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Minimally invasive Chevron Akin (MICA) osteotomy for severe hallux valgus

Gustavo Araujo Nunes[1,2,9] · **Kepler Alencar Mendes de Carvalho**[3,4] · **Gabriel Ferraz Ferreira**[5,6] · **Miguel Viana Pereira Filho**[5,6] · **Andre Donato Baptista**[4] · **Roberto Zambelli**[7] · **Jordi Vega**[1,8]

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Abstract

Introduction The minimally invasive Chevron Akin (MICA) osteotomy has been widely used to treat hallux valgus (HV). The purpose of this study was to present a case series of patients with severe HV undergoing surgical treatment using the MICA procedure and to evaluate the clinical and radiographic outcomes.

Materials and methods Retrospective study including 60 consecutive feet (52 patients) undergoing MICA for severe HV. The data were collected pre- and post-operatively at the last follow-up. Patients were clinically evaluated by the visual analog pain scale (VAS) and AOFAS hallux MTP-IP score. Radiographic assessments included measurements of hallux valgus angle (HVA), intermetatarsal angle (IMA), metatarsal (MT) length, distal metatarsal articular angle (DMAA), and plantar translation of MT head. The complications were recorded during the follow-up.

Results The mean age was 59.9 years, and the mean follow-up was 20.5 months. The average AOFAS increased from 41.2 to 90.9 points, and the VAS from 8.1 to 1.3 at the last follow-up. The average HVA decreased from 41.2º to 11.6º, the IMA from 17.1º to 6.9º, and the DMAA from 17.9º to 7.8º. The average shortening of the first metatarsal and the plantar translation of the MT head was 5.1 mm and 2.8 mm, respectively. The most observed complication was hardware discomfort, observed in 5 feet (8.3%). There were two cases of recurrence (3.3%).

Conclusion MICA technique was demonstrated in this series of cases to be an effective procedure for severe HV, with a low rate of recurrence and an acceptable rate of complications.

Level of evidence IV; case series.

Keywords Hallux valgus · Minimally invasive surgery · Percutaneous surgery · MICA · Chevron

✉ Gustavo Araujo Nunes
gustavoanunes@hotmail.com

Kepler Alencar Mendes de Carvalho
kepler-carvalho@uiowa.edu

Gabriel Ferraz Ferreira
gabriel.ferraz38@yahoo.com.br

Miguel Viana Pereira Filho
miguel.viana.filho@gmail.com

Andre Donato Baptista
dr.andredonato@gmail.com

Roberto Zambelli
zambelliortop@gmail.com

Jordi Vega
jordivega@hotmail.com

1 MIFAS by GRECMIP: Minimally Invasive Foot and Ankle Society, Merignac, France

2 COTE Brasília Clinic, Foot and Ankle Unit, Brasília, DF, Brazil

3 Department of Orthopedics and Rehabilitation, University of Iowa, Carver College of Medicine, Iowa City, IA, USA

4 Nossa Senhora do Pari Beneficent Association, São Paulo, SP, Brazil

5 Foot and Ankle Surgery Group, Orthopaedics and Traumatology Unit, Prevent Senior, São Paulo, Brazil

6 Instituto Vita, São Paulo, Brazil

7 Mater Dei Healthcare Network, Belo Horizonte, MG, Brazil

8 Laboratory of Arthroscopic and Surgical Anatomy, Department of Pathology and Experimental Therapeutics (Human Anatomy Unit), University of Barcelona, Barcelona, Spain

