Early Radiological Outcome of MIS Bunionectomy With Guided Trajectory System

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Abstract: Early radiologic outcome and technical details of MIS bunionectomy using a guided trajectory system is reported here. From April 2022 to March 2023, 20 consecutive minimally invasive bunionectomies were performed on 17 female patients (bilateral in 3 patients) with an average age of 63.6 (range: 46 to 82). The mean IMA improved from 14.3 degrees (SD: 3.2) to 4.6 degrees (SD: 2.0), HVA from 28.2 degrees (SD: 6.3) to 6.7 degrees (SD: 2.8), DMAA from 16.6 degrees (SD: 5.6) to 6.6 degrees (SD: 1.8). Preoperatively, 17 feet (89.5%) were in TSP grades 2 and 3. Postoperatively, 19 feet (95%) improved to either TSP grades 0 and 1. The mean duration of operative time was 50 (SD: 9.25, range: 23 to 65) minutes. No intraoperative complications were reported. Overall, this study provides valuable insights into the benefits of using a guided trajectory system to improve the success of bunion correction surgeries. Level of evidence: Level 4.

Key Words: hallux valgus, MIS, MICA, bunion, guided trajectory, bunionectomy

(*Tech Foot & Ankle* 2025;00:e0444)

BACKGROUND

It has long been proven that minimally invasive surgery (MIS) for hallux valgus (HV) has outcomes comparable with those of traditional open osteotomy approaches.[1–6]

The first generation percutaneous technique was described in the early 90s by Reverdin-Isham.[7,8] The second generation MIS included Boesch osteotomy and the Endolog technique.[9] Redfern and Vernois were the first ones to describe an extracapsular osteotomy with stable internal fixation, now considered the pioneer of third generation procedures.[10]

Minimally invasive Chevron-Akin (MICA) osteotomy, representing the third generation MIS for HV, combines the advantages of an extra-articular osteotomy, stable internal fixation with screws and also high potential for deformity correction.[11] In the last few years, several authors have produced short to medium-term studies on MICA with good radiographic and clinical outcomes.[12–15]

One significant drawback of the MICA approach is the difficulty encountered in executing a reproducible maneuver. In addition, positioning the K-wires in the ideal position presents its own set of challenges. Such difficulties can lead to variations in outcomes and complicate the learning curve for surgeons new to the technique.

Most recently, Lewis and Ray coined the notion of fourth generation MIS for HV, the metaphyseal extra-articular transverse and Akin (META) osteotomy, combined with an active 3-dimensional reduction maneuver and rigid stable bicortical fixation using 2 screws.[15]

In our cohort, we will be looking at the modification of the fourth-generation MIS for HV using a special guided trajectory system. This guide jig helps with the translation of the capital fragment and maintenance of the reduction while the oblique screws are placed for fixation. To our knowledge, it is the first-of-its-kind instrument produced for minimally invasive HV correction.

In essence, the aim of the study is to describe in detail the operative technique and to evaluate the early radiologic outcome. The perioperative details, such as operating time, intraoperative difficulties, and postoperative complications, are also discussed here.

METHODOLOGY

This study represents a retrospective study. From April 2022 to March 2023, 20 consecutive MIS bunionectomies were performed on 17 female patients (bilateral in 3 patients) by a single fellowship-trained foot and ankle orthopedic surgeon, who himself developed the device.

All skeletally mature patients with painful, nonarthritic, passively correctable HV deformities who failed nonoperative treatments (toe spacer and shoe modification) were included in the study. Patients were excluded from the study if they had osteoarthritis of the first metatarsophalangeal joint or first tarsometatarsal joint, a history of prior surgery for bunion correction, and/or need for simultaneous midfoot or hindfoot procedures. Patients' demographic data were collected and recorded.

All the cases had 2 screws (3.5 to 4.0 mm) for distal metatarsal transverse osteotomy and 1 (2.8 mm) or none for Akin osteotomy.

