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First Metatarsal Length Change After Basilar Closing Wedge Osteotomy for Hallux Valgus

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ABSTRACT

Background: **Hallux valgus deformities with large intermetatarsal angles require a more proximal metatarsal procedure to adequately correct the deformity. Due to the relative ease of a closing wedge osteotomy, this technique was adopted but with concern over first metatarsal shortening. In this study, we primarily evaluated angular correction and first metatarsal shortening.** ***Materials and Methods:*** **We evaluated 70 feet in 57 patients (average age, 54 years) with 52 female and five male. The average followup was 14 (range, 6 to 45) months. The charts were reviewed for the presence of metatarsalgia. Digital radiographic measurements were made for pre- and postoperative hallux valgus and intermetatarsal angles, dorsiflexion angle of the first metatarsal, and absolute and relative shortening of the first metatarsal.** ***Results:*** **The average hallux valgus angle improved from 31 to 11 degrees ($p < 0.0001$) and intermetatarsal angle from 13.2 to 4.4 angles ($p < 0.0001$). The absolute shortening of the first metatarsal was 2.2 mm and relative shortening was 0.6 mm. There was 1.3 degrees of dorsiflexion on average.** ***Conclusion:*** **Excellent correction of the deformity with minimal dorsiflexion or new complaints of metatarsalgia was found with this technique. The new method of assessing the relative shortening found to be less than the absolute shortening, which we feel more accurately reflects the functional length of the first metatarsal.**

Level of Evidence: IV, Retrospective Case Series

Key Words: Metatarsal; Wedge Osteotomy; Dorsiflexion; Hallux Valgus

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INTRODUCTION

The majority of procedures for hallux valgus correction use a combination of soft tissue release with either a distal or proximal first metatarsal osteotomy.[18] When osteotomies are performed, other changes in the configuration of the first metatarsal may occur.[20] This may happen in the form of shortening, elongation, rotation, elevation or depression. Kummer, Jahss, and Troy studied the geometric principles governing first metatarsal osteotomies.[7–9] Their work showed that a distal chevron-type osteotomy was limited to approximately 5 degrees of correction of the intermetatarsal angle before instability of the construct occurred. A proximal first metatarsal procedure moves the center of rotation of the osteotomy closer to the origin of the deformity so more correction can be achieved. They also noted that a certain, but not always significant, degree of shortening and elevation occurred with these osteotomies. Such undesired changes may increase central forefoot loading which can lead to metatarsalgia.

The ideal osteotomy for hallux valgus should include correction of the first intermetatarsal and hallux valgus angles, without other unwanted alterations. The amount of correction provided by the numerous procedures available has been the justification for their selection. Nyska et al. performed a geometric analysis of crescentic, Ludloff, Mau, Scarf, proximal chevron, and closing wedge osteotomies.[12] The basilar angular osteotomies (Ludloff, closing wedge, crescentic) provided the most correction, however, they noted that closing wedge and crescentic osteotomies had significantly more shortening compared to the 8-degree Ludloff osteotomy. These osteotomies, although providing significant correction in moderate to severe hallux valgus deformities, can be technically demanding.

After extensive experience of over 15 years of practice using the crescentic and subsequently the Ludloff basilar osteotomies, the senior author (D.B.T.) continued to find these two osteotomies technically challenging and occasionally disappointing regarding the amount of correction. Upon

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trying the closing wedge osteotomy in 2006, it was found to be much easier to perform with a more predictable correction in his experience. A theoretical concern was that the shortening inherent to this type of osteotomy could lead to transfer metatarsalgia.[1,2,11,12,15,17] The current study evaluated the closing wedge osteotomy performed for moderate to severe hallux valgus deformities with radiographic analysis and chart review for complaints of new onset metatarsalgia. During this evaluation, two new radiographic methods for analysis, one for shortening and the other for dorsiflexion, were used.