9 SGAS, 915 Lote 68a Salas 16/17 Centro Clínico Advance 2 - Asa Sul, Brasília, DF 70390-150, Brasil

Introduction

Hallux valgus (HV) is a common foot problem, and its treatment is widely discussed in the literature [1–3]. The etiology of HV is multifactorial, with anatomical, hereditary, and biomechanical factors involved. Unfortunate cases that do not improve with conservative measures can be treated surgically [4, 5]. HV is classified based on a radiographic assessment of weight-bearing radiographs. Severe hallux valgus is defined as a hallux valgus angle (HVA) greater than 40° and, or the intermetatarsal angle between the first and second rays (IMA) greater than 20° [6]. The treatment of severe deformities is a great challenge. Surgical option is not unique, and the variety of choices has been dictated by the multiplicity of causal factors and the surgeon's personal preference [7]. Traditionally, proximal metatarsal osteotomies have been used to correct severe HV deformities [8, 9]. However, they have been accompanied by significant complications such as recurrence, pseudarthrosis, overcorrection, and prolonged recovery [8, 9]. Another good option for severe cases is Lapidus arthrodesis [10]. However, this procedure is technically demanding and associated with a prolonged period of recovery and increased morbidity when compared to metatarsal osteotomies [11].

Several minimally invasive (MIS) techniques have recently emerged and gained popularity in treating HV deformity [7]. Redfern and Vernois developed the minimally invasive Chevron Akin (MICA) [12, 13]. MICA is a third-generation percutaneous procedure for symptomatic mild to severe HV deformity [14]. According to the literature, MICA has been reported to have had excellent results and low complication rates in treating mild to moderate HV deformity [15–17]. However, there is a lack of radiographic correction, clinical improvement, and complications following percutaneous third-generation to severe HV [18, 19]. There are only two case series of MICA, including just severe deformities [18, 19]. Additionally, one of these series evaluated the radiographic parameters correction only after a 6-weeks postoperative period [19].

The present study aims to evaluate the radiographic parameters, clinical improvement, and potential complications in a case series of severe HV. We hypothesized that the MICA technique could be able to correct severe deformities with good clinical outcomes and acceptable complications and recurrence rates for severe HV.

Methods

This multicenter study presents a retrospective evaluation of 60 consecutive feet (52 patients) diagnosed with severe HV that underwent MICA. Four different surgeons, with a minimum of 5 years of experience in MIS, from three different centers, did the surgery between January 2017 and December 2020. Inclusion criteria were patients with a diagnosis of severe HV (according to the radiographic angles) who did not improve with conservative treatment, which was carried out with the adaptation of shoes and symptomatic medication. Exclusion criteria were previous history of foot surgery, arthrosis of the metatarsophalangeal joint of the hallux, rheumatological and neurological disease, vascular problems, and patients that could not follow the postoperative protocol.

All patients were clinically and radiographically assessed pre- and postoperatively, with a mean follow-up of 20.5 months. Clinical preoperative assessment included the American Orthopedic Foot and Ankle Score (AOFAS) [20] and the visual analog pain scale (VAS) [21]. The VAS was used to assess pain in the metatarsophalangeal joint of the hallux. Pain in other places, such as central metatarsalgia, for example, was considered a complication. At the last follow-up appointment, patients answered the AOFAS and rated pain on the VAS once more. Complications were also documented.

Radiographic assessments were obtained in full weight-bearing, anteroposterior (AP), and lateral views. Utilizing the mechanical axis of the first and second metatarsals and

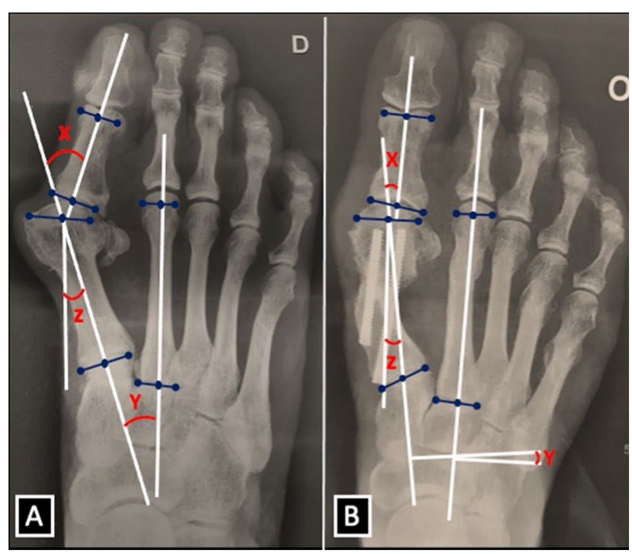

Fig. 1 Radiographic parameters. Hallux valgus angle (X), intermetatarsal angle (Y), and the distal metatarsal articular angle (Z). **A** Preoperative measurements. **B** Postoperative measurements

