Article

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Early Radiographic Outcomes of Minimally Invasive Chevron Bunionectomy Compared to the Modified Lapidus Procedure

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Abstract

Background: Minimally invasive (MIS) bunion surgery has become increasingly popular. Although early reports on outcomes have been encouraging, no study to date has compared outcomes from the MIS chevron and Akin procedures to the modified Lapidus procedure. Our primary aim was to compare early radiographic outcomes of the MIS chevron and Akin osteotomies to those of the modified Lapidus procedure in patients with comparable deformities, and secondarily to compare clinical outcomes.

Methods: Patients were retrospectively reviewed for inclusion from a prospectively collected foot and ankle registry. Patients were eligible if they underwent either the MIS bunionectomy or modified Lapidus procedure and had preoperative and minimum 5-month postoperative weightbearing radiographs. Forty-one patients who underwent MIS bunionectomy were matched to 41 patients who underwent Lapidus bunionectomy based on radiographic parameters. Demographics, radiographic parameters, complications, reoperations, and PROMIS scores were compared between groups.

Results: Both groups achieved similar radiographic correction. There was no significant difference in pre- or postoperative PROMIS scores between groups. Procedure duration was significantly faster in the MIS group ($P < .001$). Bunion recurrence (hallux valgus angle ≥20 degrees) occurred in 1 MIS patient and 2 Lapidus patients, with all patients asymptomatic. The most common reason for reoperation was removal of hardware (4 patients in the MIS group, 2 patients in the Lapidus group).

Conclusion: This is the first study to our knowledge to compare early radiographic outcomes between MIS bunionectomy and the modified Lapidus procedure in patients matched for bunion severity. We found that patients with similar preoperative deformities experience similar radiographic correction following MIS chevron and Akin osteotomies vs modified Lapidus bunionectomy. Further research is needed to investigate satisfaction differences between the procedures, longer-term outcomes, and which deformities are best suited to each procedure.

Level of Evidence: Level III, Retrospective case control study.

Keywords: bunionectomy, hallux valgus, minimally invasive, Lapidus, chevron bunionectomy

Introduction

Across the different specialties of orthopaedic surgery, there has been a consistent shift toward more minimally invasive (MIS) techniques. MIS techniques in foot and ankle surgery have now expanded to include surgical treatment of hallux valgus. Although older MIS bunionectomy techniques were fraught with complications,[17] newer techniques have proven more reliable. Third-generation MIS bunionectomy, as originally described by Redfern and Vernois, involves a

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chevron and Akin osteotomy, with rigid internal fixation of both osteotomies.[26,31] The key aspects of this technique include an extracapsular distal metatarsal osteotomy that is fixed with 2 parallel screws, with the more proximal screw crossing 2 cortices in the proximal fragment before entering the displaced head fragment.[31] Although various percutaneous techniques for hallux valgus correction have been described in the past, this article will focus exclusively on this third-generation technique.

There have recently been more reports in the literature on third-generation MIS, although there are few comparative studies. Various case series of patients undergoing MIS chevron and Akin bunionectomy have found high satisfaction, good clinical outcomes, and low complication rates, even in patients with severe deformities.[14,15,19,20] Studies comparing the MIS chevron and Akin bunionectomy to open metatarsal osteotomies have generally found less pain in the early postoperative period for patients undergoing MIS surgery and no difference in clinical or radiographic outcomes between groups.[2,10,18,22,28]

In contrast to the MIS chevron osteotomy, the modified Lapidus procedure theoretically enables a much more powerful correction, centered at the tarsometatarsal (TMT) joint. In addition, pronation of the first metatarsal can be directly corrected at the TMT joint.[7] Although traditionally patients have been kept nonweightbearing for 6 weeks postoperatively, newer techniques with more rigid fixation have enabled early, even immediate, weightbearing.[25] The procedure can also be performed percutaneously, although reports in the literature are scarce.[30]

In this study, we aimed to compare short-term radiographic and clinical outcomes between patients undergoing MIS chevron and Akin bunionectomy to patients with comparable deformities undergoing open modified Lapidus bunionectomy. We chose the Lapidus bunionectomy for the comparison group because it is arguably the most powerful means of correcting a bunion short of first metatarsophalangeal joint fusion. As MIS techniques become increasingly popular with both patients and surgeons, comparative studies between different techniques are increasingly needed. We hypothesized that the MIS group would achieve inferior radiographic correction to the Lapidus group, but that clinical outcomes would be similar between groups.

