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Third-Generation Minimally Invasive Chevron Akin Osteotomy for Hallux Valgus

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Abstract

Background: Multiple operative techniques have been developed for hallux valgus with varying success. The most recent developments in minimally invasive surgery have evolved into the third-generation minimally invasive chevron Akin (MICA) osteotomy. Good results have been shown from originator centers, but this is one of the first series from a nonoriginator center, and the first to use a validated patient-reported outcome measure.

Methods: Forty consecutive patients undergoing third-generation MICA for hallux valgus were included. Primary outcome measures included Manchester-Oxford Foot Questionnaire (MOXFQ) and American Orthopaedic Foot & Ankle Society (AOFAS) scores and Coughlin satisfaction rates at 12 months. Secondary outcome measures included radiographic parameters, complications, and recurrence rates.

Results: At 12 months, the MOXFQ score improved from 58 to 10 and the AOFAS score improved from 48 to 93, with 70% of patients reporting excellent outcomes and 30% good ones. Two cases started as mild, 29 cases as moderate, and 9 cases as severe as defined by radiographic criteria. Hallux valgus angles improved from 32 degrees to 12 degrees, and intermetatarsal angles improved from 13 degrees to 7 degrees. There were 4 cases of Akin screw removal for soft tissue irritation. There were no other complications, including recurrence.

Conclusion: The third-generation MICA technique was a safe and effective approach to treating hallux valgus. Further research should focus on long-term outcomes and comparative data with other commonly performed operative techniques.

Level of Evidence: Level IV, case series.

Keywords: keyhole bunion surgery, MIS, MICA, minimally invasive hallux valgus

Introduction

Hallux valgus is thought to affect up to 28.4%[27] of the adult population in the United Kingdom. Traditionally operative intervention has involved open bony and soft tissue procedures. More recently, minimally invasive techniques have been popularized due to the potential for decreased recovery times, smaller scars, and a greater range of early postoperative motion.[19] Early generations of the technique have been criticized for inadequate evidence for their use and high complication rates.[2] The most recent technique, minimally invasive chevron Akin (MICA), has been criticized for lack of evidence from nonoriginator surgeons.[24] In addition, previous reports of this technique have not used a validated patient-reported outcome measure (PROM). We aimed to report a case series from a nonoriginator single fellowship-trained surgeon (K.K.) using the MICA technique for hallux valgus.

Methods

Forty consecutive patients undergoing third-generation MICA surgery for hallux valgus under the care of a single fellowship-trained consultant surgeon were included from 2017 to 2018. All patients were counseled in keeping with the National Institute for Health and Care Excellence (NICE) Interventional Procedures Guidance IPG 332 and subsequent literature.[22] The mean age of patients was 51 years (range, 18-87 years), with 38 female and 2 male patients.

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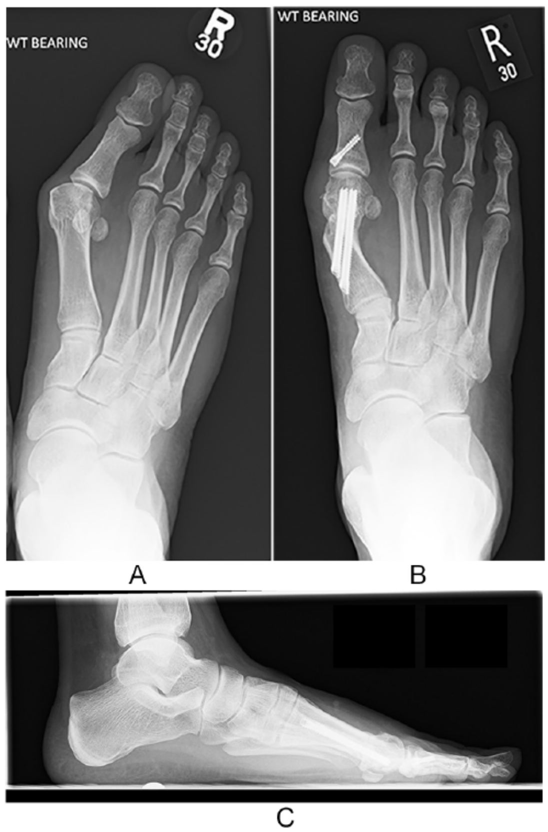

Figure 1. (A) Preop radiograph showing moderate hallux valgus. (B) Postop radiograph showing correction of deformity using the minimally invasive chevron Akin technique. (C) Postop radiograph of lateral weightbearing demonstrating sagittal alignment.