Fig. 2 Surgical steps. **A** Introducing the burr at the osteotomy point. **B** Head displacement and fixation with the first guide wire. **C** Fixation with the first screw and the second guide wire. **D** Fixation with the second screw. **E** Final result

the proximal phalanx of the hallux, the HVA, IMA, and distal metatarsal articular angle (DMAA) were measured [22, 23] (Fig. 1). The first metatarsal length (MTL) was measured in the axial plane as a distance between the center of the proximal and distal articular surface. The plantar translation of the first metatarsal was defined as the distance between the dorsal cortéx of the proximal and distal fragment of the osteotomy in the sagittal view.

Two fellowship-trained orthopedic foot and ankle surgeons not involved in the surgical procedure performed the radiographic analysis. The measurements were done preoperatively and postoperatively after 6 weeks, 6 months, and at the last follow-up. Radiographic recurrence was defined as a change in HVA > 2.6° between any two postoperative radiographs and an HVA > 15° according to the method of Kilmartin et al. [24].

All patients signed the consent form and accepted to be included in the study. Our institutional ethics committee approved this study (16213319.8.0000.5122).

Statistical data analysis

The statistical analysis was performed using the software R. Descriptive statistics were used for the nominal variables. Mean, standard deviation, maximum, and minimum were calculated for numerical variables. The Shapiro test was performed to determine whether the data were parametric or nonparametric. Nonparametric means were compared using the Wilcoxon signed rank paired test. The Student's paired *T* test analyzed variables with parametric distribution to compare the means.

Surgical technique

The technique was performed as described by Redfern and Vernois [12, 13]. The patients underwent the surgical procedure under spinal anesthesia and antibiotic prophylaxis per hospital protocol. They were placed supine with their feet hanging from the operating table. The image intensifier was positioned with the detector beneath the operated foot.

An extracapsular portal was performed at the distal metaphyseal–diaphyseal transition at the medial side of the first metatarsal. Through this portal, a Shannon burr 2 × 20 mm was introduced at the base of the flare of the distal metaphysis of the first metatarsal (Fig. 2A). The osteotomy displacement plane was performed according to the cutter orientation in both transversal and coronal planes. A Chevron osteotomy of approximately 130º was performed, with a dorsal cut perpendicular to the first metatarsal axis.

A dorsomedial guidewire was introduced at the base of the first metatarsal until it breached the lateral cortex. After introducing the guidewire, the lateral displacement of the metatarsal head was performed using an elevator or a Kirschner wire inserted in the medullar canal (Fig. 2B). The guidewire was then progressed to fix the metatarsal head, and a 4.0 mm headless cannulated screw was inserted, passing through the medial and lateral cortices before fixing the metatarsal head. A second anti-rotational screw was inserted in the same plane, slightly distal to the first screw (Fig. 2C, D). Subsequently, the medial diaphyseal prominence was resected using a Shannon 2 × 12 mm through the proximal screw entry portal.

If there was an incongruity of the metatarsophalangeal joint of the hallux or if the lateral sesamoid remained uncovered, the release of lateral soft tissues (sesamoid-phalangeal ligament and lateral head of flexor hallucis brevis) was done by an extra lateral portal. The next step was to proceed to Akin's osteotomy, performed through medial access to the base of the proximal phalanx. Using a 2 × 12 mm Shannon burr, the osteotomy was achieved in the proximal metaphyseal region cautiously to keep the lateral cortex intact (Fig. 2E). The washing and removal of bone debris were performed with abundant saline irrigation. The procedure was finished with the closure of the surgical incisions and applying a padded dressing and adhesive tape.

