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Two year outcomes of minimally invasive hallux valgus surgery

Chloe Xiaoyun Chan[a], Jonathan Zhi-Wei Gan[b], Hwei Chi Chong[b], Inderjeet Rikhraj Singh[b], Sean Yung Chuan Ng[b], Kevin Koo[b,*]

[a] Yong Loo Lin School of Medicine, National University of Singapore, 12 Science Drive 2, 117549, Singapore
[b] Department of Orthopaedic Surgery, Singapore General Hospital, Outram Road, 169608, Singapore

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ABSTRACT

Background: We report our experience with the Minimally Invasive Chevron Akin (MICA) technique for correcting hallux valgus, and evaluate its effectiveness and associated complications.
Methods: Case series of 13 feet with mild to moderate symptomatic hallux valgus treated surgically from July 2013 to December 2014, with at least 48-months follow-up. Patients were assessed pre-operatively and post-operatively with radiographical measurements (Hallux Valgus Angle (HVA) and Intermetatarsal Angle (IMA)) and clinical scores (American Orthopaedic Foot and Ankle Society (AOFAS), 36-Item Short Form Health Survery (SF-36), Visual Analog Scale (VAS)).
Results: Mean HVA and IMA decreased from 30.4° and 13.9°–10.9° and 10.2° respectively ($p < 0.05$). The mean AOFAS score improved from an average of 59.0–93.7 ($p < 0.05$). All patients reported a VAS score of 0 post-operatively, and the 4 SF-36 domains improved significantly ($p < 0.05$).
Conclusions: The MICA technique is a safe and effective method in the surgical correction of mild to moderate hallux valgus deformity, and continued use is justified.

1. Introduction

Hallux valgus is a common forefoot disorder, first coined by Carl Hueter (1871) as a condition with static subluxation of the first metatarsophalangeal joint with lateral deviation of the great toe and medial deviation of the first metatarsal [1]. It often results in functional disability and foot pain [2].

Hueter was the first to describe an operative technique for the correction of hallux valgus deformity in 1871 [3]. Multiple techniques have since been described to improve post-operative outcomes. Ferrari et al. [4] analyzed 21 randomized or "quasi-randomized" clinical trials with regards to operative technique and concluded that no one technique was superior. This highlights the current lack of consensus with regards to the most appropriate treatment.

The trend towards minimally invasive surgery (MIS) over the past 20 years was based on the assumption that equivalent technical result can be achieved with MIS with less soft tissue trauma, hence promoting a faster recovery, fewer post-operative complications, and shorter duration of hospital stay [5–7]. Early techniques of minimally invasive surgery for hallux Valgus correction included the subcapital osteotomy technique [8], the Reverdin–Isham technique [9], and the SERI (Simple, Effective, Rapid, Inexpensive) technique [10]. However, the excellent post-operative outcomes reported by the original authors were not reproducible.

It is hypothesized that the poor experiences associated with these early minimally invasive techniques could be due to the inherent instability associated with the lack of rigid internal fixation. The Minimally Invasive Chevron-Akin Procedure (MICA) proposed by Vernois and Redfern [11] was the first to incorporate internal fixation with a percutaneous approach. The aim of this case series was to analyse the results of all patients who had hallux valgus correction using the MICA technique in Singapore. This would prove useful in determining (1) whether the MICA technique is effective in correcting hallux valgus deformities, and (2) evaluating the complications associated with this technique.

2. Methods

2.1. Study design

We performed a retrospective analysis of prospectively collected data. All patients with mild to moderate symptomatic hallux valgus suitable for surgical correction were offered both the open and the MICA technique. The eventual surgery performed was based on the patients' preference. Patients who were treated

* Corresponding author.
E-mail address: chloechanxiaoyun@gmail.com (C.X. Chan).

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surgically with the MICA technique were identified. All patients were operated on by two surgeons (second last author and senior author) in a large tertiary hospital in Singapore from July 2013 to December 2014.