METHODS AND MATERIALS

A retrospective review of all proximal closing wedge osteotomies performed by the senior author (DT) for hallux valgus deformity correction from January 2006 through December 2009 was done. All patients who had preoperative and postoperative digital AP and lateral radiographs of the foot were included. All patients had a distal soft tissue procedure as well (modified McBride). We excluded patients who did not have a complete set of radiographs (i.e., patients with outside, nondigital preoperative films), had previous hallux valgus correction procedures or had a history of inflammatory disease (i.e., rheumatoid disease).

Over this time period, the senior author performed a total of 108 closing wedge osteotomies for hallux valgus. After removing patients who met the exclusion criteria, there were a total of 57 patients (70 feet). The average age of patients was 54 (range, 18 to 74) with 52 females (ten bilateral) and five males (three bilateral). Absolute shortening was measured in all patients who had no more than one Weil osteotomy (40 patients, 50 feet), and the relative second metatarsal length was measured in all patients who had no lesser metatarsal osteotomy (25 patients, 33 feet). While a chart review could be a relatively inaccurate method of assessing metatarsalgia, the senior author specifically evaluated each patient postoperatively for it as it was a concern of his with this different osteotomy. The average followup of these patients was 14 (6 to 45) months.

Radiographic measurements

All radiographic measurements were made by a surgeon not involved in the surgery (TD) using the angle measurement software of the digital radiographs. The hallux valgus angle was determined by connecting the centers of the distal most part of the metatarsal head and its proximal articular surface with a similar line made on the proximal phalanx. The center of the proximal articular surface was defined as the midpoint between the medial and lateral edges. The intermetatarsal angle was measured in the same manner as the hallux valgus angle using the same line on the first metatarsal and the same method for creating a line on the second metatarsal (Figure 1A).

Absolute shortening of the first metatarsal was evaluated by measuring from the subchondral bone at the proximal articular surface to the subchondral bone distally at the first and second metatarsal heads, respectively. The difference in lengths measured (second metatarsal length minus first metatarsal length) from the preoperative to the postoperative radiographs was determined to be the absolute shortening. In all cases, the measurements were made over the lines drawn for evaluating the intermetatarsal angle to reduce variability. In patients who had second metatarsal osteotomies, the third metatarsal was used as a reference instead. This method was used so that shortening was assessed relative to another metatarsal to minimize any magnification error (Figure 1A).

Relative first metatarsal length, a new measurement method, was evaluated in all patients who had a closing wedge osteotomy without an additional lesser metatarsal osteotomy. This method included making a line from the distal most portions of the first and third metatarsal heads. The distance from this line, as it crossed the second metatarsal shaft, to the most distal portion of the second metatarsal head was used to evaluate first metatarsal shortening as it related to the second metatarsal length (Figure 1B). This method was developed to determine whether the rotational correction of the first metatarsal altered the measured shortening relative to the second and third metatarsals.

Dorsiflexion angle was measured on the postoperative lateral radiograph with a new method, also. The proximal articular surface was identified and a line was drawn from the dorsal edge to the plantar edge. A second line was drawn parallel to the midshaft of the metatarsal distal to the osteotomy site, bisecting the center of the metatarsal head. The amount that the angle between these lines deviated from 90 degrees was defined as the dorsiflexion angle (Figure 1C).

Postoperative radiographs of all patients were reviewed until final followup for evidence of hardware failure as determined by screw back-out, screw and/or plate breakage. In addition, radiographic union was assessed on final radiographs but time to union was not calculated as the only predictable times when radiographs were taken were at the immediate postoperative period and 6 weeks after surgery. Subsequent radiographs were obtained at various intervals until final followup films were obtained and thus would have lead to inaccurate evaluation of time to healing.

Surgical technique

All patients had a standard distal soft tissue realignment (modified McBride procedure) in conjunction with the closing wedge osteotomy. The proximal cut of the osteotomy was made parallel and 5 to 7 mm from the first TMT joint. The second cut was made to converge at the medial cortex with the same or slightly more bone being resected from the plantar side to avoid dorsiflexing the osteotomy or even slightly plantarflexing it. The amount of bone resected was done by visual estimation but in general was found to be

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Fig. 1: **A**, Method for evaluating hallux valgus and intermetatarsal angle. The same lines were also used to measure the first and second metatarsal length. **B**, Method of evaluating relative first metatarsal length. **C**, Method of evaluating sagittal alignment.

acceptable after the first cut and did not usually require adjustment. The osteotomy was held provisionally with a Kirschner wire while a fluoroscopic view was obtained to assess the correction. All patients in this series had a 6-hole 2.4-mm T-plate (Synthes, Paoli, PA) with three nonlocking screws through the plate on either side of the osteotomy.