Materials and Methods

Patients were retrospectively reviewed for inclusion from a prospectively collected, institutional review board–approved foot and ankle registry at our institution. Patients were eligible if they underwent either the MIS bunionectomy or modified Lapidus procedure, were 18 years or older, and had preoperative and minimum 5-month postoperative weightbearing radiographs. Exclusion criteria included prior forefoot surgery, additional surgeries (such as metatarsal shortening), and concomitant foot conditions (such as flatfoot deformity). All surgeries were performed between 2016 and 2020.

Forty-one patients who underwent MIS bunionectomy and 81 patients who underwent Lapidus bunionectomy met the inclusion criteria. Of the latter 81 patients, 41 patients were chosen, manually matched to the MIS bunionectomy patients by preoperative radiographic parameters. Primary preference was given to match according to hallux valgus angle (HVA), then intermetatarsal angle (IMA) and tibial sesamoid position (TSP).

Surgical Technique

All surgeons in the study were foot and ankle fellowship-trained orthopaedic surgeons working at the same academic institution with similar patient populations. Each MIS procedure was performed by one of 2 surgeons, both of whom were recently trained in MIS techniques. All MIS procedures were performed using the MIS technique as described by Vernois and Redfern.[31] Both the chevron and Akin osteotomies were performed with a 2 × 20-mm cutting burr. The chevron osteotomy was fixed with two 4.0-mm fully threaded headless screws, or one 4.0-mm screw and one 3.0-mm screw. The Akin osteotomy was fixed with a fully threaded headless screw. Postoperatively, a supportive dressing was applied and patients were allowed to weightbear as tolerated immediately in a postoperative shoe.

Each Lapidus bunionectomy was performed by one of 5 surgeons. One of these surgeons also performed surgeries in the MIS group; the remaining 4 surgeons primarily perform Lapidus bunionectomies for hallux valgus. The modified Lapidus procedures were performed through a dorsal incision over the first TMT joint and a medial incision over the first metatarsophalangeal (MTP) joint, as described by Mani et al.[21] A lateral release was performed either through the distal medial incision or through a separate incision in the first dorsal webspace. Two crossing 3.5-mm or 4.0-mm screws were used for fixation at the first TMT joint. An Akin osteotomy was performed at the surgeon's discretion. Postoperatively, patients were maintained nonweightbearing for a minimum of 5 weeks, after which weightbearing was gradually progressed. Representative radiographs of each technique are shown in Figure 1.

Data Collection

Age, sex, procedure duration, and Patient-Reported Outcome Measurement Information System (PROMIS) scores were collected from the registry. Questionnaires were administered preoperatively and 1 year postoperatively. The PROMIS Physical Function, Pain Interference, Pain Intensity, Global Physical Health, Global Mental Health, and Depression questionnaires were used. Complications and reoperations

Table 1. Demographics and Radiographic Parameters Are Compared Between the MIS Group and the Lapidus Bunionectomy Group.

	MIS	Lapidus	*P* Value
Age, mean ± SD	52.7 ± 13.7	50.3 ± 13.1	.42
Sex, % female	85.4%	97.6%	.11
Radiographic follow-up, months ± SD	8.1 ± 3.1	9.5 ± 5.5	.09
HVA, degrees, mean ± SD			
Preoperative	25.1 ± 6.8	24.7 ± 7.6	.77
Postoperative	6.6 ± 5.3	6.8 ± 7.5	.88
IMA, degrees, mean ± SD			
Preoperative	13.0 ± 3.5	13.0 ± 3.0	.95
Postoperative	5.4 ± 2.4	5.7 ± 2.4	.58
TSP ≤4, % patients			
Preoperative	48.8	31.7	.18
Postoperative	85.3	92.7	.48

Abbreviations: HVA, hallux valgus angle; IMA, intermetatarsal angle; MIS, minimally invasive; TSP, tibial sesamoid position.

were collected from chart review. Recurrence was determined by an HVA exceeding 20 degrees.

