically significant ($P < .001$) differences between preoperative and postoperative measurements of the tibial sesamoid position that referenced the first metatarsal, including the first IMA, HAA, and TSP in the AP radiographic view, and the SRA and TSG in the axial view, in patients who underwent distal metaphyseal chevron osteotomy with lateral soft tissue release for the correction of hallux abductovalgus. Measurements that used the second metatarsal as the anatomical reference landmark, namely the TS-MT2D in the AP and axial views, did not reveal statistically significant differences between the preoperative and postoperative states ($P = .07$ and $P = .29$, respectively). It is the authors’ hope that this information can be used to further our understanding of the development and surgical correction of the deformity of hallux abductovalgus.

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References