The inclusion criteria for the study were:

(1) Mild or moderate hallux valgus
(2) Hallux valgus angle $\leq 40^{\circ}$
(3) Inter-metatarsal angle $\leq 20^{\circ}$
(4) Follow-up duration of at least 2 years

Exclusion criteria for the study were:

(1) Prior hallux valgus surgery
(2) Lesser toes surgery performed in the same setting
(3) Patients who were lost to follow-up

2.2. Surgical technique

The surgical technique adopted was modified from the Minimally Invasive Chevron-Akin (MICA) procedure as described by Joel Vernois and David Redfern in the United Kingdom [11]. The aim of this technique was to utilize a percutaneous approach to create a chevron-type osteotomy of the first metatarsal, at the level of the distal diaphyseal-metaphyseal junction, and an Akin-type osteotomy of the first proximal phalanx. The Chevron osteotomy was internally fixed with 1headless compression screw of 2.5 mm diameter and combined with a distal soft tissue release. The Akin osteotomy was not internally fixed.

The procedure was performed under either general anaesthesia or regional anaesthesia, with the patient placed supine with both feet apart and overhanging the edge of the operating table. This enabled the use of the mini C-arm (Mobile C-arm fluoroscopic X-ray system). A pneumatic tourniquet was applied at the thigh level as a precaution, but was not inflated in any of the cases.

A 3-mm incision was made using a beaver blade on the dorsomedial border of the first metatarsal at the base of the flare of the medial eminence. This correlated with the distal diaphyseal-metaphyseal junction. A straight periosteal elevator was inserted through this incision to clear soft tissue off the bone around the distal metaphyseal flare of the shaft in preparation for the osteotomy.

The chevron osteotomy was performed using a Shannon burr (2-mm diameter and 20-mm length) inserted through the same incision and positioned at the metatarsal neck (Fig. 1). The direction of the burr in the transverse and coronal plane was dependent on the degree of shortening and elevation required respectively, and the diameter of the burr was taken into account as well. The V-shaped chevron osteotomy was fully completed after both dorsal and plantar limbs were created from this point.

Displacement of the head along the osteotomy path was conducted via insertion of a periosteal elevator into the osteotomy and the proximal diaphyseal channel (Fig. 2). This served as a lever for displacement. The displacement was then assessed using the image intensifier and adjusted to satisfaction. A second medial incision approximately 3 cm proximal to the first incision was made. After periosteal elevation, a guidewire was inserted obliquely through this incision under image control. The wire was advanced across the osteotomy site into the metatarsal head, without entering the first metatarsophalangeal joint space (Fig. 3). One specifically designed cannulated compression screw was used for stable internal fixation (Fig. 4).

The subsequent two steps involved a distal soft tissue release via an additional 3-mm incision over the lateral metatarsophalangeal joint and a percutaneous Akin osteotomy of the proximal phalanx (Fig. 5). No screws were inserted across the Akin osteotomy. Any bony prominence medially was removed via a mini-open 5 mm incision with a small ronguer. The surgery was completed following suture of the capsule and cutaneous suture of all incisions.

2.3. Post-operative management

Post-operatively, a bandage was applied using a special strapping technique [12] crucial for the maintenance of the surgical correction. Patients were allowed to weight-bear fully in a rigid flat shoe (Darco boots – DARCO (Europe) GmbH) for up to 6 weeks. They were scheduled for follow-ups at 1 week, 2 weeks, 6 weeks, 3 months, 6 months, 1 year, and 2 years for post-operative review.

2.4. Radiographical outcome evaluation

Standard radiographs were performed, comprising both anteroposterior (AP) and lateral weight-bearing views of the forefoot. Comparisons were made between the pre-operative radiographs and the radiographs taken during the latest follow-up, and assessed for any statistical significance. The following parameters were evaluated: (1) hallux valgus angle (HVA normal value $<15^{\circ}$) and (2) intermetatarsal angle (IMA normal value $<10^{\circ}$). A single observer performed all angular measurements. Additionally, radiographs were used to assess 1st metatarsophalangeal joint congruency pre-operatively, and to determine bone union post-operatively.

2.5. Clinical outcome evaluation

Pre-operatively, clinical evaluation included a complete history and physical examination. The age, sex, race, affected side,

Fig. 1. Intra-operative radiographs showing Chevron osteotomy performed using a Shannon burr.