Primary Outcome Measures

Recorded outcomes were in accordance with NICE guidelines for research in minimal access procedures for hallux valgus correction.[23] Clinical outcome was measured using the Manchester-Oxford Foot Questionnaire (MOXFQ)[21] and the American Orthopaedic Foot & Ankle Society (AOFAS) Forefoot Score[13] (preop and 12 months postop). The MOXFQ was used as it is a validated PROM, and the AOFAS was used as a comparator to other previous publications. Patient satisfaction was measured using the Coughlin scale.[5] Results were collated prospectively by the authors not performing the surgery.

Radiographic evaluation was undertaken on standard foot anteroposterior (AP)/lateral weightbearing radiographs (Figure 1) by the first and second authors (T.J.H., S.S.S., orthopedic residents). The lead surgeon was involved only in validating the technique used, not in actual measurements. The hallux valgus angle (HVA) and intermetatarsal angle (IMA) were measured preop and postop at 12 months, with interobserver reliability measurement calculated using intraclass correlation coefficients (ICCs). Angles were measured in accordance with the AOFAS ad hoc Committee on Angular Measurements guidelines.[7] Severity of hallux valgus was classified according to the HVA (≤15 degrees, normal; <20 degrees, mild; <40 degrees, moderate; ≥40 degrees severe)[6] and the IMA (<9 degrees, normal; 9-11 degrees, mild; 12-17 degrees, moderate; ≥18 degrees, severe).[25]

Secondary Outcome Measures

All complications (defined using the Clavien-Dindo Classification of Surgical Complications[4] as "any deviation from the normal postoperative course"), radiation exposure (dose area product [DAP]), mean tourniquet time, and length of stay were recorded.

Operative Technique (Figure 2)

The operative technique is similar to that previously described by Lee et al.[17] Through use of a magnified and coned view on the image intensifier, the entry point for the skin incision and ultimately first metatarsal osteotomy was identified just distal to the beginning of the flare of the metatarsal head-neck junction (Figure 2A). A size 15 surgical blade was used to make the incision, holding the foot with the non–scalpel-holding hand dorsal and plantar to gauge the midpoint of the first metatarsal (Figure 2B). A 2 × 13–mm Shannon burr was used to create a modified chevron osteotomy of the distal metatarsal by pushing gently into the periosteum to avoid the burr sliding when moving the image intensifier and foot to obtain a lateral view. Once the burr was on the dorsal/plantar midpoint on the lateral image and just distal to the start of the flare of the metatarsal on the AP view, the burr was activated to cut perpendicular to the long axis of the bone through the far cortex. Once through the far cortex, the tip of the burr was aimed dorsally and used to cut the dorsal half circumference of the bone (Figure 2C and D). A 1.6-mm Kirschner wire (K-wire) was then passed into an acceptable position and the drill was used to create a guide hole in the metatarsal on the proximal side of the osteotomy; then the plantar cut was made. To do this, the burr was inserted into the same starting position. The plantar base was deliberately small to allow for maximum translation of the metatarsal head. Again, once the burr was passed through the far cortex it was activated and angled plantar and slightly proximal, being mindful of the plantar curve of the bone and hence requiring pulling back as the cut was completed (Figure 2E and F). Small islands of bone could be left intact, and they were felt when there was resistance to mobilizing the osteotomy. This problem was resolved by passing the burr into the starting position and moving it through the cutting arc