For the radiographic evaluation, standard foot anteroposterior and lateral weight-bearing radiographs were performed. The hallux valgus angle (HVA), intermetatarsal angle (IMA), and distal metatarsal articular angle (DMAA) were evaluated.[16,17]

Tibial sesamoid position (TSP) was described as per the AOFAS grading scale: grades 0, 1, 2, and 3.[18]

The severity of the deformity was categorized according to AOFAS criteria into 3 grades: mild (HVA <20, IMA 9 to 11 degrees), moderate (HVA 20 to 40, IMA 12 to 16 degrees), and severe (HVA >40, IMA >16 degrees).

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The authors declare no conflict of interest.

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DOI: 10.1097/BTF.0000000000000444

Radiographic evaluation was performed on the preoperative and the latest postoperative radiographs available to date.

The operative time, intraoperative difficulties, and postoperative wound issues were all documented.

The parameters were expressed as mean and SD. The 1-tailed nonparametric Wilcoxon test was used to determine the statistical significance of the difference between pre and postoperative radiographic outcomes of HVA, IMA, and DMAA. The TSP, meanwhile, was expressed as a number of subjects in groups and the corresponding frequency distribution (%). The χ^2 test was used for TSP.

A *P*-value <0.0001 was used to define statistical significance. The analysis was performed by our in-house statistician using GraphPad Prism 8.0.2.

Surgical Technique

Patient Positioning

After administration of routine anesthesia, the patient is positioned supine on a radiolucent table. A support is placed at the contralateral knee to ensure the leg is flexed at the hip and knee. The leg to be operated on is placed with the knee extended, and the heel is left hanging about 20 cm from the foot end of the table. The side of interest is elevated by about 30 degrees. This setting enables easy intraoperative insertion of guide wires and screws, plus fluoroscopy orientation. We prefer the mini C-arm over the standard-sized model because of its superior maneuverability and ease of use during the procedure. A tourniquet is placed at the distal leg, but often not inflated. We believe that the little bleeding from the osteotomy site helps to avoid thermal necrosis. The surgeon takes the position medial to the foot with an assistant on the opposite side.

Osteotomy, Reduction, and Fixation With Screws

A sterile marker is used to outline the bony anatomy of the metatarsal bone (MTB) and its midline in the sagittal plane. A stab incision is made at the neck of MTB just proximal to the sesamoid complex, staying in the midline, and the beaver blade is introduced straight to the bone. Sometimes a blunt instrument can be used to create an adequate working space before the placement of the burr. The 2.0 mm Long Shanon Isham burr (straight flute) tip is anchored on the bone, making sure it stays right in the middle of the bone on the sagittal axis. This can also be checked under fluoroscopy.

For the transverse osteotomy, the cortex is first penetrated from medial to lateral. Just before the burr exits the lateral cortex, another fluoroscopy shot is taken to confirm the position (directed towards third MTB head) and any correction can still be done at this point if necessary. Once the lateral cortex is penetrated, the burr is shifted dorsally by a slow and steady windshield-wiper movement. The same is done for the plantar cut (Fig. 1).

It is a good practice to keep the metatarsophalangeal joint dorsiflexed and plantarflexed as the burr is about to exit both dorsal and plantar cortex, respectively. This is to