Fig. 2. Intra-operative radiographs showing displacement of the osteotomy.

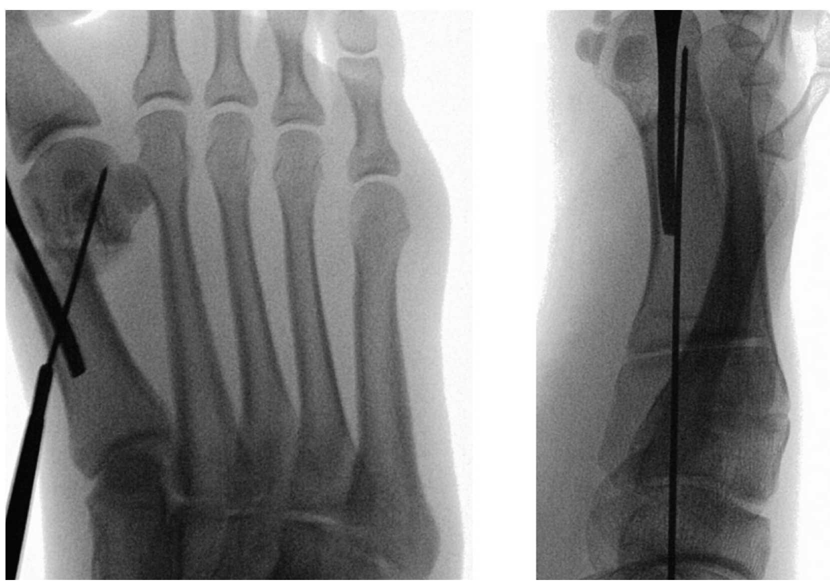

Fig. 3. Intra-operative radiographs showing insertion of guidewire.

Fig. 4. Intra-operative (A) anteroposterior and (B) lateral radiographs showing internal fixation with a cannulated compression screw.

Fig. 5. Intra -operative radiograph of the Akin osteotomy.

symptoms such as foot pain was documented. Patients were also assessed for the presence of lesser toe deformities, presence of plantar callosities, and hypermobility of the tarsometatarsal joint (TMTJ). All patients were also assessed with the American Orthopaedic Foot and Ankle Society (AOFAS) score [13], 36-Item Short Form Health Survey (SF-36) [14] and Visual Analogue Scale (VAS) pain score pre-operatively and post-operatively at 24 months. Four domains of the SF-36 were reviewed to determine improvements in pain and function; the physical functioning, bodily pain, social functioning and physical role functioning domains.

2.6. Statistical analysis

All data was compiled in Microsoft Excel 2003 (Microsoft Corp., Redmond, WA, USA) and the statistical analysis was performed using Statistical Package for the Social Sciences Version 23.0 (SPSS Inc, Chicago, Il, USA). Categorical variables are represented in percentages and continuous variables as means (standard deviations) or median (range). The paired t-test was used for the statistical evaluation of the clinical scores and angular values pre- and post-operatively. For clinical scores not normally distributed, the Wilcoxon signed rank test was utilized instead. The level of significance was set at 0.05.

2.7. Ethical aspects

This study was ethically approved by the Singhealth Centralized Institutional Review Board under the reference number (2016/2863).

3. Results

3.1. Demographics

The MICA procedure was performed on 31 feet from July 2013 to December 2014. After excluding 9 feet that underwent lesser toes surgery in the same setting, and 9 feet that were lost to follow-up, our analysis included a total of 13 feet (8 patients). All 8 patients met the inclusion and exclusion criteria, had a post-operative follow-up duration of at least 24 months and a complete set of data.

Table 1
Patient characteristics.