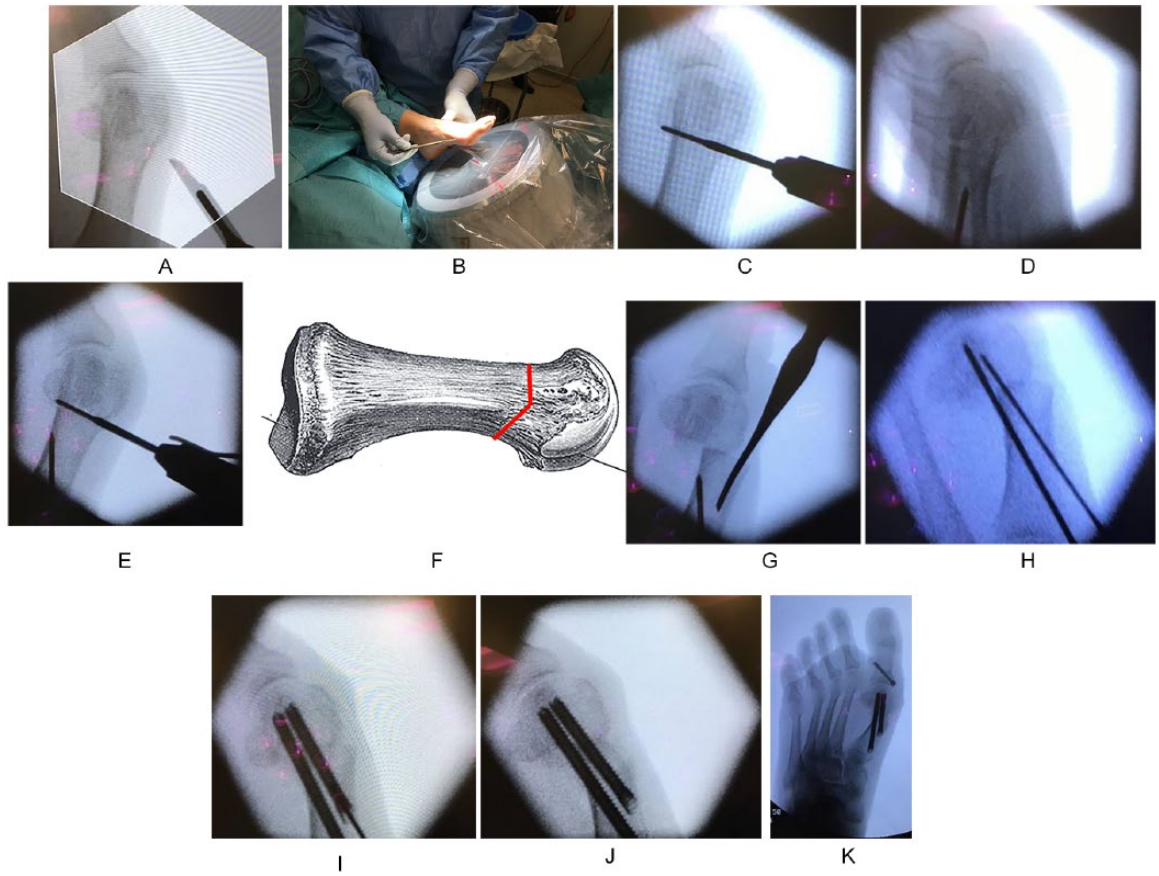

Figure 2. (A) Entry point for skin incision. (B) Initial incision. (C) Initial dorsal burr cut (anteroposterior, burr in situ). (D) Initial dorsal burr cut (lateral, burr removed). (E) Reinsertion of burr for plantar cut. (F) Artwork representation of chevron cut. (G) Displacement of osteotomy using small osteotome (radiograph). (H) K-wire initial fixation of displaced osteotomy. (I) Screw fixation of displaced osteotomy. (J) Image intensifier image postremoval of medial eminence. (K) Final intensifier image after Akin osteotomy.

until the remaining bone bridge was disrupted. The osteotomy was displaced with a surgical clip or small osteotome through the distal incision and held with a 1.6-mm K-wire (Figure 2G). A second proximal incision was made to insert a 1.2-mm K-wire to further transfix the displaced osteotomy (Figure 2H), and this was secured with a 4-mm headless cannulated screw (Marquardt Medical, Stanmore, UK). The first K-wire was then changed to a 1.2-mm guidewire to allow for the second cannulated screw to be inserted (Figure 2I). Open distal soft tissue release was only used in selected cases. The prominent medial eminence of the metatarsal diaphysis was removed with a 3.1-mm wedge burr (Figure 2J). An Akin osteotomy was performed through a fourth stab incision using a 2 × 13–mm Shannon burr, fixed with a 3-mm headless cannulated compression screw (Figure 2K). Positioning was confirmed on AP and lateral fluoroscopy views with each step. Washout of bone debris was performed with normal saline through a 19-G needle. Postoperative dressings included Steri-Strips (3M, United Kingdom), adhesive dressings, dry gauze, a softband, and a crepe bandage in a toe spica fashion.