Preoperative and minimum 5-month postoperative radiographs were used for radiographic measurements. The HVA, IMA, and TSP were measured pre- and postoperatively on weightbearing AP radiographs. The HVA is the angle between the long axis of the first metatarsal and the hallux proximal phalanx, and the IMA is the angle between the long axes of the first and second metatarsals. TSP ranges from I to VII, as defined by Hardy and Clapham, with greater numbers indicating more lateral positioning of the tibial sesamoid.[11] A postoperative TSP of IV or lower has been associated with better patient-reported outcomes from hallux valgus surgery[3]; therefore, patients were assigned to one of 2 groups (TSP ≤IV, or TSP >IV) based on this criterion for statistical analysis.

Statistical Analysis

Descriptive analysis was conducted for the MIS and Lapidus cohorts. Normality assumption was tested using the Shapiro Wilk test. Differences between groups were tested using *t* tests or Mann-Whitney *U* tests for continuous variables, and Pearson χ^2 or Fisher exact test for categorical variables. Significance was established at $P = .05$. Statistical analyses were conducted on R version 4.2.0 (R Foundation for Statistical Computing, Vienna, Austria).

Results

There were no significant differences in demographics or preoperative parameters between groups (Table 1). HVA improved in both the MIS and Lapidus groups from preoperative (mean 25.1 and 24.7 degrees, respectively) to postoperatively (mean 6.6 and 6.8 degrees). IMA also improved in the MIS and Lapidus groups from preoperative (mean 13 degrees in both groups) to postoperatively (<6 degrees in both groups) (Table 1). Procedure duration averaged 69 ± 19 minutes in the MIS group and 89 ± 28 minutes in the Lapidus group ($P < .001$). In the Lapidus group, 31 patients underwent a concomitant Akin osteotomy (75.6%).

Radiographic Outcomes

There was no significant difference in pre- or postoperative radiographic parameters between groups (Table 1). On average, the patients in this cohort had mild to moderate deformities, with 76% of patients having a preoperative HVA <30 degrees. Only 2 patients, one in each group, had an HVA greater than 40 degrees. Both groups achieved excellent radiographic correction, with the mean postoperative HVA less than 7 degrees in both groups. In both groups, at least 85% of patients achieved a TSP of ≤4, indicating improvement in sesamoid position.

Clinical Outcomes

In the MIS group, 26 patients (63%) completed all 6 PROMIS subscales preoperatively and 22 (54%) completed all 6 subscales postoperatively. In the Lapidus group, 37 patients (90%) completed all 6 PROMIS subscales preoperatively and postoperatively. There were no significant differences in pre- or postoperative PROMIS scores between the groups (Table 2).

Complications and Reoperations

Complications are compared between groups in Table 3. In the MIS group, there was one bunion recurrence, which was asymptomatic. There were 3 nonunions (7.3%): 2 asymptomatic nonunions of the chevron osteotomy and 1

Table 2. Mean Preoperative and 1-Year Postoperative PROMIS Scores Compared Between Groups.[a]

	MIS	Lapidus	*P* Value
PROMIS follow-up, y, mean ± SD	1.1 ± 0.3	1.5 ± 0.5	.005*
Physical Function			
Preoperative	47.3	49.6	.23
Postoperative	53.3	53.8	.81
Pain Interference			
Preoperative	55.6	54.9	.70
Postoperative	48.8	47.0	.42
Pain Intensity			
Preoperative	45.4	46.8	.43
Postoperative	38.9	37.4	.53
Global Physical Health			
Preoperative	50.5	51.5	.62
Postoperative	54.3	57.6	.13
Global Mental Health			
Preoperative	52.1	56.2	.07
Postoperative	56.0	57.0	.64
Depression			
Preoperative	46.4	45.2	.48
Postoperative	46.4	45.0	.50

Abbreviations: MIS, minimally invasive; PROMIS, Patient-Reported Outcome Measurement Information System.
[a]Scores range from 0 to 100, with 50 representative of the population mean, and higher scores indicating "more" of the attribute (eg, function, pain) being evaluated.
*$P < .05$.

Table 3. Complications Compared Between Groups.

