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Preoperative Planning and Intraoperative Technique for Accurate Translation of a Distal First Metatarsal Osteotomy

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ABSTRACT

We used preoperative radiographic and intraoperative anatomic measurements to predict and achieve, respectively, the precise amount of capital fragment lateral translation required to restore anatomic balance to the first metatarsophalangeal joint. Correlation was used to relate the amount of capital fragment translation and operative reduction of the first intermetatarsal angle (IMA), hallux abductus angle (HAA), tibial sesamoid position (TSP), metatarsus adductus angle, and first metatarsal length. The mean capital fragment lateral translation was 5.54 ± 1.64 mm, and the mean radiographic reductions included a first IMA of 5.04° ± 2.85°, an HAA of 9.39° ± 8.38°, and a TSP of 1.38 ± 0.9. These changes were statistically ($p < .001$) and clinically (≥32.55%) significant. The mean reduction of the metatarsus adductus angle was 0.66° ± 4.44° and that for the first metatarsal length was 0.33 ± 7.27 mm, and neither of these were statistically ($p = .5876$ and 0.1247, respectively) or clinically (≤3.5%) significant. Pairwise correlations between the amount of lateral translation of the capital fragment and the first IMA, HAA, and TSP values were moderately positive and statistically significant ($r = 0.4412$, $p = .0166$; $r = 0.5391$, $p = .0025$; and $r = 0.3729$, $p = .0463$; respectively). In contrast, the correlation with metatarsus adductus and the first metatarsal shortening were weak and not statistically significant ($r = 0.2296$, $p = .2308$ and $r = -0.2394$, $p = .2109$, respectively). The results of our study indicate that predicted preoperative and executed intraoperative lateral translation of the capital fragment correlates with statistically and clinically significant reductions in the first IMA, HAA, and TSP.

Hallux abductovalgus (HAV) is a structural deformity resulting from inherited and biomechanical influences for which surgical correction is often necessary to alleviate patient discomfort and dissatisfaction (1). The distal first metatarsal chevron osteotomy is a procedure that offers inherent stability and is commonly used for correction of mild to moderate HAV deformity (2). Bunionectomy typically entails lateral translation of the capital fragment to relatively reduce the first intermetatarsal angle (IMA). Moreover, orientation of the axis along which the capital fragment moves will enable the surgeon to raise (elevate) or lower the capital fragment or lengthen or shorten the metatarsal as the IMA is reduced. To date, few published reports have indicated to what amount the capital fragment needs to be translated to achieve adequate bunion correction (3–5).

The static relationship of the first metatarsophalangeal joint sesamoids relative to the position of the first metatarsal head has been described in published foot and ankle surgical studies (6). Incomplete sesamoid reduction (restoration of the balanced alignment of the sesamoids in their respective facets on the first metatarsal head) after HAV correction has been associated with recurrence of the deformity (7). A corrected alignment is one in which the tibial sesamoid position is adjacent to the medial cortex of the metatarsal head and thereby able to function within the metatarsophalangeal joint complex, allowing for transverse, frontal, and sagittal plane stability (6,8). Although a comparison of the preoperative to postoperative foot-related quality of life is the optimal measurement of success after surgery, correction of the radiographic alignment of the first ray is

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often used as a surrogate marker for successful hallux valgus surgery (9). It is generally accepted by surgeons that the combination of a first IMA of $\leq 8^\circ$, hallux abductus angle (HAA) of $\leq 15^\circ$, and tibial sesamoid position (TSP) 1-3 is associated with satisfactory realignment of the first ray after bunion surgery, as long as the patient's pain has been alleviated (5–7,10). A preoperative assessment of the relationship of the first metatarsal head to the sesamoids can be used by the surgeon to predict the amount of lateral translation that is needed to prevent under- or overcorrection of the deformity (11). In the present report, we retrospectively evaluated a preoperative method used to determine the precise amount of lateral translation of the capital fragment required to realign the radiographic appearance of the first ray after bunionectomy using a distal first metatarsal chevron osteotomy in a consecutive series of patients. We hypothesized that the amount of lateral translation of the first metatarsal capital fragment required to adequately correct the deformity could be precisely defined preoperatively and then achieved intraoperatively and that this would be significantly associated with normalization of the first ray alignment as measured by key radiographic parameters. Our primary aim was to define a radiographic method used to predict just how much the capital fragment would need to be laterally translocated. Our secondary aim was to correlate the amount of lateral translation with reduction of key radiographic measurements associated with HAV deformity correction.

