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Evaluation of surgical experience and the use of an osteotomy guide on the apical angle of an Austin osteotomy

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Abstract

Background: Distal osteotomies of the first metatarsal are commonly used to correct hallux valgus deformities. Of the distal osteotomies, the Austin osteotomy is popular among foot surgeons on an international level. The precision of the osteotomy is important to achieve a congruous osteotomy.
Objectives: The purpose of this study was to examine the effects of experience and technique on creating a precise Austin osteotomy.
Method: Three individuals with varying levels of experience (student, resident and podiatric physician) created Austin osteotomies in metatarsal sawbones, using three different techniques (freehand, guide wire and osteotomy guide). The medial and lateral apical angles were measured, and the mean, standard deviation, and range of the angles were calculated. The differences between medial and lateral angles were also calculated.
Results: The results indicated that the mean and range of the angles varied considerably with the freehand and guide wire techniques at all experience levels. The angles were accurate and consistent for all experience levels; however, when an osteotomy guide was used. The use of an osteotomy guide also noticeably reduced the number of divergent and convergent osteotomies.
Conclusions: The use of an osteotomy guide consistently resulted in a more precise Austin osteotomy for all experience levels.

Keywords: Osteotomy guide; Austin osteotomy; Chevron osteotomy; Hallux valgus; Osteotomy performance

1. Introduction

There are several deformities that occur at the first metatarsophalangeal joint, the most common of which is hallux valgus. Distal first metatarsal osteotomies are often used to correct hallux valgus. Many various types of osteotomies exist, and can be classified according to the location of the osteotomy. There are several types of distal osteotomies, including the Mitchell, Hohmann and Wilson osteotomies, as well as the Austin, or chevron, osteotomy and its modifications [1]. The Austin osteotomy is the most common osteotomy performed to treat mild or moderate hallux valgus. Essentially, the Austin or chevron is a 'V'-shaped transpositional osteotomy with the apex of the 'V' situated distally in the first metatarsal metaphyseal bone with the arms of the 'V' extending proximally. The apical angle of the original osteotomy is 60°; however modifications have been made that vary the angle slightly. The procedure has several advantages, including the fact that the osteotomy is performed in metaphyseal bone, which provides good contact and ultimately bone healing [1].

Numerous studies have used biomechanical testing to look at the strength and stability of various first metatarsal osteotomies. Most of these have focused on the effects of different types of fixation, cut orientation or surgical translocation on osteotomy strength. Several have used human first metatarsals for testing. For instance, Trnka et al. [2] evaluated the failure loads of six different first metatarsal shaft osteotomies: proximal crescentic, proximal chevron, Ludloff, Scarf, biplanar closing wedge and Mau. The authors found that the Mau osteotomy had the high-

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est mean strength, while the proximal crescentic osteotomy had the lowest mean strength. Higgins et al. [3] compared the ultimate load and displacement of oblique closing base wedge osteotomies fixed with 4.0 mm stainless steel screws to those from osteotomies fixed with 4.0 mm poly-L-lactic acid absorbable screws. They also compared the results from the osteotomies fixed with a 2.0 mm stainless steel Steinmann pins to those from osteotomies fixed with 2.0 mm poly-L-lactic acid absorbable pins. The results indicated that the structural stiffness was significantly greater in osteotomies fixed with stainless steel pins compared with poly-L-lactic acid absorbable pins. In addition, the ultimate displacement was significantly less for stainless steel pins compared with poly-L-lactic acid absorbable pins. There were no significant differences in the ultimate loads of the two types of pins and in any of the measurements recorded for the two types of screws. Shereff et al. [4] evaluated the stability of five different osteotomies: step-cut Mitchell, distal transverse, distal biplanar, Chevron and a basilar osteotomy. A variety of fixation techniques were examined, including single K-wires, crossed K-wires, a single AO cancellous screw, a single AO cortical screw, and three different types of sutures. The results found that the Chevron osteotomy provided greater inherent stability, while the basilar osteotomies were unstable regardless of fixation technique. With regards to fixation, the results indicated that (1) sutures were determined to be the least reliable, (2) two crossed K-wires were as effective as a single screw, and (3) a single K-wire was ineffective except with the Chevron osteotomy. Popoff et al. [5] evaluated the fixation of two osteotomies: a basal crescentic osteotomy laterally rotated 10° and a Scarf osteotomy. The osteotomies were fixed with either a single Barouk screw or with two AO cancellous screws. The results indicated that, with the Scarf osteotomy, fixation with AO screws was mechanically equivalent to fixation with the Barouk screw. However, with the crescentic osteotomy, the Barouk screw was inferior to AO screws.

