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Comparison of Tibial Sesamoid Position on Anteroposterior and Axial Radiographs Before and After Triplane Tarsal Metatarsal Joint Arthrodesis

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ABSTRACT

We reviewed the radiographic results of a group of patients who had undergone triplane correctional tarsometatarsal arthrodesis for symptomatic hallux abducto valgus with metatarsus primus abducto valgus. Of the 21 feet included in the present review, 17 (81%) displayed radiographic findings of metatarsal pronation preoperatively based on axial sesamoid views and positive lateral round sign on anteroposterior radiographs. At a mean follow-up period of 5.2 ± 1.6 months, a significant improvement in the tibial sesamoid position (TSP) on both anteroposterior (AP) and axial radiographs was measured. A negative metatarsal round sign, indicating correction of coronal plane metatarsal rotation, was observed in 20 of the 21 feet (95.2%) on AP radiographic evaluation. All 21 patients (100%) had obtained resolution of sesamoid subluxation on the sesamoid axial view at the final follow-up examination. The sesamoid axial position was consistently normal when the round sign was absent, and the TSP was in the normal range of 1 to 3 on the AP radiograph. Sesamoid subluxation from the normal position with the tibial sesamoid on or lateral to the crista was noted in 4 feet (19%) preoperatively and 0 feet postoperatively. This confirmed that lateral round sign of the first metatarsal head and a high TSP noted on the AP radiograph are both related to metatarsal pronation and can be corrected concurrently with coronal plane varus rotation of the first metatarsal as a part of the procedure.

Most often, the severity of a bunion deformity is defined along a continuum defined using measurements from anteroposterior (AP) radiographs. These measurements include the 1-2 intermetatarsal angle (IMA), proximal articular set angle (PASA), hallux abduction angle, and tibial sesamoid position (TSP). Greater values for each of these measurements are associated with greater severity of bunion deformity and decisions regarding the procedure are made according to these observations. Using the most common radiographic measurements and algorithmic process, the deformity is largely defined as a singular plane (transverse) positional deformity. Although it is common to select from the >100 procedures to correct a bunion according to this radiographic severity scale, most osteotomy procedures move the metatarsal in the transverse plane only and do not provide complete reduction owing to the presence of uncorrected deformity in the coronal and sagittal planes.

Research has suggested that the popular preoperative AP radiographic findings are inconsistent. Martin (1) found that the preoperative PASA is rarely visualized intraoperatively and was often decreased postoperatively without any procedure used to address the PASA or the head of the metatarsal. Chi et al (2), and others (3), have shown a decreased PASA with proximal bunion repair procedures using the pre- and postoperative radiographic measurements. A significant improvement has been reported in the PASA without the use of distal procedures owing to the positional artifact that is present when the first metatarsal is rotated in the coronal plane (4). A second AP radiographic finding that changes with coronal plane rotation is the TSP (4,5). The idea that the sesamoids sublux away from the head of the first metatarsal in feet with hallux valgus has been challenged by research showing that the distance from the lateral sesamoid to the second metatarsal remains constant. That finding has led to the thought that the first metatarsal drifts medially off its anchorage to the medial and lateral sesamoids (6). Others have found that the apparent sesamoid position on radiographs is attributable to coronal plane rotation of the metatarsal, with little to no translational displacement of the sesamoids from

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beneath the metatarsal in some but not all patients. In other words, the sesamoids appear displaced from the first metatarsal on the AP radiograph when, indeed, they are positioned normally in their plantar metatarsal grooves (4,7) (Fig. 1). Recently, a review and comparison between AP and axial sesamoid radiographic views showed poor agreement between the 2 regarding subluxation of the sesamoids (8). Eversion or valgus rotation might be the initial deformity that sets into motion the malposition of the hallux and subsequent retrograde medial deviation of the first ray. Therefore, it might be the coronal plane malposition of the first metatarsal that is the inciting event that sets into motion the progression to a bunion. It has also been suggested that failure to correct the TSP might be the reason for the hallux abducto valgus (HAV) recurrence and poor functional outcomes (9,10). True soft tissue balancing requires realignment and redirection of the longitudinal pull of all soft tissue structures inserting on the distal aspect of the first ray. When the first metatarsal is moved in the transverse plane exclusively, as is the case with most osteotomies, the lateral position of the sesamoids will be maintained and the vector of force with tendon action of the extensors and flexors will pull the hallux into adduction and valgus rotation and the retrograde force will push the metatarsal medially, increasing the IMA. Triplane correction of the first metatarsal position will reassure the surgeon that the sesamoids are maintained in their anatomic grooves and orientated neutrally in the sagittal plane, avoiding the pseudocorrection resulting from aligning a pronated metatarsal over the sesamoids without the latter necessarily in their anatomic grooves. This also theoretically removes the deforming forces on the hallux and, secondarily, the first metatarsal (Fig. 2).

The lateral round sign described by Okuda et al (11) has been shown to be an indicator of first metatarsal pronation. This finding can be visualized on the AP radiograph along the lateral margin of the first metatarsal head. Because the metatarsal is everted relative to the plane of the foot and the AP radiograph, the rounded plantar surface of the first metatarsal comes into view, resulting in a rounded appearance to the lateral first metatarsal (lateral round sign). Without eversion, the lateral profile of the head will be quite straight. This finding is easily visualized and can be used as a guide to restoring neutral frontal plane rotation during intraoperative fluoroscopic examination (Fig. 3).