Postoperative Rehabilitation

All patients received routine antibiotic prophylaxis as per hospital protocol. The postoperative rehabilitation involved a foot spica bandage dressing for the first 2 weeks, mobilization flat-footed in a flat postoperative shoe, and full weightbearing with the aid of crutches if required for balance and support (not to offload weightbearing). All patients went home the same day after review by physiotherapy and were followed up 2 weeks later in the outpatient clinic. After 2 weeks, gentle stretching exercises were introduced and the patient was moved into trainer shoes.

Statistics

Statistical analysis was undertaken using MedCalc for Windows version 17.5.5 (MedCalc Software, Ostend,

Table 1. Clinical Outcome Scores (MOXFQ, AOFAS) and Radiographic Outcomes (HVA, IMA) Preop and 12 Months Postop.

	Preop (range)	Postop (range)	*P* Value[a]
MOXFQ	58.5 (27-88)	9.6 (0-83)	<.001
AOFAS	48.2 (24-72)	93.4 (60-100)	<.001
HVA, deg	31.7 (12-57)	12.1 (1-43)	<.001
IMA, deg	13.2 (6-24)	6.7 (2-13)	<.001

Abbreviations: AOFAS, American Orthopaedic Foot & Ankle Society; HVA, hallux valgus angle; IMA, intermetatarsal angle; MOXFQ, Manchester-Oxford Foot Questionnaire.
[a]Paired sample *t* tests were used to determine significance.

Belgium). Paired *t* tests were used to determine the statistical significance of the difference between pre- and postoperative scores and angles.

Results

Primary Outcome Measures

AOFAS scores improved significantly from 48.2 ± 14.7 (1 standard deviation) (range, 24-72) preop to 93.4 ± 15.7 (range, 60-100) postop. MOXFQ scores improved considerably from 58.5 ± 15.9 (range, 27-88) preop to 9.6 ± 9.2 (range, 0-83) postop (Table 1). Seventy percent (28/40) of patients rated their outcome as excellent, and 30% (12/40) as good at 12 months.

HVA improved considerably from 31.7 ± 10.3 degrees (range, 12-57 degrees) preop to 12.1 ± 9.2 degrees (range, 1-43 degrees) postop. IMA improved considerably from 13.2 ± 3.8 degrees (range, 6-24 degrees) preop to 6.7 ± 2.9 degrees (range, 2-13 degrees) postop (Table 1). Interrater ICC scores were 0.91 (95% confidence interval, 0.80-0.96) for IMA and 0.94 (95% confidence interval, 0.87-0.97) for HVA. Two cases started as mild (mean HVA, 12 degrees [range, 12-13 degrees]; mean IMA, 10 degrees [range, 9-10 degrees]), 29 as moderate (mean HVA, 29 degrees [range, 18-40 degrees]; mean IMA, 12 degrees [range, 6-17 degrees]), and 9 as severe (mean HVA, 46 degrees [range, 36-57 degrees]; mean IMA, 17 degrees [range, 11-24 degrees]) as defined by the HVA and IMA measurements.[6,25]

Secondary Outcome Measures and Complications

Our complication rate was 10%, with 4 patients requiring Akin screw removal after bony union due to soft tissue irritation. There were no cases of recurrence or other complications at 12 months. All patients were treated and discharged on the same day, with no overnight stays. The mean tourniquet time (equivalent to operating time) was 54.4 minutes. The mean DAP of radiation exposure was 3.12 cGycm^2 (range, 0.51-8 cGycm^2).