Postoperative care

Patients were placed in a bunion wrap at the time of surgery. Partial heel weightbearing in a postoperative shoe was allowed for the 1st week after surgery and then foot flat weightbearing to tolerance for weeks 2 through 6. Patients were advanced to regular shoe wear at that time as pain permitted.

Statistical analysis

A paired T-test was employed to evaluate the difference between measurements taken preoperatively and postoperatively with p less than 0.05 defined as significant.

Intraobserver variability analysis

The intraclass correlation coefficient was calculated for the radiographic variables to evaluate the intraobserver reliability. A subset of ten patients was remeasured for all variables. Intraobserver reliability was defined as minimal (correlation coefficient, less than 0.25), low (0.26 to 0.49), moderate (0.50 to 0.74), high (0.75 to 0.90), or very high (greater than 0.9).

RESULTS

Hallux valgus correction

The mean hallux valgus angle preoperatively was 31 (range, 18 to 49) degrees and measured 11 (range, −4 to 22) degrees postoperatively for an overall correction of 20 degrees ($p < 0.0001$).

Intermetatarsal angle correction

The mean preoperative intermetatarsal angle was 13.2 (range, 8 to 21) degrees and postoperatively measured 4.4

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(range, −1 to 11) degrees for an overall mean correction of 8.8 degrees ($p < 0.0001$).

Absolute first metatarsal shortening

The mean postoperative shortening observed was 2.2 (range, 2.1 to −4.8) mm (p less than 0.0001)

Relative first metatarsal length

On average the observed relative first metatarsal length was shortened by 0.6 (range, 1.2 to −2.8) ($p < 0.0001$). A comparison of absolute to relative shortening of the first metatarsal showed a significant difference ($p = 0.0002$).

Dorsiflexion assessment

The sagittal alignment as measured radiographically showed a mean postoperative difference of 1.3 degrees of dorsiflexion (range, 7 degrees plantarflexion to 9 degrees dorsiflexion) ($p = 0.002$).

Metatarsalgia

We found seven out of 70 feet to have postoperative metatarsalgia. Of these, five had Weil osteotomies for preoperative metatarsalgia which only partially relieved the metatarsalgia and one patient had second and third metatarsal overload preoperatively which was not relieved by the bunion correction. There was one new onset of metatarsalgia.

Complications

There were a total of seven hardware failures in 70 patients during the postoperative course. However, all osteotomies had united on the final followup radiographs. Screw complication was observed in six (three broken screws and three screws backed out) of seven. A total of two broken plates were observed. Both broken plates occurred within 6 weeks postoperatively, and screw breakage/backout occurred within 6 months postoperatively (one on first postoperative visit). A subset two sample paired T-test was performed on hardware failures versus those with intact hardware which showed no significant difference in postoperative sagittal alignment, i.e., the hardware failure did not result in significant dorsiflexion ($p = 0.34$). Surgery for hardware removal was performed in four of these seven feet. There were no wound-healing problems, symptomatic hardware or other complications noted.

Reliability

The intraobserver correlation coefficients for all radiographic measurements showed high intraobserver reliability. Reliability was highest for postoperative shortening (0.98), while the reliability of the hallux valgus angle (0.97) the relative first metatarsal length (0.94), postoperative sagittal alignment change (0.87), and intermetatarsal angle (0.84) were also high.