We hypothesized that triplane tarsometatarsal joint (TMTJ) arthrodesis would result in normalization of the TSP on the AP radiograph, not because of soft tissue balancing, but because of correction of the coronal plane of the deformity. We also sought to evaluate the association of an increased TSP with a positive lateral round sign to determine whether the 2 findings will be normalized concurrently when the first metatarsal has been inverted as a part of the corrective procedure (triplane correction TMTJ arthrodesis). Finally, we aimed to identify the percentage of patients in the present cohort with pure rotational deformity causing sesamoid changes on the AP radiograph (no sesamoid subluxation) and the percentage with associated sesamoid subluxation causing the AP TSP abnormality and to compare this to previous published research data reporting the incidence of sesamoid subluxation as a part of HAV deformity (Fig. 2).

Patients and Methods

The Des Moines institutional review board exempted the present retrospective analysis. We reviewed a consecutive series of symptomatic HAV patients who had undergone triplane TMTJ arthrodesis by a single surgeon from September 2015 to June 2016. The subjects were identified through a medical record search using the Common Procedural Terminology codes 28297 and 28740. The criteria for inclusion in the study were $\geq$2 months of postoperative follow-up data available, the availability of pre- and postoperative weightbearing AP and sesamoid axial radiographs, and patient participation in an early weightbearing protocol.

The surgical procedure was performed through a dorsal longitudinal incision over the first TMTJ. The metatarsal position was manually corrected in the transverse, coronal, and sagittal planes after TMTJ release and held with a specialized clamp before the bone cuts. The IMA was corrected to $<8^{\circ}$, and the coronal and sagittal planes of the deformity were corrected to neutral. Intraoperative fluoroscopic guidance was used to adjust and confirm the metatarsal correction. The criteria for complete correction was a TSP <2, an IMA $<8^{\circ}$, and anatomic alignment of the MTPJ and hallux. The prepared first TMTJ was reduced and provisionally fixated with an olive Kirschner wire. Two small-profile, 4-hole titanium locking plates were used in biplanar fashion to maintain correction in the transverse, frontal, and sagittal planes. No compression screw was used with this fixation approach. An intermetatarsal neutralization screw was used in 17 of 21 feet (81%) for added stability of the fixation after complete correction was achieved. No additional distal metatarsal osteotomy was performed. Capsular balancing was not performed in any of the patients. Postoperatively, the patients underwent an early weightbearing protocol with protected weightbearing in a removable walking boot at an average of 13.3 $\pm$ 3.1 (range 0 to 14) days. One of us (P.D.) measured the IMA, HVA, lateral shape of the metatarsal head (lateral round sign) (11), and TSP on the pre- and early postoperative AP radiographs. The TSP was measured using the Hardy and Clapham 1 to 7 scale (12). The semi-weightbearing sesamoid axial views were used to evaluate frontal plane rotation of the first metatarsal relative to the plane of the lesser metatarsals and subluxation of the metatarsal off the sesamoids. A standardized patient position with a rigid foam block was used to ensure consistency in obtaining the axial views. The results of the measurements were reviewed by both of us (P.D., M.F.) and discussed to ensure accuracy. Paired *t* tests (corrected for multiple comparisons) were conducted to determine the change in the radiographic morphologic measures.

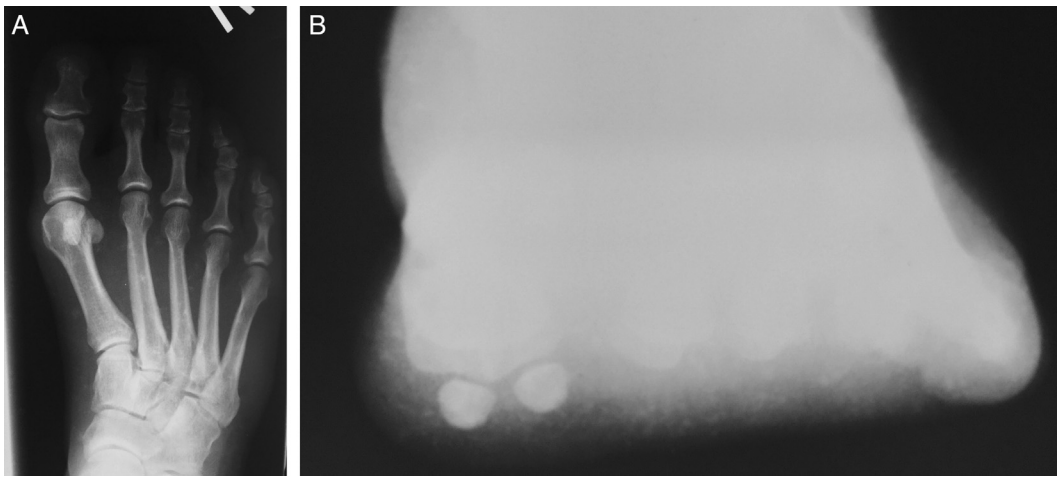

Fig. 1. (*A*) Anteroposterior radiograph showing positive lateral round sign and tibial sesamoid position suggesting metatarsal eversion. Traditional evaluation of the tibial sesamoid position would suggest metatarsal subluxation off the sesamoids. (*B*) Semi-weightbearing sesamoid axial view showing sesamoids located normally, medially and laterally to the median crista. Eversion of the first metatarsal has altered the findings visualized and assessed on the anteroposterior projection.