Characteristic	Study population (n = 13)	
	n/Mean	%/SD
Age (years)	50.7	13.1
Gender		
Male	3	23.1
Female	10	76.9
Race		
Chinese	11	84.6
Malay	2	15.4
Body Mass Index (kg/m^2)	23.0	2.73
Duration of follow-up (years)	2.9	0.38
Site of hallux valgus		
Left	8	61.5
Right	5	38.5

Three patients had a left hallux valgus surgery performed, whereas five patients had bilateral hallux valgus operated on. These patients had a mean age of 50.7 ± 13.1years (range 36.1–70.7). 3 feet (23.1%) belonged to males and 10 (76.9%) to females. 11 (84.6%) feet were of Chinese ethnicity, and 2 (15.4%) were of Malay ethnicity. The mean body mass index (BMI) was 23.0 kg/m^2 (SD = 2.73 kg/m^2), and the mean duration of follow-up was 2.9 ± 0.38 years (range 2.10–3.29) (Table 1). The mean hospital length of stay was 1.33 days (SD = 0.24 days).

3.2. Radiological outcomes

The pre- and post-operative radiological outcomes of our study population are reported in Table 2. The mean pre-operative HVA was 30.4° ± 5.9° (range 17.9°–39.4°) which was post-operatively corrected to a mean of 10.9° ± 7.2° (range 0.55°–20.8°) at the latest follow-up ($p < 0.001$) (Table 3). The mean IMA decreased from 13.9° ± 3.5° (range 7.5°–18.8°) pre-operatively to 10.2° ± 3.3° (range 4.9°–15.2°) post-operatively ($p = 0.001$) (Table 3). Fig. 6 shows the pre- and post-operative radiographs of one of our patients.

3.3. Clinical outcomes

All patients completed their pre-operative and post-operative AOFAS, VAS and SF-36 scores as detailed in Table 4. There was a statistically significant ($p < 0.05$) improvement in all six clinical outcome measurements. The AOFAS score improved from 59.0 ± 13.1 to 93.7 ± 8.0; The VAS score improved from 5.1 ± 1.7 to 0 in all patients; The SF-36 (physical functioning domain) improved from 82.3 ± 16.2 to 92.7 ± 7.0; The SF-36 (bodily pain domain) improved from 49.1 ± 12.3 to 85.5 ± 17.3; The SF-36 (social functioning domain) improved from 86.5 ± 18.7 to 100 in all patients; and the SF-36 (physical role functioning domain) improved from 42.3 ± 37.3 to 96.2 ± 9.4(Table 3).

3.4. Complications

2 feet in 1 patient (15.4%) required early reoperation at 1 month after the initial operation due to mobility at the osteotomy sites of both halluces. During the 3-week follow-up visit, routine X-rays showed movement at the osteotomy site. The patient did not report an increase in pain, and there was no history of trauma to the operation site.

Table 2
Patient information and radiological outcomes.

Case	Sex	Age (yrs)	Laterality	Anaesthesia mode	Follow-up (yrs)	Pre-operative (°)		Post-operative (°)	
						HVA	IMA	HVA	IMA
1	M	39	Left	GA	3.29	35.81	18.78	20.78	15.24
2	M	39	Right	GA	3.29	39.39	17.36	19.52	11.67
3	F	43	Left	GA	3.27	30.25	16.01	11.43	14.92
4	F	38	Right	GA	3.00	32.02	7.85	20.69	10.47
5	F	38	Left	GA	3.00	24.90	7.47	3.32	4.94
6	F	36	Left	GA	3.00	26.48	13.15	16.67	9.24
7	F	53	Left	GA	3.00	25.65	10.98	0.55	7.84
8	F	61	Right	RA	3.03	17.93	11.91	5.72	7.80
9	F	61	Left	RA	3.03	27.83	16.18	13.96	9.70
10	F	70	Left	GA	2.83	36.02	14.69	0.83	5.75
11	F	70	Right	GA	2.83	34.48	14.25	6.48	13.02
12	M	63	Left	GA	2.10	28.96	14.14	9.71	8.41
13	F	44	Right	GA	2.13	35.03	17.32	12.58	13.10

GA = general anaesthesia; RA = regional anaesthesia; HVA = hallux valgus angle; IMA = inter-metatarsal angle.