Complication	MIS Cases, n (%)	Lapidus Cases, n (%)
Nonunion	3 (7.3)	0
Bunion recurrence (HVA ≥ 20 degrees)	1 (2.4)	2 (4.9)
Painful hardware requiring removal	4 (9.8)	2 (4.9)
Asymptomatic hardware complication, no treatment required	3 (7.3)	0
Persistent pain	3 (7.3)	5 (12.2)
Wound healing complication	1 (2.4)	2 (4.9)
First TMT joint subluxation	2 (4.9)	0
Hallux malrotation requiring reoperation	0	1 (2.4)
First MTP stiffness requiring reoperation	0	1 (2.4)
Second metatarsal stress fracture	0	1 (2.4)

Abbreviations: HVA, hallux valgus angle; MIS, minimally invasive; MTP, metatarsophalangeal; TMT, tarsometatarsal

symptomatic Akin osteotomy nonunion. The patient with the Akin osteotomy nonunion was last seen 7 months postoperatively, at which time symptoms were improving despite persistent radiographic lucency (Figure 2). She chose to defer further surgical intervention. There were 3 hardware complications that did not end up requiring treatment (for instance, an Akin screw that lost fixation, followed by uneventful healing). There were 2 cases of asymptomatic first TMT joint subluxation, neither of which met the 20-degree HVA criterion for bunion recurrence. An example is shown in Figure 3. There were 3 patients with persistent pain (7.3%): 1 at the medial eminence, 1 from first MTP joint arthritis, and 1 from persistent plantar pain consistent with sesamoid arthritis. There were 5 reoperations (12.2%): 2 for removal of hardware, 1 removal of hardware and first metatarsal ostectomy, 1 screw exchange for a backed-out screw, and 1 secondary wound closure 16 days postoperatively.

In the Lapidus group, there were 2 bunion recurrences, both asymptomatic. There were no nonunions. Nonoperative

Figure 1. Preoperative weightbearing radiographs are shown for (A, C) 2 patients with similar intermetatarsal angles. Six-month postoperative radiographs are shown for each patient, illustrating (B) the minimally invasive technique and (D) the modified Lapidus technique.

complications included a second metatarsal stress fracture diagnosed 3 months postoperatively; despite uneventful healing, this patient had persistent pain from first MTP arthritis and hammertoes. There were 5 other patients with continued pain: 3 from first MTP stiffness/arthritis, 1 medial eminence, 1 adjacent TMT arthritis, and 1 metatarsalgia/sesamoiditis. Two wound complications were treated successfully nonoperatively. There were 3 reoperations (7.3%): 1 removal of hardware with first MTP capsulotomy and manipulation for stiffness, 1 proximal phalanx osteotomy for derotation, and 1 removal of hardware.

Discussion

There are relatively few literature reports on outcomes of third-generation MIS chevron and Akin osteotomies. There are even fewer comparative studies, most of which compare the MIS chevron technique to the open scarf osteotomy. In our study comparing the MIS chevron technique to the modified Lapidus procedure, we found that both groups achieved the same degree of radiographic correction. This finding was unexpected, as we had hypothesized that the Lapidus group would achieve better radiographic outcomes. It demonstrates the corrective power of this distal metatarsal osteotomy, as even the open scarf osteotomy has been found to achieve inferior radiographic outcomes to the modified Lapidus procedure.[27,29]

Other authors have reported comparable correction with the open distal metatarsal osteotomy and the modified Lapidus procedure, with correction maintained at a follow-up of 8-11 years.[9] However, we did not know if the MIS chevron technique would produce similar results. Most outcome reports on the third-generation MIS chevron technique have been small case series. Most report high satisfaction (greater than 90%) and low complication rates.[14,16,20,22] The most common reason for reoperation has been for removal of hardware.[19] Rates of nonunion are variably reported, but range from 0% to 2.8%.[16,19,28] There is a learning curve effect, with one study identifying better outcomes after the first 50 patients for one surgeon.[16]

The largest study available in the literature reported on 292 feet treated with MIS chevron and Akin osteotomies with minimum 2 years' follow-up. The authors found significant improvement in clinical outcomes scores and good radiographic correction. More than 25% of the patients in this study had severe deformities (HVA $>$40 degrees), a much higher percentage than in the present study. Rates of symptomatic bunion recurrence (0.9%) and symptomatic delayed union (1.5%) were relatively low. Asymptomatic recurrence and asymptomatic delayed union were not reported. In this study, 69 patients or 138 feet (41%) had both feet treated on the same day, which argues for the feasibility of bilateral surgery with this technique.[19] Importantly, the surgeon who performed all surgeries in this cohort had already performed more than 100 MIS bunionectomies prior to the start of the study, and thus a learning curve effect was not present.