Patients and Methods

The institutional review board of Sinai Hospital (Baltimore, MD) approved the present investigation, which involved a review of the medical records and foot radiographs of consecutive patients who had undergone first metatarsal chevron osteotomy for correction of HAV from February 2011 to February 2013. The series of patients came from the practice of 1 of us (B.M.L.), and that same surgeon performed all the operations. Another 1 of us (J.W.) used the International Classification of Diseases, version 9, code 735.0 (World Health Organization, Geneva, Switzerland) and Current Procedural Terminology code 28296 (Current Procedural Terminology, American Medical Association, Chicago, IL) to identify potentially eligible patients in the electronic medical record. A database search of all surgeon operative records was also conducted for the study period specified. To be included in the present series, the patients had meet the following criteria: chevron osteotomy of the first metatarsal with screw or pin fixation with or without adjunctive capsule-tendon balancing; the presence of both sesamoids; intact sensation; and a mild to moderate preoperative first IMA (range 9° to 15°). The following factors were considered exclusion criteria: patients with HAV who had not been surgically treated with a distal chevron osteotomy, hallux rigidus, inflammatory arthropathy, Charcot neuroarthropathy, a loss of protective sensation, traumatic arthropathy, revision bunionectomy, patient age <18 years, absent pedal arterial pulse, unable to consent to clinical research, and inadequate data in the medical record.

Adjunctive procedures were indicated for certain patients for other associated pathologic features, including calcaneal osteotomy, metatarsal osteotomies of adjacent rays, tendon Achilles lengthening, benign soft tissue tumor excision, and nerve release procedures.

Operative Intervention

As noted, a single surgeon (B.M.L.) performed all the chevron osteotomies, either in isolation or combined with adjunctive procedures. Before surgery, the surgeon measured the precise amount of first metatarsal capital fragment lateral translation by measuring the perpendicular distance from the lateral margin of the fibular sesamoid to the lateral margin of the first metatarsal head, as viewed on the weightbearing (standing) anteroposterior (AP) radiograph (Fig. 1). By convention, for this surgeon, this radiographic measurement was recorded in the preoperative notes and used in the operating room to define the amount of lateral translation of the first metatarsal capital fragment. Thereafter, the surgery was performed with the patient supine under monitored anesthesia care with a pneumatic ankle tourniquet inflated to 200 mm Hg. A 4.5-cm, full-thickness incision was created medially, sparing the dorsal and plantar neurovascular elements, and oriented along the medial glabrous skin junction. A linear dorsal capsular incision was created to allow for resection of the medial eminence in line with the medial cortex of the metatarsal shaft. Through the medial incision, a lateral first metatarsal phalangeal joint capsulotomy was performed. A chevron osteotomy was created with an oscillating saw with 60° oriented dorsal and plantar arms. A ruler was implemented to precisely measure the translation of the capital fragment in keeping with preoperative planning specifications. Provisional fixation was used, followed by definitive fixation (either screw or pin), oriented dorsally to plantarly and perpendicular to the plantar wing of the osteotomy, aiming toward the metatarsal crista, centrally. Redundant medial capsule was reefed without undue tension and evaluated to ensure congruence of the first metatarsophalangeal joint. Postoperatively, the patient was bandaged with a dry sterile dressing and cotton gauze toe spacer with a wooden bottom surgical shoe and permitted to weight bear as tolerated.