Discussion

Many open operative techniques for hallux valgus correction have been developed. A recent systematic review demonstrated minimal difference between techniques, with only the distal chevron osteotomy demonstrating effective pain relief compared with no surgery. It highlighted a lack of high-quality studies comparing treatments that assess the same outcome as a limitation.[14] This is one reason we have tried to maintain the same technique and outcome measures as those in previously published research.[17] Complication rates in open surgery are reported to range from 0% to 2.4%. However, definitions of complications have been lacking, varying from mild wound infection requiring a short course of oral antibiotics to recurrence requiring revision surgery.[14]

First- and second-generation minimally invasive surgery (MIS) techniques have involved proximal and distal metatarsal osteotomies with either no fixation or K-wire fixation or proximal metatarsal osteotomy with screw fixation. The average HVA correction for mild to moderate hallux valgus has been shown to improve from 29.6 degrees preoperatively to 13.2 degrees postoperatively, and for moderate to severe hallux valgus from 41.5 to 13.2 degrees. IMA has been shown to improve from 14.6 to 8.6 degrees.[2] This is comparable to the MICA technique in our series. Complication rates range from 0% to 19%, including recurrence of hallux valgus, stiffness of the first metatarsophalangeal joint (MTPJ), malunion, and infection.[2]

This nonoriginator third-generation MICA case series supports the safety and success rate of the MICA technique for hallux valgus. For other third-generation MIS studies (Table 2), Jowett and Bedi[12] reported a prospective case series of 106 cases (78 patients) with an average follow-up of 25 months. They demonstrated AOFAS score improvement from 56 to 87. Radiographic parameters included HVA improvement from 29.7 to 10.3 degrees and IMA improvement from 14 to 7.6 degrees. Eighty-seven percent of the cases reported satisfaction with the procedure; 13% were dissatisfied due to discomfort from prominent hardware, scar sensitivity, nonunion, and recurrence. The reported complication rate was 42%, of which half required

Table 2. Comparative Outcomes With Contemporaneous Studies.

	No. of Cases	Mean Follow-up (mo)	MOXFQ, Preop to Postop	AOFAS, Preop to Postop	Satisfaction (%)	HVA, Preop to Postop (deg)	IMA, Preop to Postop (deg)	Complication Rate (%)	Length of Stay (d)	Surgical Time (min)
Present study (2019)	40	12	58.5 to 9.6	48.2 to 93.4	Excellent, 70 Good, 30	31.7 to 12.1	13.2 to 6.7	10	0	54.4
Jowett and Bedi (2017)	106	25	—	56 to 87	Satisfied, 87	29.7 to 10.3	14 to 7.6	42	—	—
Lee et al (2017)	25	6	—	61.3 to 88.7	Excellent, 84 Good, 16	31.4 to 7.6	15.6 to 6.4	24	—	—
Lucas y Hernandez et al (2016)	45	60	—	62.5 to 97.1	Satisfied or very satisfied, 97	26.6 to 9.6	11.8 to 7.9	15.5	—	—
Lam et al (2015)	23	18	—	59.3 to 88.4	—	31.7 to 14.4	13.8 to 8	17	2.6	94.3
Vernois and Redfern (2013)	341	12-36 (mean not stated)	—	—	Excellent or good, 95	33.7 to 7.3	14.5 to 5.5	2	—	—

Abbreviations: AOFAS, American Orthopaedic Foot & Ankle Society; HVA, hallux valgus angle; IMA, intermetatarsal angle; MOXFQ, Manchester-Oxford Foot Questionnaire.

surgical intervention (screw removal, bumpectomy, revision osteotomy, extensor hallucis longus lengthening, wound infection, periprosthetic fracture) and half was being managed nonoperatively (delayed union, under- or overcorrection, recurrence, scar sensitivity, short first metatarsal). This is somewhat higher than the finding in other studies and our own, and probably reflects the fact that they included their learning curve complications.

Lee et al[17] reported a prospective randomized trial evaluating 25 MICA versus 25 open surgery cases, with 6 months of follow-up. They demonstrated AOFAS score improvement from 61.3 to 88.7 in the MIS group. Radiographic parameters included an HVA improvement of 31.4 to 7.6 degrees and an IMA improvement from 15.6 to 6.4 degrees. They reported excellent patient satisfaction in 84% of patients and good in 16% in the MIS group. The complication rate was reported at 24% with prominent hardware requiring screw removal in 6 out of 25 patients in the MIS group. This is slightly higher than our experience and may well reflect the difference in screw design. Their chevron screw had a square headless design, whereas the chevron screw used in our series had an oblique headless design, which theoretically sits more flush with the cortex, minimizing soft tissue irritation.