Postoperative protocol

Patients were allowed full weight-bearing according to tolerance when discharged from the clinic using a rigid sole orthopedic shoe worn for 6 weeks. Crutches were used if required. In the first 14 days after surgery, they were instructed to keep their foot elevated above the level of the ipsilateral hip to minimize postoperative swelling. After the 1st week, the surgical dressing was replaced by Steri-Strips applied to the portals. Thenceforth, the dressings were changed daily by the patients. Gentle exercises for the range of motion of hallux were introduced in the 2nd week and intensified during the follow-up according to the patient's evolution. After the 6th week, the patients were allowed to wear conventional shoes with a wide anterior chamber and a rigid sole.

Results

In this study, 60 feet (52 patients) with severe HV were evaluated pre- and post-operatively. The mean age of the patients was 59.9 (ranging from 32 to 82) years, and 45 patients were female. The mean follow-up was 20.5 months (ranging from 18 to 32). Additional minimally invasive procedures were performed on 20 (33%) feet, including nine osteotomies of the fifth metatarsal for bunionette, ten distal minimally invasive osteotomies of the second, third, and fourth metatarsals, and 14 proximal phalangeal osteotomies with a selective flexor longus tenotomy for lesser toe corrections.

Clinical outcomes and radiographic assessment

Clinical and radiographic variables assessed pre- and postoperatively showed statistically significant improvement, as demonstrated in Table 1.

Complications

There was a complication in 14 (23.3%) cases. The most common complication was the removal of screws in 5 feet (8.3%) due to discomfort from the hardware at the insertion point in the proximal metatarsal region. Two patients (3.3%) had medial dorsal cutaneous nerve neuropraxia that self-resolved, and another three (5%) had a superficial infection that resolved with oral antibiotics. Two cases (3.3%) of HV recurrence and two (3.3%) had a medial wall fracture of the first metatarsal 1 week after surgery treated conservatively. There was no delayed union, pseudarthrosis, or malunion. (Fig. 3).

Discussion

The most important contribution of this study was to demonstrate the clinical improvement and radiological correction in a case series of patients with severe HV who underwent surgical treatment with MICA. The results of this study collaborate to increase the scientific evidence on the safety and effectiveness of this technique for the treatment of severe HV.

Correcting severe deformities is challenging, since there is evidence of increased complication rates [25, 26]. Several open techniques are described in the literature, but there is still no unanimity [7]. Some studies emphasize that diaphyseal and proximal osteotomies are more appropriate to correct severe hallux valgus than distal osteotomies [6, 27]. Law et al. [28] analyzed 18 severe cases that achieved an open scarf osteotomy and a mean decrease in HVA and IMA of 32.1° and 10.4°, respectively. Wang et al. [29] treated 30 severe HV cases with open double metatarsal osteotomy, achieving a mean decrease in HVA and IMA of 29.5° and 9.3°, respectively. The present study demonstrated a similar improvement with a mean decrease in HVA and IMA of 29.6° and 10.2°, respectively. Although MICA is a distal metatarsal procedure, metatarsal osteotomy is extracapsular.

Table 1 Clinical and radiographic outcomes

Outcome	Preoperative (mean, standard deviation)	Postoperative (mean, standard deviation)	Preoperative and postoperative difference	*p* value
HVA	41.2 (5.4)	11.6 (7.2)	29.6	< 0.001
IMA	17.1 (3.1)	6.9 (3.3)	10.2	< 0.001
DMAA	17.9 (8.1)	7.8 (5.2)	10.2	< 0.001
PT	–	2.8 (1.0)	–	–
MTL	65.1 (5.9)	60.0 (5.4)	5.1	< 0.001
AOFAS	41.2 (17.0)	90.9 (9.8)	49.7	< 0.001
VAS	8.1 (1.6)	1.3 (2.0)	6.8	< 0.001

HVA hallux valgus angle, *IMA* intermetatarsal angle, *DMAA* distal metatarsal articular angle, *PT* plantar translation of the first metatarsal in milimeters, *MTL* first metatarsal length in millimeters, *AOFAS* American Orthopedic Foot and Ankle Society Scale, *VAS* pain visual analog scale

Fig. 3 **A** Preoperative radiography. **B** Postoperative radiographic control showing the evolution of bone consolidation in the 6th postoperative week and **C** 12th postoperative week

It uses a specific fixation with screws that make it possible to perform large displacements of the metatarsal head and obtain excellent radiographic corrections to severe deformity.