There have only been a few studies comparing the MIS chevron technique to open techniques. Studies comparing MIS chevron osteotomies to open metatarsal osteotomies have generally found no difference in clinical or radiographic outcomes, although pain appears to be lower in the early postoperative period among patients undergoing the MIS technique.[2,10,18,28]

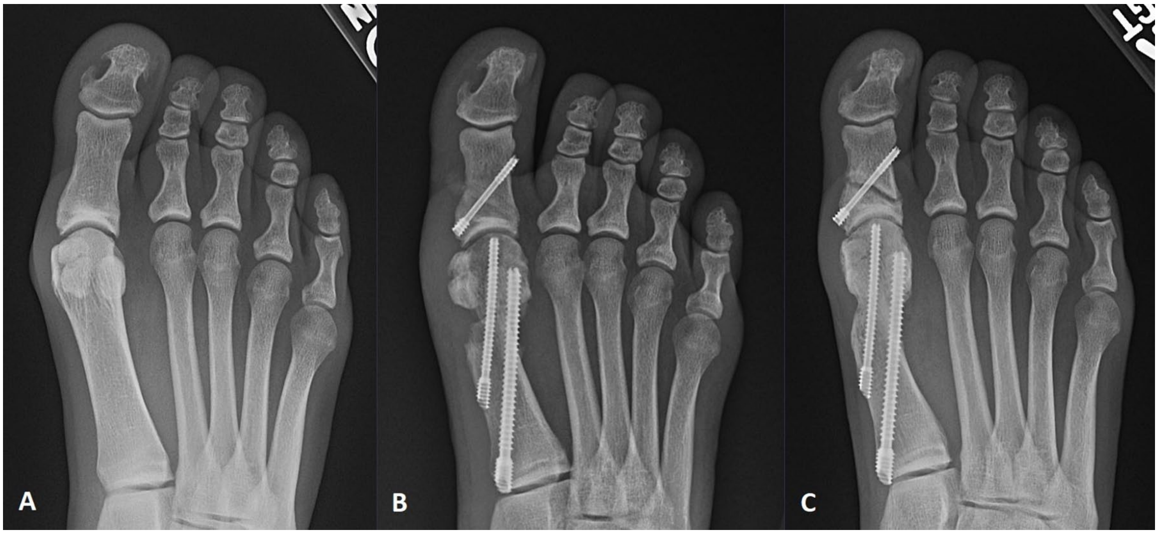

Figure 2. (A) Preoperative, (B) 6-week postoperative, and (C) 7-month postoperative radiographs are shown for a patient with nonunion of the Akin osteotomy site following minimally invasive bunionectomy.

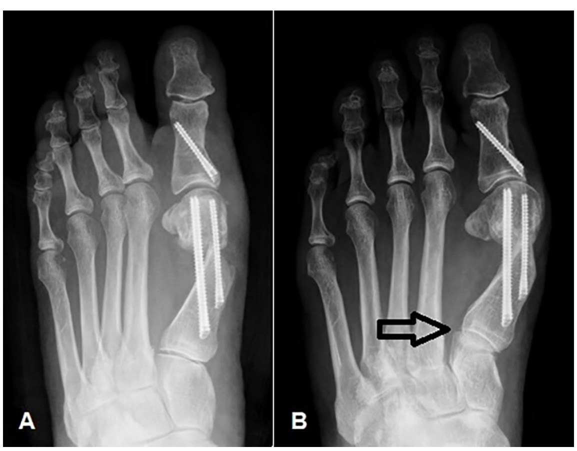

Figure 3. An example of first tarsometatarsal (TMT) joint subluxation following minimally invasive bunionectomy is shown. (A) Two-week postoperative radiographs show a congruent first TMT joint. (B) One-year postoperative radiographs show subluxation at the first TMT joint (arrow) with recurrence of hallux valgus.

