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Original Article

Minimally invasive Chevron-Akin osteotomy: clinical and radiographic results

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Abstract

Objective: To present the clinical and radiographic results of surgical treatment of patients with moderate to severe hallux valgus (HV) by minimally invasive Chevron - Akin osteotomy (MICA).

Methods: The case series comprises 25 patients (30 feet) with diagnoses of moderate to severe HV treated surgically with the MICA technique. All patients answered the American Orthopedic Foot and Ankle Score (AOFAS) and rated pain on visual analogue scale (VAS) at preoperative assessment and at the last follow-up consultation. Radiological assessment included measurement of the valgus angles of the hallux (HVA) and the 1st and 2nd ray intermetatarsal angle (IMA). Complications and satisfaction ratings were also documented.

Results: Mean follow-up was 14.6 months. Mean AOFAS increased from 42.8 to 90 and VAS reduced from 8.6 to 1.7. Mean HVA reduced from 31.7° to 8.4° and IMA from 14° to 5°. All these improvements were statistically significant ($p<0.001$). The most common complication observed was discomfort caused by hardware, affecting five feet (16.6%). Two patients (6.6%) had transitory neurapraxia and one patient (3.3%) developed reflex sympathetic dystrophy. There were no cases of infection, relapse, pseudarthrosis, or malunion of osteotomies. Subjective satisfaction ratings classified 93.3% of results as good or excellent.

Conclusion: Minimally invasive Chevron-Akin osteotomy is a safe and reproducible technique that achieves good clinical and radiographic results for treatment of moderate to severe hallux valgus.

Level of Evidence IV; Therapeutic Studies; Case Series.

Keywords: Hallux valgus; Minimally invasive surgical procedures; Metatarsal bones/surgery; Osteotomy/methods; Forefoot, human/surgery.

Introduction

Hallux valgus (HV) is a very common pathology that affects approximately 2 to 4% of the population. Painful cases that do not improve after changing footwear and adaptation to the deformity are indicated for surgical intervention[1]. A range of different procedures are described in the literature and nowadays minimally invasive techniques exist that can be used to correct deformities via smaller incisions, causing less surgical trauma and postoperative pain[2].

Development of percutaneous techniques to treat HV was initiated by Isham[3], who developed the first generation method, with a distal metatarsal osteotomy accomplished via a percutaneous access without internal fixation[4]. This was followed by second-generation osteotomies fixed with Kirschner wires[5,6], which were associated with a range of serious complications such as pseudarthrosis and malunion[7-9]. This situation prompted two surgeons to further develop the technique, describing a third-generation method. This is a chevron osteotomy of the first metatarsal combined with an Akin osteotomy of the proximal phalanx of the great toe (MICA - minimally invasive Chevron - Akin osteotomy) conducted via a percutaneous approach using specific burrs and combined with a stable internal fixation of the metatarsal fragment using two cortical screws[10].

The combination of a stable and rigid internal fixation combined with a minimally invasive approach revolutionized percutaneous HV treatment[10,11] and, as a result, has become very

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popular with foot and ankle surgeons for HV repair[11]. While there are some studies demonstrating the promising results of the MICA technique[12-14], there is still a lack of scientific evidence proving its superiority over traditional procedures[11]. Moreover, some authors still question the procedure's advantages and reproducibility[15]. It is also important to point out that although there are some case reports using the technique in the literature[12-14] the majority of authors, including those who have criticized the technique in their papers[15], included modified versions of the procedure and did not reproduce the technique as originally described by Redfern and Vernois[10].

The objective of this study is to present a case series and evaluate the clinical and radiographic outcomes in patients with moderate to severe HV who underwent surgical treatment using the original MICA technique.

Methods

This study was approved by the Institutional Review Board and registered on the Plataforma Brasil database under CAAE (Ethics Evaluation Submission Certificate) number: 16213319.8.0000.5122. All of the patients included in this study signed free and informed consent forms.