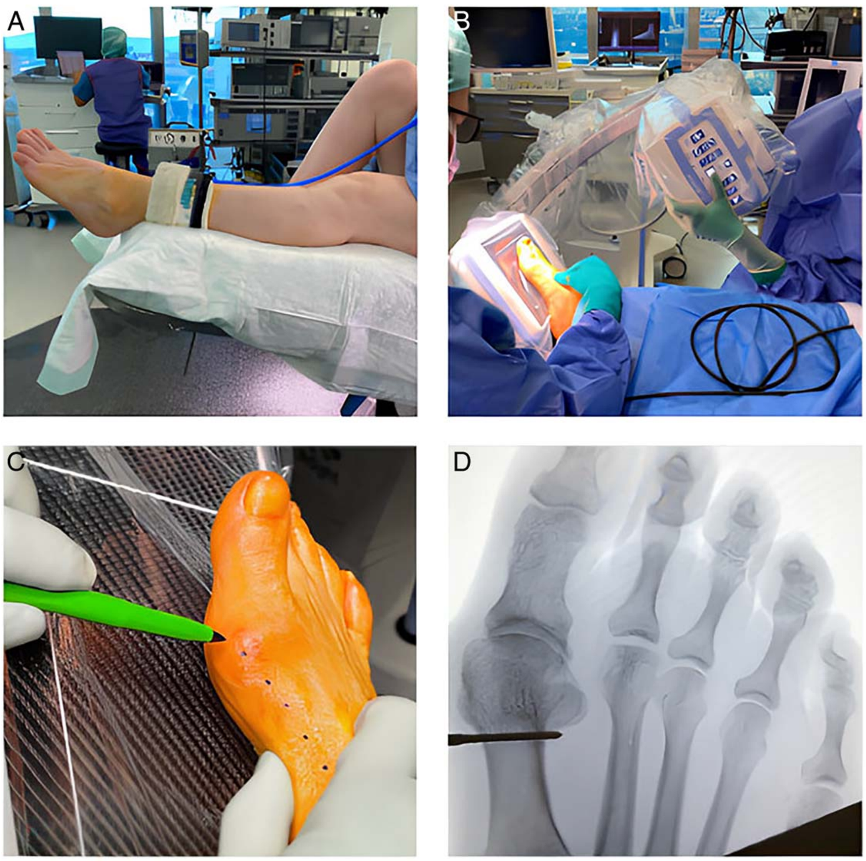

FIGURE 1. (A) The position of the patient on the operating table. (B) The orientation of the mini C-arm. (C) Skin marking of the MTB mid-axis. (D) Site of transverse osteotomy just proximal to the sesamoids.

FIGURE 2. (A) Introduction of the intramedullary hook. (B) Surgeon's thumb holds the jig while the index finger grasps the phalanx, achieving the desired DMAA correction. (C) The targeting arm is attached to the CFS. (D) The direction of the proximal guide wire is before penetrating the lateral cortex. Note the almost 100% displacement of the head.

relax the soft tissues and reduce the risk of any inadvertent injury to the extensor and flexor tendons. A fluoroscopy image is taken to check the mobility of the MTB head after completing the osteotomy.

Next, by the same incision, the hook of the trajectory guide is introduced into the medullary canal of the MTB. Here, we also have to note where the capital fragment shifter (CFS) contacts the skin overlying the head of the MTB, and a stab incision is made there.

The end of the CFS is pushed through to lie directly on the head fragment. While one hand is used for a reduction maneuver to correct the rotational 3-dimensional deformity and hold firmly the position, the other hand drives the capital wire through the shifting device. The targeting device is designed to target the tip of this wire to be where the proximal wire will end up. The capital wire should be parallel to the articular surface and centered in the sagittal plane. It should not be too close to the osteotomy because, in that case, it will limit the proximal wire purchase in the capital fragment.

The CFS knob is then turned clockwise to move the head laterally where we can displace the head as much as 80% to 100% of the width of the MTB at osteotomy site.

Next, the targeting guide is slid over the capital wire. The capital wire positioning knob is tightened such that the thickest laser line of the capital wire is in line with the top of the knob. The more proximal knob controls the proximal to distal placement of the targeting guide which is pushed as proximal as possible against the skin so that the proximal sleeve guide lies just proximal to the tarsometatarsal joint (TMTJ) at the level of the medial cuneiform. On the sagittal plane, it is imperative that the targeting guide contacts the MTB on the marked midline of the shaft (Fig. 2).

There should be no excessive force in introducing the wire as it should gently penetrate the medial cortex, lateral cortex, and head of the MTB in its lateral half. This proximal guide wire acts as a positional wire but can even be used for screw fixation if necessary.

After confirming the ideal position under fluoroscopy, the guide wire sleeve is then moved distally to the intended second screw position. The second distal guide wire is inserted, penetrating the medial cortex and positioning the head either in the lateral half or the central position, going through the osteotomy site.