Other investigators conducted biomechanical tests on the fixation and stability of various osteotomies using first metatarsal sawbone models. Jacobson et al. [6] tested four different fixation techniques for the offset V osteotomy: (1) two 2.7 mm AO cortical screws, (2) two 2.0 mm AO cortical screws, (3) one 2.7 mm AO cortical screw (distal) and one 2.0 mm AO cortical screw, and (4) one 2.7 mm AO cortical screw (distal) and one 0.062″ threaded K-wire. They found that the most common failure site was the distal screw. The type of fixation that could resist the most force before fracture was the group with the 2.7 mm AO cortical screw and a 0.062″ threaded K-wire. Khuri et al. [7] also evaluated fixation of the offset V osteotomy. Again, four different types of fixation were examined: (1) two 2.0 mm cortical screws, (2) two 2.7 mm cortical screws, (3) two 3.5 mm cortical screws, and (4) one 2.7 mm cortical screw and one 0.045″ K-wire. The authors concluded that the mechanical properties were similar for all four constructs. Jones et al. [8] compared the fixation strength of proximal crescentic osteotomies that have been fixed with either (1) a specially designed titanium plate applied on the dorsolateral aspect of the base of the first metatarsal and secured with four 2.7 mm screws or (2) a 3.5 mm cortical screw and one 0.062″ K-wire applied dorsal–distal to plantar–proximal. The results indicated that, for the specimens fixed with the plate, the ultimate failure strength and stiffness were statistically greater than for those fixed with the screw and K-wire.

The examples given here are just a few of the many papers that describe bench-top biomechanical testing of the stability and strength of various osteotomies and types of fixation. While information regarding biomechanical testing of various osteotomies and assorted methods of fixation is readily available in the literature, there are no reports of studies evaluating the influence of accuracy of the osteotomy prior to testing the stability of an osteotomy. This is significant, particularly in the case of the Austin osteotomy, where unanticipated changes in the apical angle can result in instability. Convergence or divergence of the osteotomy arms can interfere with transposition and congruency of the planes of the osteotomy following transposition. The stability and performance of the osteotomy depends on the creation of the consistent apical angle and reproducible bone cuts. The purpose of this study was to examine whether the use of an Austin osteotomy guide improves osteotomy accuracy for individuals of varying experience levels.

2. Methods

A total of nine groups were evaluated in this study. Three individuals with varying levels of experience (a fourth-year podiatric medical student, a third-year podiatric surgical resident and a podiatric physician with at least five years of experience) each used three different techniques (freehand, an apical guide wire alone, or an osteotomy guide) to produce an Austin osteotomy. Each of the three individuals made ten osteotomies for each technique.

The osteotomies were performed on left first metatarsal sawbones. To avoid variation between groups, the apex for the osteotomy was established prior to cutting. The apex was marked with a black pen at a distance of 1 cm proximal to the distal end of the metatarsal on all sawbones. For the freehand cuts, the black ink mark was the only point of reference. A 1.3 mm K-wire was inserted through the apical ink mark for the guide wire cuts (Fig. 1). For the osteotomy guide cuts, a BioPro® Accu-Cut™ osteotomy guide with an apical angle of 55° was secured onto the sawbone with two 1.3 mm K-wires, one of which passed through the apical ink mark (Fig. 2).