This study presents a retrospective assessment of a series of 25 patients (30 feet) diagnosed with HV and treated surgically using the MICA technique from November 2017 to January 2019 by the same surgeon. Patients were included who had been diagnosed with moderate or severe HV that had not improved after conservative treatment, which consisted of adapted footwear and symptomatic medication.

Hallux valgus was defined as moderate if deformities had a hallux valgus angle (HVA) exceeding 20° and/or an intermetatarsal angle between the first and second rays (IMA) exceeding 12°, while severe HV was defined as deformities with HVA exceeding 40° and/or IMA exceeding 16°. Exclusion criteria were prior history of surgery, arthritis of the metatarsal phalangeal joint of the hallux, concurrent deformities of the hindfoot and midfoot, and rheumatological and neurological diseases.

Preoperative assessment included administration of the American Orthopedic Foot and Ankle Score (AOFAS)[16] and a visual analogue pain scale (VAS) to all patients. Supplementary examinations comprised anteroposterior (AP) and lateral X-rays, both with support. The HVA and IMA were measured[17].

At the last follow-up appointment, patients answered the AOFAS, rated pain on the VAS once more, and underwent radiographic assessment. The following variables were also noted: radiographic union (defined as osseous consolidation of three or more cortexes on orthogonal X-rays), complications, and patient satisfaction rated on the Coughlin scale (excellent, good, fair, poor, or very poor)[18].

Statistical analysis was conducted using GRETL software (2017c). Student's *t* test was used to compare measures before and after intervention. In this study, we adopted a value of 0.05 for alpha error and consequent rejection of the null hypothesis.

Surgical technique

The operation was performed according to the original technique described by Redfern and Vernois[10].

Patients underwent the surgical procedure with administration of spinal anesthesia and sedation. They were placed in dorsal decubitus with the feet hanging over the operating table edge, supported on the image intensifier tube. Specialized minimally intensive surgery instruments were used: electric motor with a high torque, low speed hand piece, beaver blade, percutaneous burrs, and manual retractor and rasps.

The first step was to insert a 2x20mm Shannon burr at the center of rotation of the metatarsal (Figure 1A), via an extracapsular portal of approximately 3 millimeters at the distal diaphysis-metaphysis transition in the medial region of the first metatarsal. The osteotomy displacement plane was determined according to the orientation of the burr in the transverse and coronal planes. A chevron osteotomy was made in a "V" shape with an angle of approximately 130°, with a dorsal cut parallel to the axis of the first metatarsal and a plantar cut in the proximal direction.

The second step was to insert a dorsomedial guidewire at the base of the first metatarsal until it penetrated the lateral cortex. After introduction of the guidewire, the head of the metatarsal was displaced laterally, using a retractor or a Kirschner wire inserted into the medullary canal, until the deformity was corrected (Figure 1B). The guidewire was then advanced until the head of the metatarsal was fixed. A 3.5 millimeter full-thread, headless cannulated screw was then inserted, perforating the medial and lateral cortexes before fixing the metatarsal head