Lucas y Hernandez et al[18] reported a case series of 45 procedures in 38 patients with a mean follow-up of 60 months. They demonstrated AOFAS score improvement from 62.5 to 97.1. Radiographic parameters included HVA improvement from 26.6 to 9.6 degrees and IMA improvement from 11.8 to 7.9 degrees. Ninety-seven percent of patients reported being satisfied or very satisfied. They had complications in 15.5% of cases, including 1 failure of fixation, 1 delayed wound healing, 1 painful residual exostosis, and 4 screw removals.

Lam et al[15] reported a case series of 23 cases in 20 patients with a mean follow-up period of 18 months. They demonstrated AOFAS score improvement from 59.3 to 88.4. Radiographic parameters included HVA improvement from 31.68 to 14.39 degrees and IMA improvement from 13.77 to 7.98 degrees. Their complication rate was 17% with 4 cases of Akin screw impingement requiring removal. Other secondary outcomes included mean operating times of 94.3 minutes and mean hospital stay of 2.6 days. Their rates of complications, operating time, and hospital stays are slightly higher than those in our experience; this may reflect the learning curve experience incorporated in their series and the relatively low patient numbers. Patient satisfaction was not reported in their series.

Vernois and Redfern[28] reported a case series of 341 patients with follow-up ranging from 12 to 36 months. Radiographic parameters included HVA improvement from 33.7 to 7.3 degrees and IMA improvement from 14.5 to 5.5 degrees. They demonstrated satisfaction rates of 95% excellent or good. The complication rate was reported at 2%, with 7 recurrences due to failed primary fixation, and 1 case of transfer metatarsalgia. Their reported complication rate is much lower than those in other reports, including our own, and they do not include formal PROMs.

The chevron screw used in our study has an oblique profile to the head, allowing it to be placed flush with the metatarsal bone, whereas the Akin screw has a square profile (Figure 3). This may also explain in part the tendency for irritation from the Akin screw rather than the chevron screw. Further product development may reduce this complication more. Rates of malunion and recurrence are likely to be less due to the rigid screw fixation of the osteotomy (compared with K-wire fixation in many earlier techniques).

MTPJ stiffness is theoretically likely to be less than that in earlier techniques as the screw fixation does not impinge movement of the MTPJ compared with the K-wires of earlier techniques, and early aggressive rehabilitation including stretching exercises at 2 weeks improves this outcome

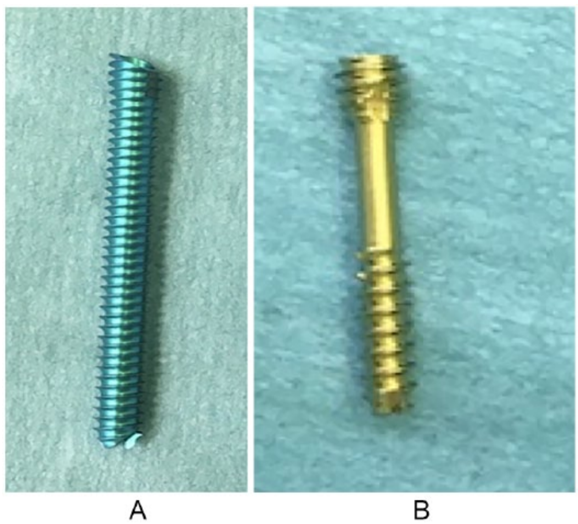

Figure 3. (A) Chevron screw (note the oblique proximal end). (B) Akin screw (note the square proximal end).

without undue complication. However, this has only been indirectly assessed in this study through the AOFAS scores and therefore warrants further study.