Only two series cases included just severe HV that underwent the third-generation MIS technique. [18, 19]. The first one, described by Lewis et al. [18], reported the clinical and radiological outcomes of 53 severe HV in a long follow-up term. They achieved an average decrease in HVA and IMA of 32.5° and 12.4°, respectively. The second study [19] reported a 6-week postoperative radiographic result of 106 patients with severe HV, reaching an average decrease in HVA and IMA of 34.4° and 11.9°, respectively. The similarity of these radiographic results with our study reinforces the power of the third-generation MIS procedure in correcting severe HV deformities. Regarding the DMAA, a unique study analyzing this variable after MICA was described by Kepler et al. [30]. They showed an average decrease of 9.6°, while our study had a similar decrease of 10.1°. Although MICA does not remove a wedge to correct the tilt of the joint surface, it changes the anatomical axis of the first metatarsal preoperatively to the mechanical axis postoperatively, decreasing the DMAA [30].

The present study demonstrated an improvement in the function of the patients, with a mean increase of the AOFAS going from 41.2 to 90.9 points. Other studies involving the MICA technique for treating moderate to severe HV have shown similar clinical improvement [30, 31]. First, Kepler et al. [30] analyzed 70 feet and achieved an average increase in the AOFAS score from 43.9 to 90.1 points. Jowett and Bedi [31] improved AOFAS from 56 to 87 points in a study of 106 patients. It has been shown that there is a clinical improvement up to 2 years of follow-up after MICA [32]. Therefore, the positive clinical results of the present study can improve over time.

The complication rate of this study was 23.3% (14 patients). The most common complication was discomfort caused by the screws in 5 feet (8.3%) that improved after reoperation removing the screws. Despite this, a rigid fixation was essential to avoid major complications. There was no delayed union, pseudarthrosis, or malunion. A higher rate of these complications has been observed in the non-fixed MIS techniques [33, 34]. Two patients (3.3%) had a medial wall fracture of the first metatarsal one week after surgery, treated conservatively. They were maintained with an elastic bandage to keep the correction with non-weight bearing for 6 weeks. Two other patients (3.3%) had a recurrence of the deformity.

There is concern about the high recurrence rate with distal osteotomies for treating severe deformities [35]. In this series, two patients (3.3%) had a recurrence of HV. This rate compares well to the literature, with the reported recurrence rate for open surgery for severe hallux valgus ranging from 2.7 to 16% [36]. Lewis et al. [19], in a study with a similar follow-up to ours, obtained a resembling recurrence rate of 2.8% in 106 patients with severe HV treated by MICA. Despite being a distal technique, as suggested by Nunes et al., MICA locks the first metatarsal cuneiform joint in a maximum medial position, stabilizing the transverse plane and reducing the risk of recurrence [37]. Both recurrences of this study occurred due to an increase in HVA and developed a mild HV (Fig. 4).

There is criticism of minimally invasive surgery concerning the excessive metatarsal shortening caused by drills [38]. According to the burr orientation at the transverse plane, the surgeon can decide whether or not to shorten the metatarsal with MICA. For severe deformities, shortening is desirable