Once both the guide wires are in, the screw length is measured. The depth device is removed, leaving the sleeve in place. An appropriately sized drill is used for drilling. Next the trajectory guide is removed and the bevel-headed screws are inserted, again with the proximal one first (Fig. 3). The bevel end of the screws should be properly aligned with the metatarsal.

Akin Osteotomy

The medial closing wedge osteotomy of the proximal phalanx of the hallux is done in all our patients. The beaver blade is introduced by a stab incision at the junction of the proximal third and distal two-thirds of the medial cortex, centered at the midline of the phalanx. The medial, dorsal,

FIGURE 3. (A) The preoperative radiograph of one of the patients. (B) The AP view of postoperative radiograph with 2 parallel screws of MTB. (Akin not fixed). (C) The lateral view of postoperative radiograph shows good alignment and screw position.

and plantar cortices are penetrated sequentially with the 2.0 mm short Shanon burr, and care is taken to preserve the lateral cortex as it serves as a hinge for correction. The angle of cut is typically 35 to 45 degrees, directed from distal-medial cortex to proximal-lateral. We commonly use a 2.8 mm headless compression screw (HCS) for this percutaneous osteotomy.

Exostectomy (Can Be Done Before or After Akin Osteotomy)

A conical wedge burr is introduced either by the distal screw or the CFS portal. The dorsal-medial edge of the MTB osteotomy site and the prominent medial eminence are flattened. Irrigation is then done with cold saline to prevent thermal necrosis.

Very rarely, if the osseous correction is not satisfactory, we might consider the lateral release by doing a lateral capsulotomy and release of the suspension ligament of the lateral sesamoid or the adductor hallucis tendon.

TABLE 1. Preoperative and Postoperative Radiologic Values

	IMA	DMAA	HVA
*	Mean ± SD	Mean ± SD	Mean ± SD
Preoperative (deg.)	14.3 ± 3.2	16.6 ± 5.6	28.2 ± 6.3
Postoperative (deg.)	4.6 ± 2.0	6.6 ± 1.8	6.7 ± 2.8
Pre to postchange (deg.)	−9.8 ± 2.6	−10.0 ± 5.1	−21.4 ± 6.0

DMAA, distal metaphyseal articular angle; HVA, hallux valgus angle; IMA, intermetatarsal angle.

RESULTS

A total of 20 feet were analyzed in 17 female patients (bilateral in 3 patients). The mean age of the cohort was 63.6 years (min: 46; max: 82).

All 20 subjects had preoperative and postoperative radiograph values except for 1 patient whose preoperative radiograph data were classified as missing data. Out of the 19 patients whose radiograph values were available, 1 was mild, 17 deformities were in the moderate bracket, and 1 was categorized as severe.

Table 1 summarizes preoperative and postoperative radiologic values and shows a significant decrease in HVA, IMA, and DMMA in postoperative values compared with preoperative values.

All the analyzed radiograph values were statistically significant ($P < 0.0001$).

The TSP showed improvement postoperatively. Initially, most subjects were classified as grades 3 and 2. After the procedure, the majority shifted to grades 1 and 0, with only a few remaining in grade 2 (Table 2).

The mean duration of operative time was 50 (SD: 9.25, range: 23 to 65) minutes.

There were no intraoperative difficulties or complications documented. All patients experienced no wound

TABLE 2. Preoperative and Postoperative Tibial Sesamoid Position

	TSP frequency distribution			
	TSP = 0, (%)	TSP = 1, (%)	TSP = 2, (%)	TSP = 3, (%)
Preoperative	0	2 (10.5)	8 (42.1)	9 (47.4)
Postoperative	8 (40)	11 (55)	1 (5)	0

TSP, tibial sesamoid position.

complications and did not require a return to the operating theater for any postoperative issues.

DISCUSSION

This article describes in detail the technical steps and nuances associated with using a novel targeting device. To our knowledge, this is the first article to describe the radiologic outcomes of a consecutive series of patients who underwent surgical hallux valgus correction using a specific targeting device.