This study is the first to report a validated patient outcome score in the form of the MOXFQ score. Further studies should incorporate—and in fact are in progress—validated outcome tools such as this.[17] The poorer baseline AOFAS score in our study may in part be due to the relative social deprivation in our catchment area leading to more severe disease at presentation.[9,10]

We had 1 case with good overall satisfaction but poor MOXFQ/AOFAS scores due to associated referred pain from the spine, and this occasional contrast between overall satisfaction and PROMs is recognized in the orthopedic literature.[8] We had another case where the absolute angular correction was not as large as others in the series; however, the PROMs and satisfaction scores were comparable. The relationship between absolute angular correction and PROMs/patient satisfaction is not clear and has been reported previously in hallux valgus corrective surgery.[1]

Recurrence rates after hallux valgus surgery have been reported to be as high as 16%.[16] Recurrent hallux deformity can present a particular challenge due to a lot of scar tissue and a higher rate of complications compared with primary surgery.[20] Magnan et al[20] have recently published long-term results (average, 9.8 years) in 35 cases undergoing percutaneous distal osteotomy that is temporarily held with a K-wire, demonstrating good results with only 1 recurrence at 14 years. The modern MICA technique, with a stronger screw purchase in the bone, may reduce this rate even further, but it is yet to be studied in revision surgery.

No other study has reported radiation exposure in either MIS or open hallux valgus surgery, an important element to consider in the MIS technique. The DAP associated with a chest radiograph[26] in an adult is 15 $cGycm^2$ and with a foot radiograph[11], 7 $cGycm^2$; our mean DAP of 3.12 $cGycm^2$ is much lower than this. Therefore, any risk associated with radiation exposure with this technique is theoretically extremely low.

Limitations

This is a case series demonstrating safe and effective use of the technique outside of an originator surgeon center. It did not attempt to directly compare the technique with others, although given the confusion surrounding optimal open techniques, the design of such a study may be challenging.[14] There is a considerable learning curve with this technique.[12] The results reported here are post–fellowship training and thus do not include the learning curve results. The follow-up period presented in this series is relatively short (12 months); however, the data still help answer a previously unknown question regarding the safety and efficacy of the technique in a nonoriginator center. Further long-term data collection, largely to determine recurrence rates and long-term patient satisfaction, will be evaluated in due course in this cohort. The AOFAS score is not a validated assessment tool; however, it is the most commonly used outcome score in evaluating outcomes in MIS hallux valgus surgery and therefore allows for direct comparison to previously published results. The MOXFQ score was used as a validated assessment tool to record patient outcomes; however, the previous studies reporting this technique have not used a validated outcome measure, and therefore it is not possible to directly compare this. The distal metatarsal articular angle (DMAA) was not used as a radiographic outcome measure in this study, as it has been shown to have poor interobserver reliability[3] and is not commonly used in research for this reason.[2]

Conclusion

Our series of third-generation MICA with headless screw fixation was a safe and effective method of hallux valgus correction with excellent results at 12 months. Longer-term follow-up and further comparative trials are required to determine its benefits over traditional open surgery.

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Declaration of Conflicting Interests