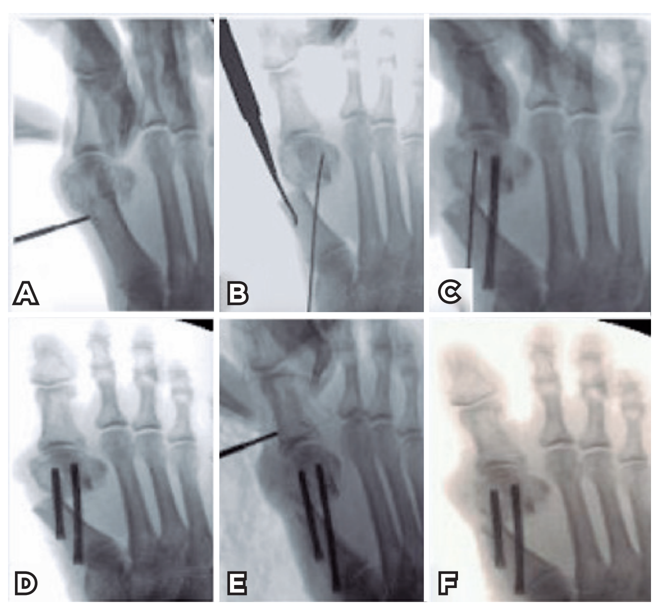

Figure 1. Intraoperative sequence showing surgical technique; A) Insertion of the Shannon burr. B) Displacement of the metatarsal head and fixation with the first guidewire. C) Fixation with the first screw and second guidewire D) Fixation with second screw. E) Akin osteotomy F) Final appearance.

(Figure 1C). A second, anti-rotational, screw was then inserted in the same plane, slightly distal of the first screw (Figure 1D). We then proceed with resection of the medial diaphyseal eminence with a 2 x 12 mm Shannon burr and a 3.1mm wedge burr via the proximal screw access portal.

If, after fixation of the osteotomy, there was any misalignment of the metatarsal-phalangeal joint of the hallux or if the lateral sesamoid was uncovered, medial soft tissues were released (freeing the adductor). The next step was to proceed with the Akin osteotomy, performed at the proximal metaphyseal region of the proximal phalanx without internal fixation. (Figure 1E). Bone fragments were removed and the area washed by abundant immersion in saline. Once the procedure was finalized, with final fluoroscopic assessment (Figure 1F), surgical incisions were sutured, padded dressing applied, and the foot bandaged, maintaining correct alignment of the hallux.

Postoperative care

Patients' dressings were applied and changed by the medical team weekly for 4 weeks. After the fourth week, a toe spacer was worn for a further 2 weeks. Immediate weight bearing was enabled by a Barouk sandal, worn for 6 weeks. Control X-rays were taken 2, 6, and 12 weeks after surgery.

Results

In this study, 25 patients (30 feet) with diagnoses of moderate (63%) and severe HV (37%) were assessed. Mean age of the participants was 53.6 years (32 to 79 years) and just 1 participant (4%) was male. Mean follow-up time was 14.6 months, varying from 12 to 18 months.

As shown in table 1, mean AOFAS increased from 42.8 to 90 points and VAS dropped from 8.6 to 1.7 points. With regard to angles, it was observed that mean HVA reduced from 31.7° to 8.4° and mean IMA reduced from 14° to 5°. All of these improvements were statistically significant ($p < 0.001$). Twelve feet (40%) had concurrent pathologies of smaller toes, which were operated on using minimally invasive techniques during the same operation (Table 2).

Eight patients (26.6%) had complications. The most common complication was discomfort caused by hardware, observed in five feet (16.6%). After union of osteotomies, these devices were removed, with complete resolution of the complaints. Two patients (6.6%) had neurapraxia of medial dorsal cutaneous nerves, with complete recovery in response to clinical treatment. One patient (3.3%) developed reflex sympathetic dystrophy with partial improvement after 6 months of drug treatment. There were no cases of infection, wound dehiscence, or relapse of deformities. There were also no cases of delayed union, pseudarthrosis, or malunion of osteotomies (Figure 2).

All patients returned to their normal activities and none had footwear limitations. The subjective satisfaction ratings classified 93.3% results as good or excellent. One patient classified the result as poor because of reflex sympathetic dystrophy that could not be controlled clinically and improved partially in response to clinical treatment.

Table 1. Comparative analysis of the study variables

Variables	Mean value		p
	Preoperative	Postoperative	
AOFAS	42.8	90.0	<0.001
VAS	8.6	1.7	<0.001
HVA	31.7°	8.4°	<0.001
IMA	14.0°	5.0°	<0.001

AOFAS (American Orthopedic Foot and Ankle Score); VAS (visual analog pain scale); HVA (hallux valgus angle); IMA (intermetatarsal angle between first and second metatarsals).
Source: the author

Table 2. Concurrent pathologies and procedures

Associations	Number of patients	Procedures
Hammer toe	1	PP Ost + FCB tenotomy
Metatarsalgia	5	DMMO
Bunionette	6	Oblique osteotomy of 5th mtt

PP Ost (proximal phalanx osteotomy); FCB (flexor hallucis brevis); DMMO (distal metatarsal minimally invasive osteotomy); mtt (metatarsal).