In MIS for HV, the issues that are often not disclosed by most authors are the intraoperative difficulties such as positioning of the K-wires or screws, reduction of the deformity and maintaining the correction throughout the procedure. Lewis and Ray described at length the 3-dimensional reduction maneuver, which also involves the usage of an intramedullary reduction tool to laterally displace the head of MTB.[15] Toepfer introduced the "K-wire first technique," detailing the placement of guide wires free-hand before osteotomy to ensure easier reduction and fixation with screws.[19]

To address these issues, the trajectory device used in the study comes with an intramedullary hook, CFS, and multiple targeting slots in one precise construct. This facilitates more precise reduction and maintains the correction while introducing the guide wires for screws, allowing a single operating surgeon to perform the procedure with minimal assistance and ensuring reproducible results.

Previous authors have also pointed out the proximal entry point dilemma in MICA.[20] The proximal screw requires a very unforgiving course of the guide wire to exit the lateral cortex just proximal to the osteotomy site and to pick up the metatarsal head in its lateral half.[19] A common issue encountered here is the wire sliding into the intramedullary canal after penetrating the medial cortex. The

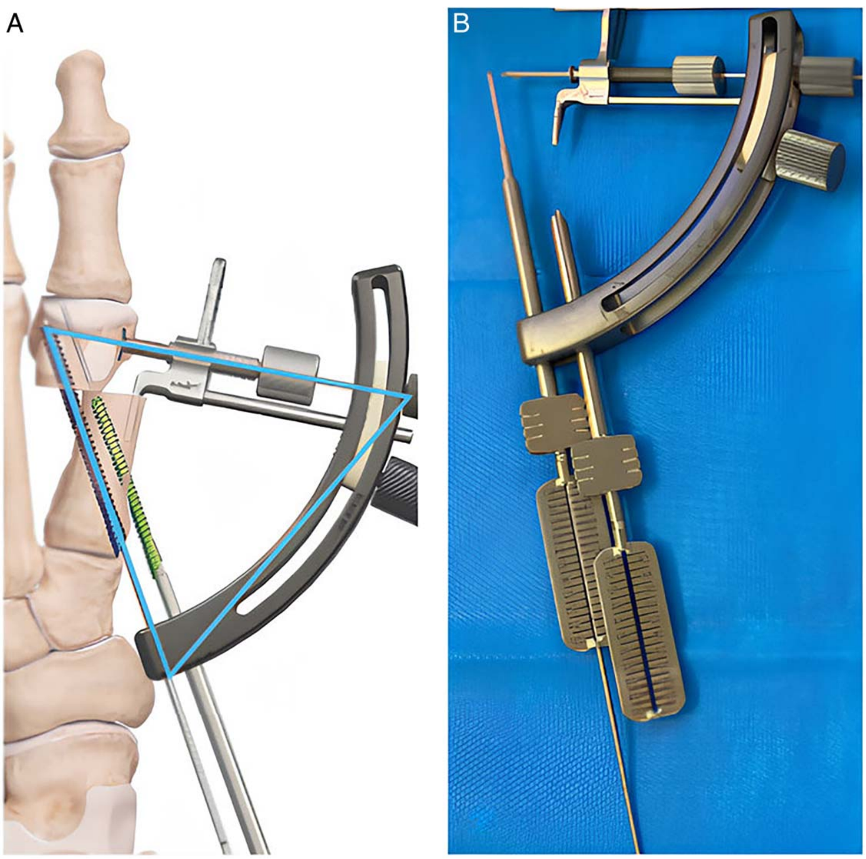

FIGURE 4. (A) The schematic representation of the device. (B) The actual device showing the concept of a circumtriangle, where the circumradius of equal length (the capital shifter wire and proximal guide wire) meet at the tip of the triangle.

multislotted targeting arm of this trajectory system comes with a depth device that ensures good anchorage of the guide wire on the cortical surface. This allows for the precise positioning of the wire's starting point at various locations along the medial cortex of the MTB at a consistent angle. The distal antirotation screw can also be inserted in one of the parallel slots to the proximal one, resulting in the ideal position of the screws as described by Toepfer and Strassle.[19] In our study, all patients had the proximal screws with 3-point-fixation (medial cortex, lateral cortex and the lateral half of first MTB head) while the distal screws were fixed with 2-point-fixation (medial cortex and central or lateral half of the MTB head).