Intra-operative findings were that of slight mobility of the osteotomy sites of both halluces in the sagittal plane. The original screws were intact, appeared to be of adequate length, and no loosening was noted. The osteotomy sites were re-positioned with image guidance, and each was further secured with an additional 2.0 mm and 2.5 mm cannulated compression screw, for a total of 3 screws per osteotomy site. These were placed approximately medial and lateral from the original screw. Subsequent intra-operative stability of the osteotomy site was excellent.

The patient was followed-up closely, and recovered uneventfully thereafter. Serial x-rays showed no further shifting of the osteotomy site, and at 3 years post-operation, the patient was well, and walking without pain. X-rays showed good healing.

1 foot in 1 patient (7.7%) was found to have superficial wound infection at the two-week follow-up. X-rays did not show signs of osteomyelitis. A wound culture grew pan-sensitive Staphylococcus aureus. She was treated with 13 days of intravenous amoxicillin/clavulanic acid, which was converted to oral form for a week after. Wound inspection was clean at the next follow-up, and the wound was noted to be healing. She was well at the two-year follow-up.

Complaint of stiffness of the operated toe was noted in 1 patient (7.7%). Clinical assessment noted a mild decrease in range of motion. Compared to the opposite toe, there was a decrease in dorsiflexion of approximately 10 degrees, and a decrease in plantarflexion of less than 10 degrees. There was no pain, and he had no limitation of ambulation. Complaint of paresthesia of the tip of the operated big toe in 1 patient (7.7%) was noted at the 3-month follow-up. He was treated with vitamin B complex supplementation. The paresthesia resolved at the 1-year follow-up. No cases of osteotomy non-union were noted. No patient had avascular necrosis, transfer metatarsalgia, deep-vein thrombosis, persistent residual pain, or screw impingement.

Table 3
Radiological and clinical results.

Measure		Study population (n = 13)		P-Value
		Mean	SD	
Radiological outcomes (°)				
HVA	Pre-operative	30.4	5.9	
	Post-operative	10.9	7.2	
	Difference	19.5		<**0.001**
IMA	Pre-operative	13.9	3.5	
	Post-operative	10.2	3.3	
	Difference	3.7		**0.001**
Clinical outcomes (points)				
AOFAS	Pre-operative	59.0	13.1	
	Post-operative	93.7	8.0	
	Difference	34.7		**0.001**
VAS	Pre-operative	5.1	1.7	
	Post-operative	0.0	0.0	
	Difference	5.1		**0.001**
SF-36 (PF)	Pre-operative	82.3	16.2	
	Post-operative	92.7	7.0	
	Difference	10.4		**0.028**
SF-36 (BP)	Pre-operative	49.1	12.3	
	Post-operative	85.5	17.3	
	Difference	36.4		**0.002**
SF-36 (SF)	Pre-operative	86.5	18.7	
	Post-operative	100.0	0.0	
	Difference	13.5		**0.041**
SF-36 (PRF)	Pre-operative	42.3	37.3	
	Post-operative	96.2	9.4	
	Difference	53.9		**0.003**

HVA = hallux valgus angle; IMA = inter-metatarsal angle; AOFAS = American Orthopaedic Foot and Ankle Society (AOFAS) score; VAS = Visual Analogue Scale; SF–36 = 36-Item Short Form Health Survery (PF = physical functioning, BP = bodily pain, SF = social functioning, PRF = physical role functioning).

4. Discussion

There is currently great interest in minimally invasive surgery due to its frequently reported advantages [5,6]. However, efforts to identify the most effective technique have been unsuccessful [6].

Fig. 6. Pre-operative and post-operative AP weight-bearing radiographs of the foot.

Table 4
Patient clinical outcomes.

