Why Minimally Invasive Techniques Are the Future of Foot Surgery?

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Abstract—Minimally invasive surgical techniques have become increasingly prevalent in recent years. The first data on MIS correction of foot deformities dates back to 1940, when the first instrumentation for minimally invasive foot surgery was developed. With the advent of X-ray in the 1960s, both instruments and surgical techniques have been improved. X-ray control is at the heart of this type of surgery. Over the years, the instrumentation and implants used for this type of surgery have undergone rapid development. Nowadays, the question is whether to use open surgery at all for the treatment of foot deformities? The aim of this article is to show the application of minimally invasive techniques for the correction of various orthopeadic diseases of the foot and ankle - benefits, negatives, scope of application and results.

Keywords—minimal invasive, foot surgery, future

1. Introduction

Minimally invasive surgical techniques have become increasingly prevalent in recent years. The first data on MIS correction of foot deformities dates back to 1940, when the first instrumentation for minimally invasive foot surgery was developed. With the advent of X-ray in the 1960s, both instruments and surgical techniques have been improved. In 1980, Isham published the first generation MIS technique for hallux valgus correction. This technique does not use internal fixation. (see fig. 1.)

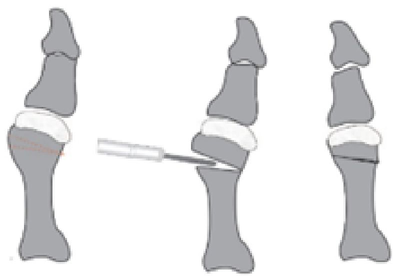

Fig.1. Isham first generation MIS osteotomy

In 1990, Giannini added internal fixation with a K-wire and a subcapital osteotomy for hallux valgus correction. The technique is called SERI (simple, effective, radical, inexpensive). The wire is inserted medially to the phalanx of the big toe, supporting the lateral subcapital fragment of the 1st MTP joint and entering the diaphysis of the metatarsal (see fig. 2).

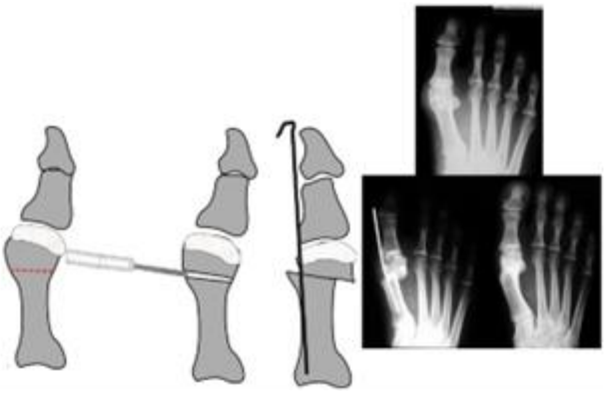

Fig. 2. Bosch osteotomy and K wire fixation

As internal fixation developed, the first compression screws for MIS surgery of the forefoot also appeared. In 2010, Joel Vernoua and his team introduced the so-called MICA technique. The correction is performed by percutaneous Chevron and Akin osteotomies and fixation with 2 compressive 3.5mm titanium screws placed through the base and distal third of the 1st MTP joint. The proximal phalanx osteotomy is also fixed with a compression screw. The goal is clear - stable internal fixation and immediate patient mobilization. In recent years, this technique has been modified and developed further. (see fig. 3, 4.)

Fig. 3. MICA 3rd generation with compression screws internal fixation

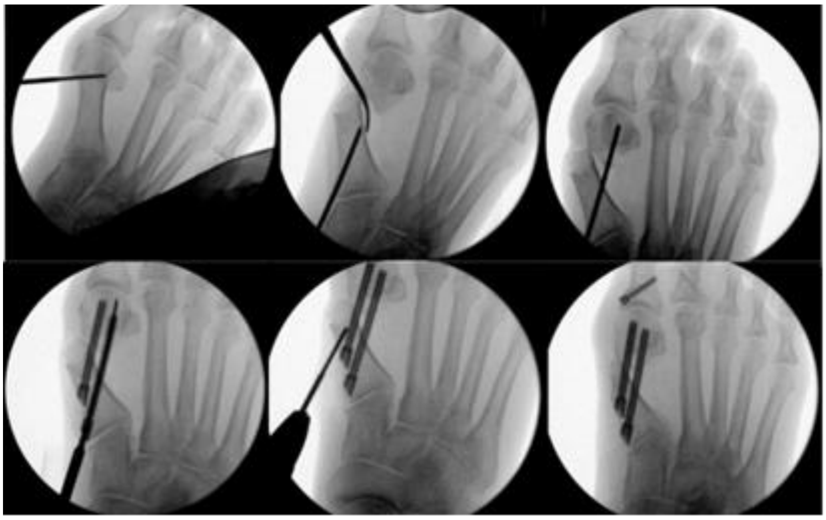

Fig. 4. Steps of MICA correction for hallux valgus deformity

In 2018, the term PETA (percutaneous transverse osteotomy and Akin) was introduced. Instead of a Chevron osteotomy, a transverse osteotomy is now used, which allows for large translation of the fragments and correction of pronation by rotation of the distal fragment.