The key point that needs to be highlighted in this trajectory system engineering is the precision with which it operates. The core essence used here is geometry. A circumradius of a triangle is defined as the distance from the vertices of the triangle to the center of the circumcircle. The same principle is applied here, where the tip of the proximal wire (a circumradius) should meet the tip of the capital shifter wire (another circumradius with the same length) when introduced (Fig. 4, Arthrex, Inc., Naples, FL). This mechanism definitely ensures the accurate placement of the screws, both in coronal and sagittal planes.

In short, this novel trajectory system provides a controlled security of each step of the bunionectomy which certainly lacking in the previously described techniques of MIS for HV. The learning curve to familiarize with the usage of this device is not too steep, as long as no direct comparison is made with any subspecialised foot and ankle surgeons who have a high volume of bunionectomy.

It is also fair to note that there was no any intraoperative complication such as guide wire breakage, iatrogenic fracture, loss of reduction after screw fixation, and inadvertent injury to the important anatomic structures. The mean operative time was 50 minutes, which is almost similar to the duration reported by Palmonovich et al.[21]

Our study also demonstrated a high potential for correction, even for severe hallux valgus deformities. The improvement of the HVA, IMA, and TSP is comparable with the values in the literature.[22–26] Kepler reported a mean drop of DMAA from 16.3 (SD: 8.6) degrees to 7.8 (SD: 5.4) degrees postoperatively, while our study recorded a drop from 16.6 (SD: 5.6) to 6.6 (SD: 1.8).[27]

Aiyer et al[28] pointed out that there is no significant difference in ultimate load, yield load and stiffness between transverse and chevron osteotomy constructs. We choose to practice the transverse osteotomy. It is inherently unstable compared with a Chevron. We used this feature to our advantage in maneuvering the head during correction by using the lateral soft tissue restraint as a hinge. The capital shifter of the trajectory device then takes over to provide the locking stability needed to maintain the reduction.

The limited number of studies on minimally invasive HV surgery and various modifications of the previous generation techniques makes any direct comparison of the long-term clinical and radiologic outcomes difficult. Hence, the main focus of our article is the detailed description of the technical steps and pearls of using the new trajectory device with comparable early radiologic outcomes.

STRENGTH AND LIMITATION

We acknowledge a few limitations in our study. The sample size of 20 is statistically less powerful compared with the other MIS studies. Besides, there is a potential bias in the study as the device was developed by a surgeon who also performed the procedures. The lack of a comparison group also theoretically makes it difficult to prove the superiority of this over other techniques, which in any way was not our main intention. Since all the patients in the series were operated on by a senior foot and ankle surgeon, the learning curve of an independent surgeon using this device might be different in the early stages. Another limitation is that our evaluation focused solely on radiologic outcomes, specifically targeting the evaluation of the position of the screws, without encompassing other potential clinical or functional outcomes.

The strength of this article lies in the fact that this is the first paper produced by the design surgeon regarding the usage of this device. The many pertinent points mentioned in the technical steps were indeed from long-term trial and error before the final construct of the trajectory system was produced. We included consecutive patients in the study to reduce the selection bias. The data was analyzed retrospectively by a member of the research team and statistical analysis was done by another, who both have no conflict of interest or financial disclosure to declare

FUTURE DIRECTION

Among the areas of interest for future studies include bigger sample size, medium, or long-term radiologic outcomes, functional patient reported outcome measures (PROM), and in-depth analysis of the learning curve.

CONCLUSION

Our study demonstrates the successful use of a guided trajectory system for minimally invasive HV correction with the ideal screw placement, good early radiologic outcomes and without extensive operating time. The absence of intraoperative complications or difficulties further highlights the efficacy of this system. In short, this 5G bunionectomy with a guided trajectory system is indeed the next big step to improve the consistency and success of MIS for HV. Even though the learning curve of operating the device may be steep at the early stages, it is a very reproducible technique for more controlled and accurate MIS bunionectomy.

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