DISCUSSION

Most surgeons agree when correcting hallux valgus deformities that with greater deformity, most often assessed with a greater IM 1–2 angle, that a basilar first metatarsal procedure yields a much more powerful correction than a distal procedure. The senior author has found the basilar crescentic and Ludloff osteotomies technically demanding, sometimes yielding less correction than expected. A basilar closing wedge osteotomy has been found to be far easier in his experience. While the osteotomy cuts were made visually, the second author in his practice uses a template method for preoperatively determining the amount of bone to be resected (Figure 2).

Theoretically, a closing wedge osteotomy would lead to shortening and thus an increased risk of postoperative transfer metatarsalgia. Shortening of the first metatarsal was evaluated with two different radiographic methods. The average absolute shortening measured was 2.2 mm which could possibly lead to metatarsalgia. We evaluated a new radiographic measure, shortening relative to the second and third metatarsals, which was only 0.6 mm. Since the first metatarsal is rotated almost parallel to the lesser metatarsals, it relatively lengthened it and thus the shortening was much less. Figure 3 demonstrates the hinge point along the medial cortex where the metatarsal is rotated toward the second metatarsal. This method of assessing relative

Fig. 2: A preoperative radiograph with the templating method of one of the authors aiming to correct the intermetatarsal angle to 0 degrees. In this case with a 15-degree angle, a 5-mm wedge would be resected.

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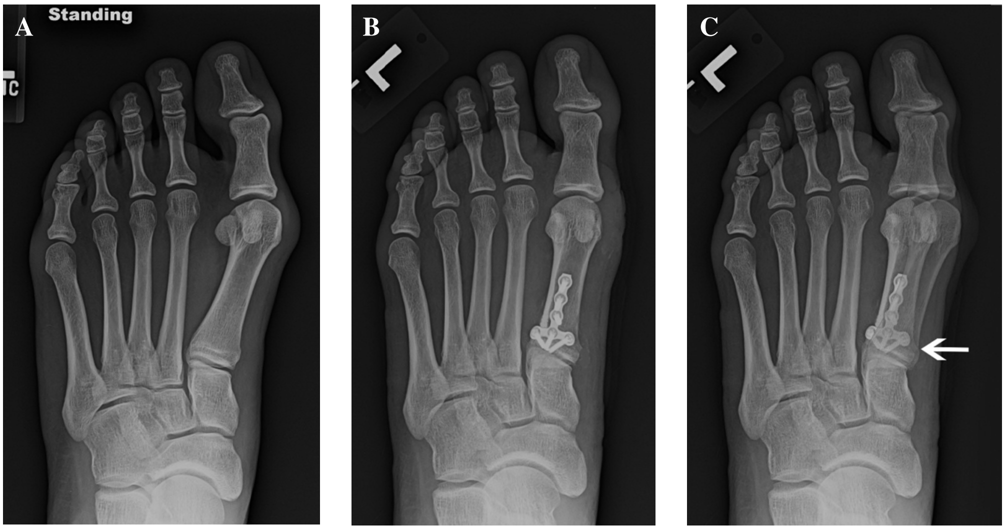

Fig. 3: **A**, Preoperative AP radiograph of typical deformity. **B**, Postoperative AP radiograph of same patient. **C**, The postoperative radiograph overlies a preoperative radiograph here. The first metatarsal has been rotated with a hinge point along the medial cortex (arrow) almost parallel to the lesser metatarsals.

metatarsal length did have a high intraobsesrver reliability of 0.94.

In a sawbone model, Nyska et al. found a statistically significant amount of shortening of 2 (SD, 0.6) mm at a templated 8 degrees of correction for a basilar closing wedge osteotomy.[12] Another sawbone model evaluating closing wedge osteotomies found shortening of 1.7 mm at 10 degrees of correction.[1] In that study, a bone clamp was used to secure the osteotomy, compared to the use of a screw in the study by Nyska et al. They concluded that the more compressive effect of a screw accounted for the difference in shortening. Kummer, in a mathematical model of the closing wedge osteotomy, found 2.6 mm of shortening.[8] Also, sawbone studies obviously do not evaluate any change in alignment that may occur postoperatively.