Since 2022, there has been talk of a 4th generation minimally invasive technique - transverse osteotomy, special compression screws with beveled heads, specialized instrumentation and guides for this type of surgery (see fig. 5.). The general term currently used is MIBS (minimally invasive bunion surgery). One-day surgery, immediate weight-bearing, minimal pain and swelling, excellent cosmetic results, the possibility of treating multiple deformities in one surgical intervention (both feet at the same time) have made this type of intervention the gold standard. Nowadays, the question is whether to use open surgery at all for the treatment of foot deformities?

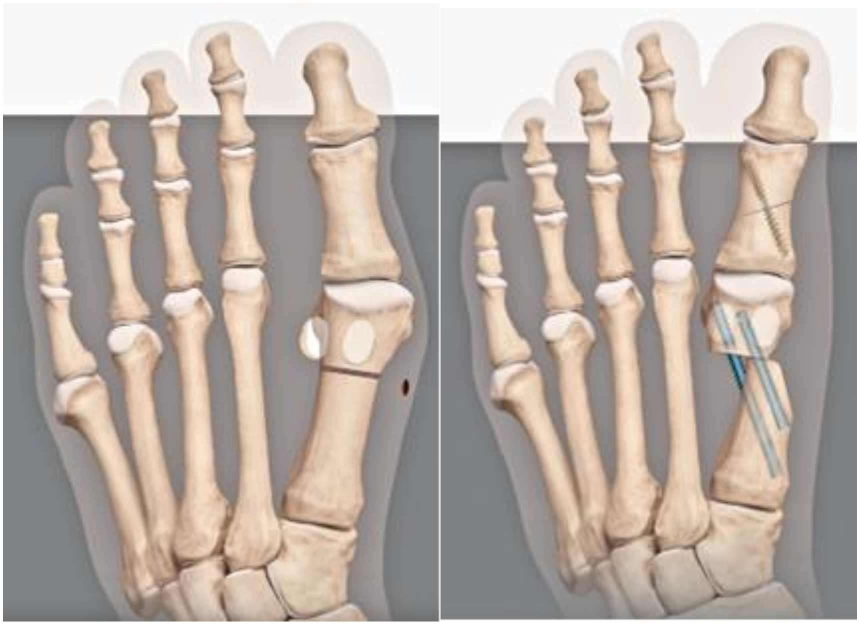

Fig. 5. MIBS or Peta osteotomy 4th generation MIS

2. Materials and Methods

During the study period from 2019 to 2024, 85 women with MIBS (Metatarsal Intraosseous Base Surgery) on one foot were included. Additionally, 5 women underwent MIS (Minimally Invasive Surgery) triple arthrodesis for the treatment of PCFD (Posterior Calcaneal Facet Displacement), 1 woman had MIS correction of cavus deformity (close wedge midfoot osteotomy, see Fig. 6.), 8 women underwent MIS calcaneal osteotomies for Haglund deformities, 6 women received bilateral correction for hallux valgus, 1 man underwent minimally invasive halluxectomy for hallux rigidus (see Fig. 7.), and 3 men had MIS arthrodesis of the first metatarsophalangeal joint due to arthritis.

Fig. 6. close wedge osteotomy for correction of cavus with MIS burr

Fig. 7. MIS arthrodesis of the big toe – treatment of hallux rigidus combined with DMMO for metatarsalgia and bunionette correction

3. Results and Discussion

A standard postoperative protocol was applied to all patients, regardless of their underlying pathology. All patients were discharged from the hospital on the day of surgery. Dressings and sutures were removed on the 14th day. Follow-up radiographs were performed at 45 and 90 days, and then at 6 months, 1 year, and 2 years after surgery. Results were evaluated both radiographically and functionally using VAS and AOFAS scores. (see Fig. 8.)

Fig. 8. bone remodeling of the first metatarsal 1 year after MIS hallux valgus surgery

Improvement was observed in all evaluated parameters, with excellent cosmetic and functional results. In 5 cases, implant removal was required due to soft tissue irritation in tight shoes. In 1 case, revision and osteoplasty were required due to pseudoarthrosis of the first metatarsophalangeal joint.