In the present study, the 12.2% rate of reoperation, mostly for hardware complications, is comparable to other reports in the literature for this technique. Like other reports in the literature, we found good clinical outcomes and low recurrence rates. We did report higher rates of delayed union compared to the studies listed above. Our relatively high 7.3% rate of nonunion reported in the MIS group may be related to the relative inexperience of the 2 surgeons in this study in MIS techniques. Thermal necrosis from the burr may be a contributing factor. However, both surgeons currently use copious bulb irrigation while using the burr to help prevent this complication, as we have found that the irrigation provided by the burr attachment with some systems is insufficient. It is also possible that nonunion rates are underreported in the literature, as some studies only reported on symptomatic nonunions, and computed tomography is seldom used to confirm union. One other group has also identified a higher rate of delayed union following percutaneous Akin osteotomies.[12]

In this study, we also identify the complication of subluxation at the first TMT joint following MIS bunionectomy. Other authors have identified a relationship between pes planus deformity and hallux valgus recurrence in patients treated with metatarsal osteotomies.[13,29] Therefore, it is our preference to treat most hallux valgus deformities presenting with concomitant pes planus (especially with medial column instability) with the modified Lapidus procedure in order to decrease the risk of deformity recurrence. The complication of postoperative TMT subluxation has not yet been specifically described elsewhere, but we believe that it is a complication that surgeons performing these procedures should be aware of. Other authors have described the aim of the technique being to “lock” the first TMT joint in a maximally translated position, which should theoretically decrease the risk of recurrence.[23] However, continued translation at the joint nonetheless remains a mechanism of recurrence.

Theoretical advantages of the Lapidus bunionectomy over MIS chevron bunionectomy include the ability to directly correct metatarsal pronation. In another study on patients treated with the modified Lapidus procedure, hallux valgus recurrence rates were lower among those patients whose pronation was corrected compared to those whose pronation was not.[4] Our 0% nonunion rate in the Lapidus group is lower than that reported in the literature. A meta-analysis of studies on the modified Lapidus procedure including multiple types of fixation found a nonunion rate of 4%.[32] Using crossed-screw technique, the nonunion rate has been reported to average 5%.[8]

Strengths of this study include matching of patients based on severity of deformity, inclusion of multiple surgeons supporting generalizability of results, and standardized techniques between surgeons. No prior studies have compared radiographic outcomes between patients treated with MIS chevron and Akin osteotomies and patients treated with the modified Lapidus procedure. Weaknesses include relatively short follow-up times in both groups, relatively low rates of PROMIS completion in the MIS group, the lack of a power analysis, inconsistent use of the Akin osteotomy in the Lapidus group, and the possibility of a learning curve effect in the MIS group. In addition, the majority of deformities in our study were mild or moderate in severity. It is possible that differences might be found when comparing patients with more severe deformities, which may be better corrected with the modified Lapidus procedure.

Addressing the relatively short radiographic follow-up, a radiographic follow-up of less than 6 months is well supported in the literature. This relatively short follow-up time is supported by a study evaluating bunion recurrences: most recurrent bunions were identified by 3 months postoperatively, and all were identified by 6 months postoperatively. Radiographic parameters (HVA and IMA) stabilized for patients without recurrences by 6 months.[24] Other studies on hallux valgus have shown no difference between radiographic parameters at 3 months vs later time points up to 2 years.[1] Multiple previous studies assessing outcomes from the modified Lapidus procedure have used a 5-month minimum radiographic follow-up.[5-7] Finally, the primary aim of our radiographic assessments was to assess the corrective ability of each procedure, not necessarily the risk for recurrence or other longer-term complications. For this reason, the minimum 5-month radiographic follow-up was felt to be appropriate.

With this study, we have demonstrated that the MIS chevron and Akin technique can achieve the same degree of radiographic correction as the modified Lapidus procedure for mild to moderate deformities at short-term follow-up. An area of concern identified with the MIS technique includes the potential for postoperative TMT joint subluxation leading to deformity recurrence. Future studies will be needed to determine differences in satisfaction between patients undergoing each procedure, as well as which patient factors might guide selection of one procedure over another.

Ethical Approval

Ethical approval for this study was obtained from the Foot & Ankle Research Steering Committee, which manages the prospective Foot & Ankle Research Registry. This registry has been approved by the Hospital for Special Surgery Institutional Review Board (no. 2013-038).

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Scott J. Ellis, MD, reports consulting fees from Styker/Wright Medical. A. Holly Johnson, MD, reports royalties or licenses and consulting fees from Novastep. ICMJE forms for all authors are available online.