After the osteotomies were performed, the first metatarsals were assigned a random number, in order to blind the evaluator who was conducting the angle measurements. The medial and lateral angles of each osteotomy were then

Fig. 1. First metatarsal sawbone with a guide wire through the apex.

measured with a protractor. After all measurements were taken, the data were unblinded and sorted into groups. The means and standard deviations for both the medial and lateral angles, and the difference between the medial and lateral angles were calculated. In addition, the range of angles measured was determined for each group. Finally, the numbers of osteotomies that diverged (negative difference between medial and lateral angles) and converged (positive difference between medial and lateral angles) were determined. In order to compare groups for significant differences, a one-way ANOVA was conducted between groups, with the Holm-Sidak Method used for all pairwise multiple comparisons. Significance was defined as $p < 0.05$.

3. Results

The results for the medial and lateral angular measurements are shown in Table 1, while the mean and ranges for the medial and lateral angles are shown graphically in Figs. 3 and 4, respectively.

Fig. 2. First metatarsal sawbone with the osteotomy guide in place.

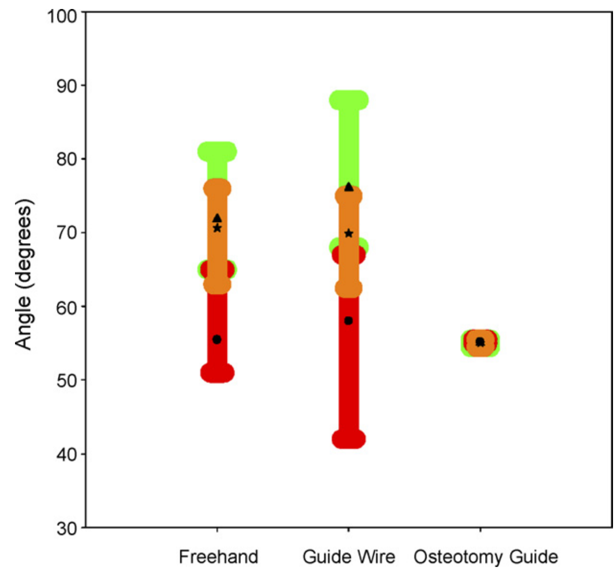

Fig. 3. Bar graph representing the ranges of the medial apical angles. The green bars indicate the ranges of angles for the fourth-year student, the red bars indicate those for the third-year resident, and the orange bars indicate those for the podiatric physician. The mean angles for each are indicated by a symbol (triangle for the fourth-year student, circle for the third-year resident, and star for the podiatric physician).

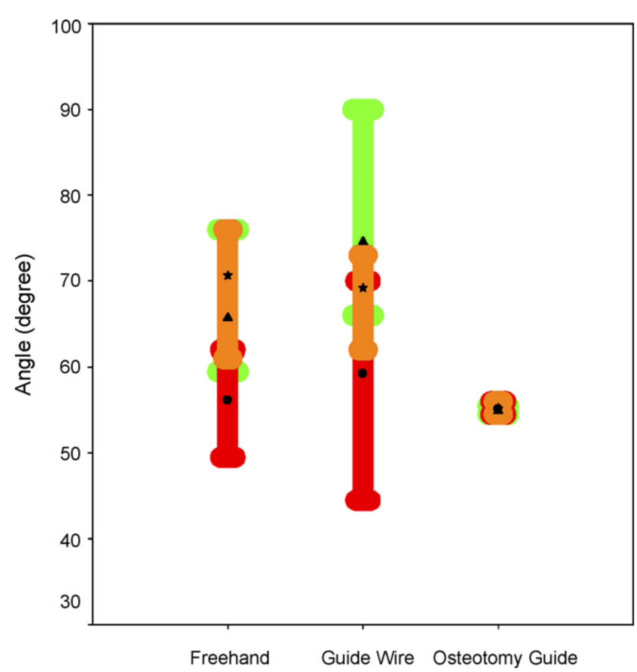

Fig. 4. Bar graph representing the ranges of the lateral apical angles. The green bars indicate the ranges of angles for the fourth-year student, the red bars indicate those for the third-year resident, and the orange bars indicate those for the podiatric physician. The mean angles for each are indicated by a symbol (triangle for the fourth-year student, circle for the third-year resident, and star for the podiatric physician).