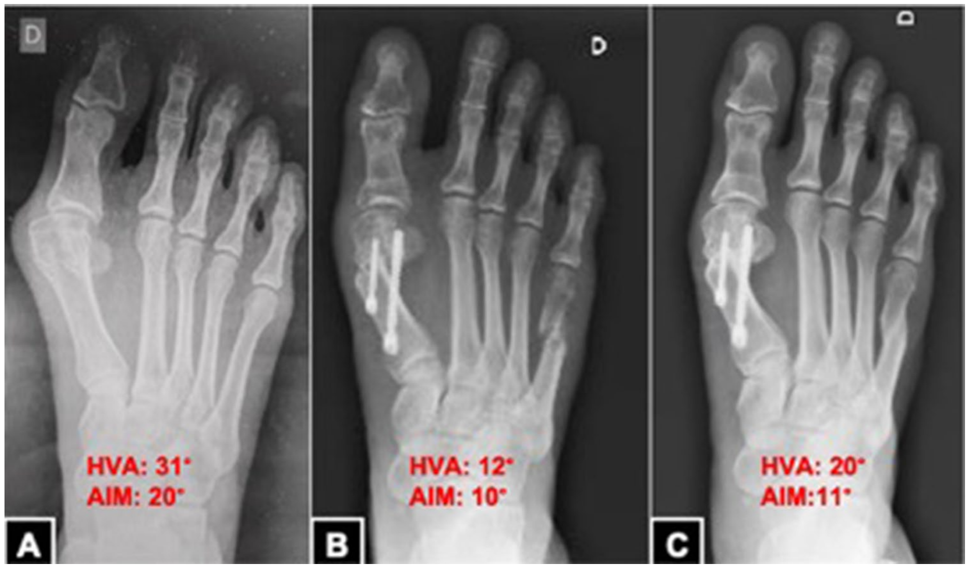

Fig. 4 **A** Preoperative radiography. **B** Postoperative radiographic control in the 6th postoperative week and **C** after 1 year showing the deformity recurrence

Fig. 5 **A** Frontal view showing the plantar inclination of the burr used to achieve a plantar displacement of the metatarsal head. **B** Lateral postoperative radiograph demonstrating the plantar translation of the metatarsal head. Note the distance from the red lines that tangent the dorsal cortex of the proximal and distal fragments

and essential to achieving good correction, reducing soft tissue tension, and preventing recurrence [39]. To compensate for the shortening and to decrease the risk of a transfer metatarsalgia, the osteotomy can be done with an orientation of more than 10º from dorsal to plantar in the coronal plane, promoting a plantar translation of the metatarsal head. In this case series, the mean metatarsal shortening of 5.1 mm was accompanied by a mean plantar displacement of 2.8 mm (Fig. 5), and there were no cases of transfer metatarsalgia.

Surgical treatment of severe HV cases is still challenging due to the heterogeneity of factors related to HV and the lack of the ideal procedure [1, 9]. The first metatarsal rotation directly correlates with HV recurrence [40, 41]. We believe that some degree of metatarsal rotation correction occurs automatically during the medial displacement of the head. After repositioning the metatarsal head, the force vector generated by the soft tissues fits into the correct axis and collaborates to correct the rotation. Recently Nunes and Baumfeld described an MIS third-generation rotational osteotomy [42]. However, it is only a technical report, and further studies will be required to evaluate the correction of the first metatarsal rotation.

This study has several limitations, such as the small number of patients, inhomogeneous cohort, additional surgeries in 30% of the cases, and the short follow-up period. A large number of patients and a long-term follow-up would increase the study's validity, as correction of severe HV needs time to evaluate possible late complications and HV recurrence. In addition, a comparative study with open procedures will be required.

Conclusion

This study confirms our hypothesis that the MICA technique can correct severe deformities with good clinical outcomes and acceptable complications and recurrence rates. Prospective and comparative studies with a similar open comparison group would be fundamental to reinforce our results.

Author contributions All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by GAN, GFF, MVPF, ADB, KAMC, RZ, and JV. The first draft of the manuscript was written by GAN and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials The datasets generated during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest Gustavo Araujo Nunes is Novastep Speaker. The authors declare no potential conflicts of interest with respect to the research, authorship, and publication of this article. ICMJE forms for all authors are available online.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study was approved by the Bioethics Committee of Medical Institution, CAAE (Ethics Evaluation Submission Certificate) number: 16213319.8.0000.5122.

Consent to participate Informed consent was obtained from all individual participants included in the study.

Consent to publish The authors affirm that human research participants provided informed consent for publication of the images in Figs. 1, 2, and 3. The participant has consented to the submission of this case series to the journal.

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