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References

1. Biz C, Fosser M, Dalmau-Pastor M, et al. Functional and radiographic outcomes of hallux valgus correction by mini-invasive surgery with Reverdin-Isham and Akin percutaneous osteotomies: a longitudinal prospective study with a 48-month follow-up. *J Orthop Surg Res*. 2016;11(1):157. doi:10.1186/s13018-016-0491-x
2. Brogan K, Lindisfarne E, Akehurst H, Farook U, Shrier W, Palmer S. Minimally invasive and open distal chevron osteotomy for mild to moderate hallux valgus. *Foot Ankle Int*. 2016;37(11):1197-1204. doi:10.1177/1071100716656440
3. Chen JY, Rikhraj K, Gatot C, Lee JY, Singh Rikhraj I. Tibial sesamoid position influence on functional outcome and satisfaction after hallux valgus surgery. *Foot Ankle Int*. 2016;37(11):1178-1182. doi:10.1177/1071100716658456
4. Conti MS, Patel TJ, Zhu J, Elliott AJ, Conti SF, Ellis SJ. Association of first metatarsal pronation correction with patient-reported outcomes and recurrence rates in hallux valgus. *Foot Ankle Int*. 2022;43(3):309-320.
5. Conti MS, Caolo KC, Ellis SJ, Cody EA. Radiographic and clinical outcomes of hallux valgus and metatarsus adductus treated with a modified Lapidus procedure. *Foot Ankle Int*. 2021;42(1):38-45. doi:10.1177/1071100720952079
6. Conti MS, MacMahon A, Ellis SJ, Cody EA. Effect of the modified Lapidus procedure for hallux valgus on foot width. *Foot Ankle Int*. 2020;41(2):154-159. doi:10.1177/1071100719884556
7. Conti MS, Willett JF, Garfinkel JH, et al. Effect of the modified Lapidus procedure on pronation of the first ray in hallux valgus. *Foot Ankle Int*. 2020;41(2):125-132. doi:10.1177/1071100719883325