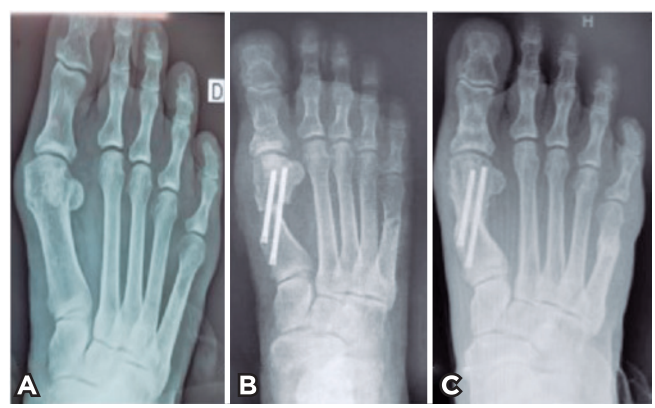

Figure 2. A) Preoperative X-ray. B) Postoperative control X-rays at week 6 and, C) at week 12, showing osseous consolidation.

Discussion

This study presents the clinical and radiographic outcomes of a case series of patients with moderate to severe HV who underwent surgical treatment with the MICA technique. There was considerable radiographic improvement, with reduced HVA and IMA and favorable clinical outcomes with significant improvement in pain and increased quality of life, according to VAS, AOFAS, and patient satisfaction ratings. The most common complication was discomfort caused by hardware. There were no serious complications and none of the osteotomies had to be revisited.

The MICA technique is capable of achieving considerable radiographic correction to treat HV. Silva et al. described a series of 26 cases of patients with moderate to severe HV treated using a third generation minimally invasive techniques in which they obtained improvement in mean HVA of 29.7° to 12.8 and in mean IMA of 14.2°to 8.2[19]. Holme et al. presented a case series of 40 patients treated using this technique with mean improvement in HVA and IMA of 20° and 6°, respectively[14]. In this study, the MICA technique achieved very powerful radiographic correction in terms of improved HVA and IMA with mean reductions of 23.3° and 9°, respectively. Since the osteotomy is extracapsular, with minimal biological aggression, it is possible to perform large displacements of the metatarsal head without compromising its vascularization, achieving sufficient radiographic correction to treat more severe deformities.

With regard to the clinical results, several studies have reported significant improvement in patient quality of life. Holme et al. reported preoperative and postoperative AOFAS of 48 and 93, respectively[14] and Jowett and Bedi achieved AOFAS improvement from 56 to 87 points in postoperative assessment of 106 patients[21]. In this series, patients had significantly improved function, with improvement from a preoperative AOFAS of 42.8 to 90 postoperatively.

The results of the MICA technique are also similar to those of the open technique when assessed over the medium and long term[20,22]. Lee et al. conducted a randomized prospective study of 50 patients comparing clinical and radiographic results of surgical treatment of hallux valgus with percutaneous Chevron osteotomy to conventional open osteotomy. They observed that pain during the acute postoperative phase was statistically lower in the subset treated with percutaneous surgery[20]. Conventional open surgery for hallux valgus demands extensive dissection of soft tissues and this can result in painful and slow postoperative recovery. A major advantage of minimally invasive surgery is the less painful and more comfortable postoperative course[23,24]. This series adds weight to findings in the literature, with improvement in mean VAS from 8.6 to 1.7 points.

Some complications have been associated with this technique, but it is important to emphasize that the majority are related to hardware and that serious complications such as avascular necrosis, pseudarthrosis, malunion, and problems related to healing of soft tissues are infrequent[12-14].