Case	Pre-operative (points)						Post-operative (points)					
	AOFAS	VAS	SF-36 (PF)	SF-36 (BP)	SF-36 (SF)	SF-36 (PRF)	AOFAS	VAS	SF-36 (PF)	SF-36 (BP)	SF-36 (SF)	SF-36 (PRF)
1	67	3	100	61	100	75	100	0	100	100	100	100
2	67	3	100	61	100	75	100	0	100	100	100	100
3	80	5	100	72	100	100	100	0	90	100	100	100
4	34	7	90	41	62.5	25	88	0	95	72	100	100
5	54	6	90	41	62.5	25	95	0	95	72	100	100
6	54	6	95	52	100	100	100	0	95	100	100	100
7	77	7	90	61	100	50	87	0	90	72	100	75
8	47	7	55	32	100	0	100	0	90	100	100	100
9	47	7	55	32	100	0	100	0	90	100	100	100
10	67	3	70	41	75	0	80	0	80	72	100	100
11	54	4	70	41	75	0	80	0	80	72	100	100
12	52	5	75	51	100	50	88	0	100	51	100	75
13	67	3	80	52	50	50	100	0	100	100	100	100

AOFAS = American Orthopaedic Foot and Ankle Society (AOFAS) score; VAS = Visual Analogue Scale; SF–36 = 36-Item Short Form Health Survery (PF = physical functioning, BP = bodily pain, SF = social functioning, PRF = physical role functioning).

We have adopted the Minimally Invasive Chevron-Akin (MICA) procedure [11], a third-generation technique, in treating patients with mild to moderate hallux valgus. The study was designed to evaluate the effectiveness of correcting hallux Valgus deformities and the complications associated with this technique.

With regards to radiological outcomes, all angular measurements improved significantly post-operatively at the latest follow-up ($p \leq 0.001$) (Table 3). There was a mean HVA correction of 19.5° ($p < 0.001$) in our study population. This was higher than the reported mean HVA correction in a majority of the other MIS series reviewed [8,15–25] (Table 5). There were no cases of over-correction resulting in hallux varus. This result was encouraging, considering that this study reviewed the first cohort of patients to undergo this procedure. Despite the steep learning curve, results were satisfactory. Our mean IMA correction was 3.7° ($p = 0.001$), which was lower than the reported results of most of the other studies reviewed [8,15–25] (Table 5). We note that the initial cases were outliers, and contributed significantly to the high mean IMA. A majority of the subsequent cases had post-operative IMAs within the normal range (≤10°). Given greater experience and familiarity with the technique, radiological outcomes would be expected to improve. The degree of correction achieved in our cohort was sufficient to attain a good clinical outcome. We note that several previous studies reported radiological correction of the distal metatarsal articular angle (DMAA) pre- and post-operatively in their results. However, our study does not include these measurements, due to previous reports of poor inter-observer reliability [25].

Clinical outcomes improved significantly post-operatively in all 3 clinical scores – AOFAS, VAS, and SF-36 (Table 3). Of greatest importance would be the absolute reduction of pain symptoms, where 2-year post-operative VAS scores were 0 in all patients. The AOFAS scores in our study improved from 59.0 ± 13.1 to 93.7 ± 8.0. Our clinical outcomes were comparable to both minimally invasive techniques [15,18,20,21,23,24] and open hallux valgus surgery [26–29] outcomes in pre-existing literature. However, in our series, we noted a discrepancy between clinical outcomes and radiological outcomes. This was seen in cases 1, 2, 3, 6 and 13, where excellent clinical outcomes were reported despite sub-optimal corrections (HVA > 15° and/or IMA > 9°). Cases 4 and 5 by definition were not true hallux valgus as the pre-operative IMA was <9°. However, these 2 cases were notable for significantly reduced pre-operative clinical scores. Despite an increase in the IMA after surgical correction, case 4 still reported improvements in clinical scores. Thordarson et al. [31] concluded that the degree of improvement of clinical scores does not correlate linearly with the magnitude of change in HVA or IMA, the residual deformity, or the surgical technique performed. This suggests that radiological and clinical outcomes do not have a linear correlation, and that both parameters should be taken into account in deciding the success of the surgical correction.

With regards to the length of hospital stay, the mean duration was 1.33 days (SD = 0.24 days) in our case series. This was comparable to the minimally invasive distal osteotomy group in the study by Maffulli et al. [7] with an average stay of 1.1 days (SD = 0.4 days), compared to the open scarf osteotomy group with

Table 5
Radiological angular measurements of other MIS series.