Table 1
Angular measurements for the medial and lateral sides of the metatarsal, in degrees

	Freehand			Guide wire			Osteotomy guide		
	Med	Lat	Diff	Med	Lat	Diff	Med	Lat	Diff
Fourth-year student									
Mean	71.9	65.7	6.2	76.1	74.6	1.6	55.1	55.0	0.1
S.D.	5.2	6.0	5.0	5.9	8.4	3.8	0.4	0.4	0.2
Range	65 to 81	59.5 to 76	2 to 14.5	68 to 88	66 to 90	−6 to 5.5	54.5 to 55.5	54.5 to 55.5	0 to 0.5
Third-year resident									
Mean	55.5	56.2	−0.7	58.0	59.3	−1.3	55.2	55.1	0.1
S.D.	4.8	3.9	2.9	6.7	7.5	3.4	0.2	0.4	0.3
Range	51 to 65	49.5 to 62	−4 to 3	42 to 67	44.5 to 70	−8 to 3.5	55 to 55.5	54.5 to 56	−0.5 to 0.5
Podiatric physician									
Mean	70.7	70.7	0.0	69.9	69.2	0.7	55.1	55.2	−0.2
S.D.	4.1	4.7	2.9	3.5	3.4	1.1	0.4	0.4	0.2
Range	63 to 76	61 to 76	−4.5 to 3.5	62.5 to 75	62 to 73	−1 to 2	54.5 to 55.5	54.5 to 56	−0.5 to 0

3.1. Medial angles

The results for the medial angles indicated that, for osteotomies made freehand, the average angle was 71.9° for the fourth-year student, 55.5° for the third-year resident, and 70.7° for the podiatric physician. The mean angle cut by the third-year resident was significantly less than that produced by the fourth-year student and the podiatric physician ($p < 0.05$), and was essentially equivalent to the correct Austin osteotomy angle of 55°. There was no significant difference between the average lateral angles for the fourth-year student and the podiatric physician ($p = 0.623$).

For the osteotomies made using only a guide wire, the average angle was 76.1° for the fourth-year student, 58.0° for the third-year resident, and 69.9° for the podiatric physician. The differences between groups were all significant ($p < 0.05$).

For the osteotomies made using the osteotomy guide, the average angle was 55.1° for the fourth-year student, 55.2° for the third-year resident, and 55.1° for the podiatric physician. The difference between the groups was not statistically significant ($p = 0.755$). Using the osteotomy guide, all the three experience groups essentially achieved the desired angle of 55°, with variations of only ±0.5°. The consistency in achieving the desired angle with the osteotomy guide, despite experience level, is clearly evident in Fig. 3, which shows a very small range for all the three experience levels, in contrast to the range of angles achieved freehand or with a guide wire.

3.2. Lateral angles

The results for the lateral angles showed that, for osteotomies made freehand, the mean angle was 65.7° for the fourth-year student, 56.2° for the third-year resident, and 70.7° for the podiatric physician. The differences between experience levels were all significant ($p < 0.05$).

For the osteotomies made using only a guide wire, the average angle was 74.6° for the fourth-year student, 59.3° for the third-year resident, and 69.2° for the podiatric physician. The mean angle cut by the third-year resident was significantly less than that produced by the fourth-year student and the podiatric physician ($p < 0.05$). There was no statistically significant difference between the average lateral angles for the fourth-year student and the podiatric physician ($p = 0.068$).

For the osteotomies made using the osteotomy guide, the average angle was 55.0° for the fourth-year student, 55.1° for the third-year resident, and 55.2° for the podiatric physician. The difference between the groups was not statistically significant ($p = 0.409$). Using the osteotomy guide, all groups essentially achieved the desired angle of 55°, with variations of no greater than ±1 degree. As with the medial angles, the consistency in achieving the desired angle with the osteotomy guide, despite experience level, is demonstrated in Fig. 4. There is a very small range for all the three experience levels when the osteotomy guide is used, in contrast to the range of angles achieved freehand or with a guide wire.