In the current study, the variation in absolute first metatarsal length (2.1 mm to −4.8 mm), and relative first metatarsal length (1.2 mm to −2.8 mm) may be accounted for by surgical technique. The senior author performed the osteotomy cuts by visual measurement without preoperative templating. However, intraoperative fluoroscopy was used to assess the angular correction before internal fixation was placed. In addition, osteotomy cuts were intentionally made to attempt to avoid dorsiflexion or even slightly plantarflex the osteotomy. Another cause of such variation may be translation at the osteotomy site but we did not note any translation on the postoperative films. Saxena and McCammon reported plantar translation of the osteotomy site when directing the osteotomy plantarly.[15]

Although one of the goals of surgery was to avoid dorsiflexion at the osteotomy site, the average sagittal alignment still produced an unpredictable amount of dorsiflexion (average of 1.3 degrees). We believe the majority of this occurred during the healing phase when minor shifts developed despite the internal fixation. Schuberth et al. observed an elevation of 6.7 mm in a closing wedge osteotomy.[17] After proximal crescentic osteotomy, Mann et al., noted an unquantified amount of elevation in 28% of patients.[11] The effects of first metatarsal elevation on plantar pressure have been recently studied. In a prospective study, Brodsky et al. showed a postoperative increase in second metatarsal pressures. In their model, a proximal crescentic osteotomy was used. They found that the sagittal plane alignment was unpredictable despite attempts to modify the surgical technique to produce plantarflexion.[2] The current study measured sagittal plane alignment in terms of angular measurement relative to the first metatarsal proximal articular surface instead of attempting to quantify the vertical displacement of the first metatarsal. With the small amount of dorsiflexion, we had no significant problems with the development of transfer metatarsalgia postoperatively.

We found a total of seven hardware failures in 70 feet. This incidence may be partially attributed to the geometry of the osteotomy which is intrinsically unstable. There is no osseous resistance to deforming forces; therefore its stability relies completely on internal fixation.[14] Excessive dorsiflexion may place undue stress on plate fixation constructs leading to failure. Also, the plate was placed dorsally which is the compression side of this bone which is less stable. Interestingly, the seven feet with hardware failures showed no difference in postoperative sagittal alignment difference compared to ones with intact hardware suggesting that fortunately, enough bone healing had occurred by the time of hardware failure to avoid subsequent displacement. Also, the patients were allowed to heel weightbear immediately after surgery which would likely have lead to some stress on the plate.

We found seven out of 70 feet to have metatarsalgia . Only one patient had a new onset of metatarsalgia and the postoperative amount of shortening was much more than the

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average (absolute shortening, 4.8 mm; relative shortening, 2.8 mm). The post-op sagittal alignment for this patient was measured to be 7 degrees of plantarflexion which did not make up for the excessive shortening. Brodsky et al. demonstrated a change in peak plantar pressure under the second metatarsal head with elevation or depression of the first metatarsal head by 2 mm.[2]

In 1982, Cedell et al. reported their experience with the closing wedge osteotomy in 43 consecutive patients. Based on patient response of postoperative residual symptoms, they reported excellent results in 78% of patients and good results in 11% of patients.[4] They did not measure the amount of shortening in their study nor focus on metatarsalgia.

There were several limitations to the current study. Although this was primarily a radiographic study, the method of obtaining radiographs was not standardized. To correct for possible variations in X-ray beam distances, shortening was measured by two methods, each of which referenced a constant length (second or third metatarsal length) of an intact metatarsal bone. All measurements were performed by a single observer (T.D.). Although high intraobserver reliability was seen, the method for evaluating sagittal alignment is a new approach, and has not been validated by previous studies. Few studies have evaluated the reliability of methods used to study radiographic parameters in hallux valgus deformity.[5,6,16]

CONCLUSION

We found that a basilar first metatarsal closing wedge osteotomy in combination with the modified McBride procedure can reliably correct the hallux valgus deformity in the coronal plane without a significant functional loss of first metatarsal length with good sagittal alignment. New techniques for evaluating sagittal alignment and relative first metatarsal length are presented. Hardware failure was not observed to be associated with a significant amount of dorsiflexion.

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