Study	Year	Technique	Mean Pre-op HVA (°)	Mean Post-op HVA (°)	Difference (°)	Mean Pre-op IMA (°)	Mean Post-op IMA (°)	Difference (°)
Bosch et al. [8]	2000	SCOT	36	19	17	13	10	3
Maffulli et al. [15]	2005	SCOT	32.0	14.1	17.9	11.5	7.5	4.0
Magnan et al. [16]	2005	SCOT	31.5	13.7	17.8	12.3	7.3	5.0
Giannini et al. [17]	2007	SERI	33	16	17	13	7	6
Kadakia et al. [18]	2007	SERI	25	12	13	10.3	6.4	3.9
Bauer et al. [19]	2009	Reverdin-Isham	28.0	14.0	14.0	13.0	10.0	3.0
Huang et al. [20]	2011	SCOT	26.7	15.5	11.2	11.9	7.2	4.7
Radwan et al. [21]	2012	SCOT	27.6	13.1	14.5	12.6	7.8	4.8
Faour-Martín et al. [22]	2013	SCOT	34.2	14.6	19.6	17.6	8.1	9.5
Brogan et al. [23]	2014	MICA	30.5	10.4	20.1	14.6	7.1	7.5
Lucas et al. [24]	2016	PERC	26.2	9.6	16.6	11.8	7.9	3.9
Jowett et al. [25]	2017	MICA	29.7	10.3	19.4	14.0	7.6	6.4
This study	2017	MICA	30.4	10.9	19.5	13.9	10.2	3.7

SCOT = subcapital osteotomy technique; SERI = simple effective rapid inexpensive; MICA = minimally invasive chevron akin; PERC = percutaneous, extraarticular reverse-L Chevron; Pre-op = pre-operative; Post-op = post-operative; HVA = hallux valgus angle; IMA = inter-metatarsal angle.

length of stay averaging 2.1 days (SD = 1.4 days) (p = 0.041). This further supports the use of minimally invasive techniques to minimize length of hospital stay.

In our series, the first two cases (in the same patient) required early re-operation due to movement at the osteotomy sites of both halluces on the X-rays at 3 weeks. There were no complaints of pain or discomfort, and no other patient experienced a similar complication. Intra-operative assessment revealed an adequate screw length, but a review of x-rays suggested that direction and length of screw insertion into the metatarsal head could have been further optimized. The revision surgery involved the insertion of two additional screws across the osteotomy site, placed approximately medial and lateral from the original screw for greater stability of the osteotomy. Walker and Redfern [32] had similar experiences with loss of position of the unicortical fixation using 1 cannulated screw. Chronologically, this patient was the first to undergo surgery by the MICA technique. Given the steep learning curve in any novel surgical technique, technical issues with fixation of the osteotomy were a possible cause. This issue would be expected to resolve with greater experience. No subsequent patients experienced loosening as a complication, giving further credence to this cause of loosening. Good results were obtained with single screw fixation in our study, showing that stability of the osteotomy site can be achieved with just one screw. The MICA technique has since been modified to include the insertion of 2 cannulated screws through the Chevron osteotomy site for greater stability, as described in studies by Jowett and Bedi [25] and Lee et al. [33]. Our current practice has evolved in the light of new evidence, and all osteotomy sites are currently stabilized with two large proximal screws. In the series by Huang et al. [20], there was one case (0.8%) of plantar angulation of the head fragment using the percutaneous SCOT technique at the 6th week follow-up. Revision surgery was performed with the Kirschner-wire repositioned. Lucas et al. [24] also reported 1 case (2.2%) of failure of fixation.

Range of motion was satisfactory in all patients, and there was only 1 complaint of stiffness of the 1st metatarsophalangeal joint (MTPJ) which did not affect ambulation. Post-operative stiffness is a key concern in open techniques and intra-articular osteotomies [6]. Fuhrmann et al. [28] reported a rate of more than 20% in open scarf osteotomies. Given that stiffness is an important component that affects clinical outcome, this greatly supports the use of the extra-articular approach of the MICA technique to reduce this risk.