Preoperative radiographic assessment of hallux valgus angle revealed that all cases were classified as moderate or severe deformity using the AOFAS severity-based radiographic classification for hallux valgus deformity. Mean preoperative intermetatarsal angle (IMA) was 16.2° (SD 2.7, range 11.0–21.5) and mean hallux valgus angle (HVA) was 30.6° (SD 5.5, range 21.8–42.1)

Significant correction can be achieved by comparing preoperative and postoperative radiographs at 45 days. The IMA decreased by an average of 10.8° (SD 2.8, range 2.4–16.7) from 16.2° to 5.4° ($p<0.001$), and the HVA by an average of 22.1° (SD 5.8, range 10.3–36.0) from 30.6° to 8.5° ($p<0.001$). Please see Table 3 in the supplementary material section for the radiological outcome of each case.

The radiation exposure to surgeons was measured using two separate radiation dosimeters specifically for MICA, one at chest level and the other attached to protective eyewear. Over a period of more than 3 years, monthly evaluations did not show any elevated radiation levels.

The revision and poor outcome rates for MICA are comparable to those reported by other authors. Chan et al. reported a revision rate of 15.4%, requiring early reoperation at 1 month after the initial surgery due to osteotomy instability. Their case series included only 13 feet in 8 patients, and their technique (single-screw fixation) differed from the original 3rd-generation MICA. Holm et al. reported a complication rate of 10%, with 4 patients requiring Akin screw removal after bone healing due to soft tissue irritation. Jowett et al. documented 22 complications in 106 patients requiring surgery, mostly due to screw malposition/protrusion, and an overall reoperation rate of 15%. Altenberger et al. provided a detailed description of MICA in German literature in 2018. Their complication rate in 43 cases was reported as equal to conventional open surgical technique, but failed to present specific numbers. Frigg et al. reported a reoperation rate of 27% (13/48) in their MICA group, mostly related to screw removal. Similar to Chan and other authors, their percutaneous technique differed from the original 3rd-generation MICA, making direct comparison difficult. The most recent 3rd-generation MICA publication by Lewis et al. reports an overall complication rate of 21.3% in 292 cases and a "screw removal rate for any reason" of 6.3%. Comparing MICA to other generations or techniques for minimally invasive hallux valgus correction seems challenging, as indications and follow-up care may vary significantly. Nonetheless, as Biz et al. demonstrated in their recent publication, not only is 3rd-generation MICA capable of adequate correction of moderate to severe hallux valgus deformity with a minimally invasive technique. Their long-term follow-up of the MIIND (minimally invasive intra-medullary device) technique also showed favorable results with an implant removal rate of 6% (6/100) and a high correction potential (mean IMA correction 9.9°, mean HVA correction 27.1°).

Our study shows good bone alignment after surgery (even in severe cases): (IMA) decreased from 16.2 degrees to 5.4 degrees, and (HVA) decreased from 30.6 degrees to 8.5 degrees.

Other studies on MICA surgery reported similar results: Vernois et al.: Average IMA correction of 9.0° (from 14.5° to 5.5°) and HVA of 26.4° (33.7° to 7.3°) [6], Chan et al.: Average IMA correction of 3.7° (from 13.9° to 10.2°) and HVA of 19.5° (from 30.4° to 10.9°), Holme et al.: Average IMA decrease of 6.5° (from 13.2° to 6.7°) and HVA of 19.6° (from 31.7° to 12.1°) and Frigg: Average IMA correction of 7° (from 13° to 6°) and HVA of 18° (25° to 7°). Interestingly, studies using only one screw for fixation (Chan et al., Frigg et al.) achieved less correction compared to the original two-screw technique. This suggests that two screws might provide better stability and allow for greater bone movement during surgery.

The VAS score averaged 5.4 before surgery and decreased to 2.5 in the first week after surgery.

The overall AOFAS score for hallux valgus (AOFAS-HV) improved significantly after surgery. The average score went from 42.07±10,82 before surgery to 83±8,96 after surgery. This improvement was statistically significant ($p<0.0001$).

The score improvement was seen in all three parts of the AOFAS-HV score:

Pain: The average pain score increased from 20.71±9,97 to 32.14±6,99 ($p=0.00386$). Higher scores indicate less pain.

Function: The average function score increased from 21.36±6,42 to 36.86±4,22 ($p<0.0001$).

Alignment: The average alignment score increased from 0±0 to 14±2,54 ($p<0.0001$).

We focus mainly on bunion correction results [hallux valgus] since that's our most common case. While other procedures also have great outcomes, this article highlights minimally invasive surgery for these corrections. We want to show the excellent results achieved with this method, but also emphasize the potential risks and the steep learning curve involved.

4. Conclusion

With MIS surgery, we solve the surgical tasks with minimal trauma to the soft tissues, which leads to much less pain, swelling and faster patient recovery. Overall, we can gain up to 2 months faster recovery. Excellent cosmetic results are also important for most patients. Immediate loading, verticalization and discharge on the same day also meet modern medical standards, which leads to reduced hospital costs. In conclusion, minimally invasive surgical techniques address all the needs of 21st-century patients with their dynamic lifestyles.

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