Some surgeons considered experienced and pioneers of minimally invasive surgery have presented cases series with low rates of complications[10,13]. Jowett and Bedi state that the occurrence of complications is related to the surgeon's learning curve. They reported a case series of 106 patients distributed into 2 similar groups and operated on by the same surgeon, observing that the group that comprised the first 53 cases had worse results and the screws had to be removed in 19% of cases. They emphasize the importance of conducting preoperative fluoroscopic assessment in internal oblique view to determine the correct positioning for screws in the medial cortex of the metatarsal[21]. The complication rate in the present series was 26.6% (eight patients), the majority related to discomfort caused by hardware. After removal of screws, all patients exhibited complete remission of symptoms. It is hypothesized that the high rate of hardware removal in those series may be related to the surgeon's learning curve and to the square shaped proximal extremity of the screws used in the series. Some authors point out that screws manufactured specifically for this surgery, with an oblique chamfered design at the proximal extremity, achieve a better fit in the metatarsal and reduce the likelihood of irritation of soft tissues[10,14]. Despite a high rate of implant removal, use of a rigid and stable internal fixing achieved excellent radiographic results and no delayed union, pseudoarthritis, or malunion was observed. Some studies of percutaneous osteotomies with no fixation or only fixed using Kirschner wires reported higher rates of this type of complication[9,25,26]. Two patients in the study had neurapraxia and one patient had sympathetic reflex dystrophy that was resistant to clinical control. It should be noted that, although we consider 26.6% to be a high rate of complications, there were no serious complications, all osteotomies were consolidated within 3 months, there were no problems related to soft tissue healing, and none of the osteotomies needed to be revisited. Moreover, more than 90% of the patients were satisfied with their treatment.

There has been criticism of minimally invasive surgery related to excessive shortening that can be caused by burrs[27]. The decision on whether or not to shorten the first metatarsal is taken on the basis of the radiographic characteristics of each patient. In some severe deformities, shortening is desirable and essential to achieve good correction. In order to compensate for the shortening caused and reduce the likelihood of transference metatarsalgia, the osteotomy cut can be made at angle of more than 10° from dorsal to plantar in the coronal plane, provoking plantar displacement of the head of the metatarsal. It is worthy of note that none of the patients in this study suffered from this complication.

This study is subject to several limitations, such as the small number of participants, inclusion of the learning curve of the surgeon responsible for the cases, the presence of additional procedures in some of the cases, and use of the AOFAS score. The AOFAS score is a tool that has certain limitations for assessing the pathology in question, but it is the most widely-used score for evaluating the results of HV surgery and therefore enables direct comparison with earlier publications. Edema was not assessed in the study because of the difficulties involved in measuring it objectively. The distal metatarsal joint angle was not used as a radiographic outcome in this study because it has been shown to have weak interobserver reliability and is not generally used in other studies[28]. Although there are few studies of percutaneous techniques for treatment of severe and moderate HV, the results reported in this study are consistent with the current literature.

Conclusion

It can be concluded that the MICA technique is safe and reproducible and can achieve good clinical and radiographic results for treatment of moderate and severe HV and that to obtain these the learning curve should be respected and prior training should be conducted on practical courses with cadavers. Comparative studies with higher level scientific evidence and larger numbers of participants are needed to support these findings.

Authors' contributions: Each author contributed individually and significantly to the development of this article: GAN *(https://orcid.org/0000-0003-4431-5576) conceived and planned the activities that led to the study; interpreted the results of the study; participated in the review process; approved the final version; JMM *(https://orcid.org/0000-0002-4224-8149) conceived and planned the activities that led to the study; interpreted the results of the study; participated in the review process; TB *(https://orcid.org/0000-0001-9244-5194) conceived and planned the activities that led to the study; interpreted the results of the study; participated in the review process; RZ *(https://orcid.org/0000-0001-9692-5283) conceived and planned the activities that led to the study; interpreted the results of the study; participated in the review process; approved the final version. *ORCID (Open Researcher and Contributor ID) iD.

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