8. Donnenwerth MP, Borkosky SL, Abicht BP, Plovanich EJ, Roukis TS. Rate of nonunion after first metatarsal-cuneiform arthrodesis using joint curettage and two crossed compression screw fixation: a systematic review. *J Foot Ankle Surg*. 2011;50(6):707-709. doi:10.1053/j.jfas.2011.08.003
9. Faber FW, van Kampen PM, Bloembergen MW. Long-term results of the Hohmann and Lapidus procedure for the correction of hallux valgus: a prospective, randomised trial with eight- to 11-year follow-up involving 101 feet. *Bone Joint J*. 2013;95-B(9):1222-1226. doi:10.1302/0301-620X.95B9.31560
10. Frigg A, Zaugg S, Maquieira G, Pellegrino A. Stiffness and range of motion after minimally invasive chevron-Akin and open scarf-Akin procedures. *Foot Ankle Int*. 2019;40(5):515-525. doi:10.1177/1071100718818577
11. Hardy RH, Clapham JC. Observations on hallux valgus. *J Bone Joint Surg Br*. 1951;33(3):376-391.
12. Herrera-Perez M, De Prado-Serrano M, Gutierrez-Morales MJ, Boluda-Mengod J, Pais-Brito JL. Increased rates of delayed union after percutaneous akin osteotomy. *Foot Ankle Surg*. 2018;24(5):411-416. doi:10.1016/j.fas.2017.04.010
13. Heyes GJ, Vosoughi AR, Weigelt L, Mason L, Molloy A. Pes planus deformity and its association with hallux valgus recurrence following scarf osteotomy. *Foot Ankle Int*. 2020;41(10):1212-1218. doi:10.1177/1071100720937645
14. Holme TJ, Sivaloganathan SS, Patel B, Kunasingam K. Third-generation minimally invasive chevron Akin osteotomy for hallux valgus. *Foot Ankle Int*. 2020;41(1):50-56. doi:10.1177/1071100719874360
15. Jowett CR, Rodda D, Amin A, Bradshaw A, Bedi HS. Minimally invasive calcaneal osteotomy: a cadaveric and clinical evaluation. *Foot Ankle Surg*. 2016;22(4):244-247. doi:10.1016/j.fas.2015.11.001
16. Jowett CRJ, Bedi HS. Preliminary results and learning curve of the minimally invasive chevron Akin operation for hallux valgus. *J Foot Ankle Surg*. 2017;56(3):445-452. doi:10.1053/j.fas.2017.01.002
17. Kadakia AR, Smerek JP, Myerson MS. Radiographic results after percutaneous distal metatarsal osteotomy for correction of hallux valgus deformity. *Foot Ankle Int*. 2007;28(3):355-360.
18. Lee M, Walsh J, Smith MM, Ling J, Wines A, Lam P. Hallux valgus correction comparing percutaneous chevron/Akin (PECA) and open scarf/Akin osteotomies. *Foot Ankle Int*. 2017;38(8):838-846. doi:10.1177/1071100717704941
19. Lewis TL, Ray R, Miller G, Gordon DJ. Third-generation minimally invasive chevron and Akin osteotomies (MICA) in hallux valgus surgery: two-year follow-up of 292 cases. *J Bone Joint Surg Am*. 2021;103(13):1203-1211. doi:10.2106/JBJS.20.01178
20. Lewis TL, Ray R, Robinson P, et al. Percutaneous chevron and Akin (PECA) osteotomies for severe hallux valgus deformity with mean 3-year follow-up. *Foot Ankle Int*. 2021;42(10):1231-1240. doi:10.1177/10711007211008498
21. Mani SB, Lloyd EW, MacMahon A, Roberts MM, Levine DS, Ellis SJ. Modified Lapidus procedure with joint compression, meticulous surface preparation, and shear-strain-relieved bone graft yields low nonunion rate. *HSS J*. 2015;11(3):243-248. doi:10.1007/s11420-015-9462-8
22. Mikhail CM, Markowitz J, Di Lenarda L, Guzman J, Vulcano E. Clinical and radiographic outcomes of percutaneous chevron-Akin osteotomies for the correction of hallux valgus deformity. *Foot Ankle Int*. 2022;43(1):32-41. doi:10.1177/10711007211031218
23. Nunes GA, Ferreira GF, Baumfeld T, Filho MVP, Baumfeld D, Lam P. Minimally invasive chevron Akin: locking the metatarsal-cuneiform joint. *Foot Ankle Spec*. 2022;19386400221079155. doi:10.1177/19386400221079155
24. Park CH, Lee WC. Recurrence of hallux valgus can be predicted from immediate postoperative non-weight-bearing radiographs. *J Bone Joint Surg Am*. 2017;99(14):1190-1197. doi:10.2106/JBJS.16.00980
25. Ray JJ, Koay J, Dayton PD, Hatch DJ, Smith B, Santrock RD. Multicenter early radiographic outcomes of triplanar tarsometatarsal arthrodesis with early weightbearing. *Foot Ankle Int*. 2019;40(8):955-960. doi:10.1177/1071100719847700
26. Redfern D, Perera AM. Minimally invasive osteotomies. *Foot Ankle Clin*. 2014;19(2):181-189. doi:10.1016/j.fcl.2014.02.002
27. Reilly ME, Conti MS, Day J, et al. Modified Lapidus versus scarf osteotomy outcomes for treatment of hallux valgus deformity. *Foot Ankle Int*. 2021;42(11):1454-1462. doi:10.1177/10711007211013776
28. Tay AYW, Goh GS, Koo K, Yeo NEM. Third-generation minimally invasive chevron-Akin osteotomy for hallux valgus produces similar clinical and radiological outcomes as scarf-Akin osteotomy at 2 years: a matched cohort study. *Foot Ankle Int*. 2022;43(3):321-330. doi:10.1177/10711007211049193
29. Thomas T, Faroug R, Khan S, Morgan S, Ballester JS. Comparison of scarf-Akin osteotomy with Lapidus-Akin fusion in cases of hallux valgus with a disrupted Meary's line: a case series study. *Foot (Edinb)*. 2020;49:101747. doi:10.1016/j.foot.2020.101747
30. Vernois J, Redfern D, GRECMIP soon MIFAS. Lapidus, a percutaneous approach. *Foot Ankle Clin*. 2020;25(3):407-412. doi:10.1016/j.fcl.2020.05.010
31. Vernois J, Redfern DJ. Percutaneous surgery for severe hallux valgus. *Foot Ankle Clin*. 2016;21(3):479-493. doi:10.1016/j.fcl.2016.04.002
32. Willegger M, Holinka J, Ristl R, Wanivenhaus AH, Windhager R, Schuh R. Correction power and complications of first tarsometatarsal joint arthrodesis for hallux valgus deformity. *Int Orthop*. 2015;39(3):467-476. doi:10.1007/s00264-014-2601-x