The single case of superficial wound infection in our study resolved with appropriate antibiotics. Pin tract-related skin infection is commonly reported in cases using percutaneous Kirschner-wire fixation [15,20,21], and was found to be as high as 8.8% (11 out of 125 feet) in Huang et al.'s study [20]. However, infections are less common in MIS techniques that do not utilize percutaneous Kirschner-wire fixations, where surgical wounds were closed with suture, and no cases of infection were reported in the MICA series' reviewed [23,25]. This was likely due to the lack of a pin-tract, which can serve as a conduit for infection.

One case of transient numbness was noted in our series, which was treated with Vitamin B supplementation, and resolved by the 1 year follow-up. Radwan and Mansour [21] noted 4 cases (12.9%) of transient diminished sensation over the incision site of the open distal chevron osteomtomy group, and Jowett and Bedi [25] reported one case of increased sensitivity over the proximal wound after MICA surgery. Permanent numbness was described in 8 patients (6.8%) by Magnan et al. [16], which used percutaneous Kirschner-wire fixation, but otherwise such a complication was not mentioned in other MIS series.

None of our patients developed non-union of the osteotomies or avascular necrosis of the metatarsal head post-operatively. This could be due to the extra-capsular approach in this technique, allowing minimal trauma to and dissection of the overlying periosteum and medullary cavity, thus minimizing the disruption of the blood supply to the metatarsal head [23].

The earlier generations of minimally invasive hallux valgus surgery had inherent problems. The Reverdin–Isham technique [9], which involved an intracapsular osteotomy with no internal fixation, was reported by Bauer et al. [34] to have several associated complications despite good 2-year AOFAS score improvements and 89% satisfaction rates. These included shortening of the 1st metatarsal and an elevated risk of 1st metatarsophalangeal joint non-congruency. As a result, this technique has largely been abandoned. The simple effective rapid inexpensive (SERI) technique, a modification of the Bösch osteotomy [8] popularized by Giannini et al. [10], utilizes a single Kirschner wire to stabilize the subcapital osteotomy. However, Kadakia et al. [18] reported a high hallux valgus recurrence rate of 38% (5 out of 13 patients) that resulted in the abortion of the study.

The MICA technique appears to be gaining popularity and has proven to be a promising technique in the field of minimally invasive hallux valgus surgery. Two recently published studies by Brogan et al. [23] and Jowett and Bedi [25] have reported optimistic radiological and clinical outcomes with minimal post-operative complications. Jowett et al. also reported better outcomes in their second batch of patients compared to the first batch, although differences were not statistically significant. This reiterates the steep learning curve involved and reaffirms the reproducibility of the technique with experience and familiarity.

Strengths

Our study gives a fresh perspective of third-generation MICA techniques in the Asian population, being the first report of local use of a third-generation MICA technique in our locale. We were able to achieve a minimum follow-up duration of 48 months, which allows analysis of short to medium term outcomes and complications. We also attempted to minimize the effect of inter-surgeon technique variability on our results, and therefore all procedures were performed by the same two surgeons utilizing the same technique. Post-operative management, protocol, and follow-up were also standardized.

Limitations

Our study population involves a small number of subjects. This was due to multiple factors; First, patients who defaulted follow-up or had a follow-up duration of less than 48 months were considered to have incomplete sets of data and were therefore excluded. Second, to maximize reliability and minimize the effect confounding factors, we excluded patients who underwent other concomitant lesser toe deformity correction. Additionally, a control or comparison group would further enhance the reliability of results. Another limitation is our overall patient follow-up duration – this study looks at early to medium-term patient outcomes. We therefore cannot draw conclusions about the long-term outcomes of this technique. Further research should keep these limitations in mind, and ideally incorporate measures for mitigation.

The results of this study lead us to conclude that the MICA technique is a safe and effective method in the surgical correction of mild to moderate hallux valgus deformity, with the added benefits of a minimally invasive surgery. Our radiological and clinical results were comparable to those published in other MIS series, and post-operative complications experienced were minimal. Despite a steep learning curve associated with the MICA technique, the good outcomes of our preliminary study justify continued use of this technique in future practice, and warrant further studies to analyze the long-term results, and compare the efficacy with open techniques.

Conflicts of interest

The authors declare that they have no conflict of interest.

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