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References

1. Baca E, Karaali E, Duramaz A, Ercin E. Hallux valgus patients, why are they happy? *Foot Ankle Orthop*. 2017;2(3): doi: 10.1177/2473011417S000101.
2. Bia A, Guerra-Pinto F, Pereira BS, Corte-Real N, Oliva XM. Percutaneous osteotomies in hallux valgus: a systematic review. *J Foot Ankle Surg*. 2018;57(1):123-130.
3. Chi TD, Davitt J, Younger A, Holt S, Sangeorzan BJ. Intra- and inter-observer reliability of the distal metatarsal articular angle in adult hallux valgus. *Foot Ankle Int*. 2002;23(8):722-726.
4. Clavien PA, Barkun J, de Oliveira ML, et al. The Clavien-Dindo classification of surgical complications: five-year experience. *Ann Surg*. 2009;250(2):187-196.
5. Coughlin MJ. Treatment of bunionette deformity with longitudinal diaphyseal osteotomy with distal soft tissue repair. *Foot Ankle*. 1991;11(4):195-203.
6. Coughlin MJ, Jones CP. Hallux valgus: demographics, etiology, and radiographic assessment. *Foot Ankle Int*. 2007;28(7):759-777.
7. Coughlin MJ, Saltzman CL, Nunley JA II. Angular measurements in the evaluation of hallux valgus deformities: a report of the ad hoc committee of the American Orthopaedic Foot & Ankle Society on angular measurements. *Foot Ankle Int*. 2002;23(1):68-74.
8. Daw RLC, Gibson J, Prescot D, Bonnett L, Smith M. What is the correlation between patient-reported outcome measure (PROM) scores and patient satisfaction following elective reverse total shoulder replacement? *Shoulder Elbow*. 2019;11(2 Suppl):42-47.
9. Department for Communities and Local Government. Annual Report and Accounts 2015-16. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/536593/56046_DCLG_ARA_Web_only.pdf. Accessed August 23, 2019.
10. Harrison MJ, Tricker KJ, Davies L, et al. The relationship between social deprivation, disease outcome measures, and response to treatment in patients with stable, long-standing rheumatoid arthritis. *J Rheumatol*. 2005;32(12):2330-2336.
11. Health Service Executive (Ireland). Section 7: Diagnostic Reference Levels (DRLs): Establishment and Use of Diagnostic Reference Levels (DRLs). https://www.hse.ie/eng/about/who/qualityandpatientsafety/safepatientcare/medexpradiatonunit/section%207%20diagnostic%20reference%20levels%20rp%20manual.pdf. Accessed June 26, 2019.
12. 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.
13. Kitaoka HB, Alexander IJ, Adelaar RS, Nunley JA, Myerson MS, Sanders M. Clinical rating systems for the ankle-hindfoot, midfoot, hallux, and lesser toes. *Foot Ankle Int*. 1994;15(7):349-353.
14. Klugarova J, Hood V, Bath-Hextall F, Klugar M, Mareckova J, Kelnarova Z. Effectiveness of surgery for adults with hallux valgus deformity: a systematic review. *JBI Database System Rev Implement Rep*. 2017;15(6):1671.
15. Lam K-LK, Kong S-W, Chow Y-H. Percutaneous chevron osteotomy in treating hallux valgus: Hong Kong experience and mid-term results. *J Orthop Trauma Rehabil*. 2015;19(1):25-30.
16. Lee KT, Park YU, Jegal H, Lee TH. Deceptions in hallux valgus: what to look for to limit failures. *Foot Ankle Clin*. 2014;19(3):361-370.
17. 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.
18. Lucas y Hernandez J, Golanó P, Roshan-Zamir S, Darcel V, Chauveaux D, Laffenêtre O. Treatment of moderate hallux valgus by percutaneous, extra-articular reverse-L chevron (PERC) osteotomy. *Bone Joint J*. 2016;98-B(3):365-373.
19. Maffulli N, Longo UG, Marinozzi A, Denaro V. Hallux valgus: effectiveness and safety of minimally invasive surgery. A systematic review. *Br Med Bull*. 2011;97(1):149-167.
20. Magnan B, Negri S, Maluta T, Dall'Oca C, Samaila E. Minimally invasive distal first metatarsal osteotomy can be an option for recurrent hallux valgus. *Foot Ankle Surg*. 2019;25(3):332-339.
21. Morley D, Jenkinson C, Doll H, et al. The Manchester-Oxford Foot Questionnaire (MOXFQ): Development and validation of a summary index score. *Bone Joint Res*. 2013;2(4):66-69.
22. National Institute for Health and Care Excellence. Overview | Surgical correction of hallux valgus using minimal access techniques | Guidance | NICE. https://www.nice.org.uk/Guidance/IPG332. Accessed June 12, 2019.
23. National Institute for Health and Care Excellence. Surgical correction of hallux valgus using minimal access techniques | Guidance and guidelines | NICE. https://www.nice.org.uk/guidance/ipg332/chapter/1-Guidance. Accessed October 18, 2018.
24. Perera A, Singh D, Lomax A. Minimally invasive forefoot surgery. *J Trauma Orthop*. 2015;3(1):50-54.
25. Piqué-Vidal C, Vila J. A geometric analysis of hallux valgus: correlation with clinical assessment of severity. *J Foot Ankle Res*. 2009;2:15.
26. Public Health England. National Diagnostic Reference Levels (NDRLs). https://www.gov.uk/government/publications/diagnostic-radiology-national-diagnostic-reference-levels-ndrls/national-diagnostic-reference-levels-ndrls. Accessed June 29, 2018.
27. Roddy E, Zhang W, Doherty M. Prevalence and associations of hallux valgus in a primary care population. *Arthritis Rheum*. 2008;59(6):857-862.
28. Vernois J, Redfern D. Percutaneous chevron; the union of classic stable fixed approach and percutaneous technique. *Fuß Sprunggelenk*. 2013;11(2):70-75.