3.3. Divergence versus convergence

The results for the number of divergent, neutral and convergent osteotomies are shown in Table 2. When making the cuts freehand or with the guide wire, neither the fourth-year student nor the third-year resident produced a neutral osteotomy, in which the medial and lateral angles are the same. The podiatric physician created only one neutral osteotomy using the freehand technique, and one with the guide wire. In contrast, when the osteotomy guide was used, more than half of the osteotomies were neutral for all the three experience levels. Fig. 5 shows the lateral aspect of a metatarsal that exhibited a divergent osteotomy.

4. Discussion

The results of this study clearly demonstrate that using an osteotomy guide provides greater accuracy of the apical angle of the osteotomy and inherent stability of the osteotomy, despite the experience level of the performing individual. An

Table 2
Number of divergent, neutral and convergent osteotomies

	Freehand divergence–neutral–convergence	Guide wire divergence–neutral–convergence	Osteotomy guide divergence–neutral–convergence
Fourth-year student	0–0–10	4–0–6	0–8–2
Third-year resident	6–0–4	6–0–4	1–7–2
Podiatric physician	4–1–5	2–1–7	3–7–0

important finding observed in the study is the consistency of the osteotomy angle when comparing the freehand technique, the guide wire and the osteotomy guide. The medial and lateral angles of the osteotomy with the osteotomy guide were consistently found to be $55^\circ \pm 1^\circ$, while the angles with the freehand technique and the guide wire were not always reproducible, as indicated by the large range in angles produced with these two techniques.

The use of the osteotomy guide resulted in a greater amount of osteotomies that neither diverged nor converged. When divergence or convergence did occur, the difference between medial and lateral angles was approximately $\pm 0.5^\circ$. An osteotomy that neither diverges nor converges in its course across the metatarsal has a far greater inherent stability. Even in the presence of fixation, inherent osteotomy stability is important to prevent unwanted potentially multiplanar migration under loaded conditions. Such a migration may result in malalignment, and ultimately malunion, of which even a small amount can result in an incongruous joint and abnormal loading. This, in turn, can contribute to the early formation of cartilage loss and eventually arthritis. Instability may also result in a greater potential for plastic deformation of the healing osteotomy in the postoperative period.

The literature contains many articles on various types of cutting guides that are used to assist the surgeon in making properly aligned cuts during procedures such as total knee arthroplasty [9–14], high tibial wedge osteotomies [15–18], and anterior cruciate ligament reconstruction [19]. However, there is not much information in the literature regarding the use of osteotomy guides in podiatric surgery. Osteotomy guides are just as important for osteotomies of the first metatarsal. They should be considered for use in treating deformities such as hallux valgus in order to obtain the proper cut alignment and angle, thus resulting in reduced pain and restoration of normal function of the hallux. It has been indicated that, in knee arthroplasty, the slotted cutting guide produced the most accurate and consistent cuts [9,14]. The osteotomy guide used in this study, which resulted in highly accurate cuts, is a slotted guide.

Fig. 5. Lateral aspect of a metatarsal as a result of a divergent osteotomy path.

The primary limitation of this study was the sawbone models. There was an inconsistency in the shape of the sawbone model, especially the plantar metatarsal head. Also there was an apparent variability in the composition of the sawbone models, creating inconsistency in the hardness throughout the metatarsal models that were used. This was noticeable when the individuals were cutting the osteotomies.

5. Conclusion

The use of an osteotomy guide appears to result in a more congruous first metatarsal osteotomy. The osteotomy guide proved effective for participants of varying experience levels. Podiatric physicians should consider using an osteotomy guide to provide a more stable and congruous osteotomy that can result in better healing and improved surgical outcomes in the treatment of hallux valgus.

Future research is directed toward comparing the stability under loaded conditions by evaluating the strength of the osteotomy and degree of motion following osteotomy performance.

Conflict of interest statement

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None of the other authors have any financial and/or personal relationships with other people or organizations that could inappropriately influence (bias) their work.

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