Study Analyses

Two of us (J.W., B.J.A.) abstracted the following independent variables from the medical records: age, sex, height, weight, body mass index, operative side, ethnicity, comorbidities, smoking history, presence of diabetes mellitus, and preoperative diagnosis. The dependent variables included the radiographic measurements used to describe the alignment of the first ray. Standard weightbearing AP, medial oblique, and lateral foot preoperative and postoperative radiographs were evaluated for each subject. The following radiographic measurements were taken on the AP view: first IMA, HAA, metatarsus adductus angle (MAA), first metatarsal length, and the TSP. The first IMA was defined as the angular relationship between the anatomic axes of the first and second metatarsals. The HAA was defined as the angle formed between the longitudinal bisections of the first metatarsal and the proximal phalanx. The MAA was evaluated using a simplified approach by measuring the angle formed from the intersection of the bisection of the second cuneiform and the bisection of the second metatarsal. The first metatarsal length was assessed by measuring the metatarsal protrusion distance, defined as the perpendicular distance between the most distal portion of the head of the first metatarsal and a perpendicular from the mid-diaphyseal line drawn at the most distal portion of the head of the second metatarsal.

The TSP was defined in accordance with the 7-point scale described by Hardy and Clapham (12). One of us (J.W.) performed all the radiographic angular (degrees) and length (mm) measurements using eFilm Workstation™, version 2.1.2 (Merge Healthcare Inc., Hartland, WI). For each of the patients in the case series, the preoperative and postoperative radiographic measurements were made and recorded. Neither of the assessors was unaware of the perioperative management of the patients who underwent chevron osteotomy for correction of HAV.

Statistical Analysis

The data were assessed with attention given to the type and distribution, and the parameters were computed to describe the series of patients as represented by their foot radiographs. The analyses were performed by 1 of us (D.S.M.). Nonparametric tests of the null hypothesis were undertaken to identify statistically significant differences in the radiographic measurements between the preoperative and postoperative conditions. Inspection of continuous numeric variables, using histograms and the Kolmogorov-Smirnov test, showed that all but the preoperative first metatarsal length and MAA and the postoperative IMA and TSP and the difference in the metatarsal length between the preoperative and postoperative values were non-normally distributed. To avoid overstating the null hypothesis, the significance of the measured differences was tested using the Wilcoxon signed ranks nonparametric test for paired (linked, preoperative and postoperative measurements of the same patient) data. Furthermore, a correlation between the amount of lateral translation of the capital fragment and the other radiographic measurements was measured using Pearson's (r) correlation coefficient. This was done in an effort to measure the strength and direction of the linear relationship between the amount of lateral translation executed in the operating room, a distance predetermined by the measurement of the distance (mm) from the lateral margin of the fibular sesamoid to the lateral margin of the first metatarsal head as viewed on the preoperative AP radiograph and the amount of change (in degrees or mm) in the alignment of the first ray as measured by the first IMA, HAA, TMA, MAA, and first metatarsal length. The data were compiled and stored in a Microsoft® Excel® (Microsoft Corp., Redmond, WA) spreadsheet and imported into Stata/SE, version 9.2, for Macintosh (Stata Corp., College Station, TX) for analyses conducted by 1 of us (D.S.M.). Statistical significance was defined at the 5% ($p \leq .05$) level.

Results

Our electronic search of the medial records yielded 53 feet in 46 patients who were potentially eligible. A total of 29 feet (55%) in 27 patients (59%) met our inclusion criteria and were included in the analyses. The sample was refined from this group using the inclusion and exclusion criteria. A statistical description of the case series is depicted in Table 1. Overall, the mean patient age was 48.45 ± 14.04 (range 17 to 68) years, and the mean patient body mass index was 30.75 ± 6.81 (range 19.2 to 48.5) kg/m^2. A total of 23 females (85.19%) and 4 males (14.82%) were evaluated. Two patients in the study underwent bilateral foot surgery. Of these patients, 6 (24%) were categorized as normal weight, 4 (16%) as overweight, and 15 (60%) as obese, and these were included in our series. However, not all of the