Interventional procedure overview of minimally invasive percutaneous surgical techniques with internal fixation for correcting hallux valgus

Contents

Table 1 Abbreviations

Abbreviation	Definition
AOFAS HMI score	American Orthopaedic Foot and Ankle Society Hallux Metatarsophalangeal Interphalangeal score
CI	Confidence interval
DMAA	Distal metatarsal articular angle
HV	Hallux valgus
HVA	Hallux valgus angle
IMA	Intramedullary angle
META	Metaphyseal extra-articular transverse and Akin osteotomy
MICA	Minimally invasive Chevron-Akin
MD	Mean difference
MOXFQ	Manchester-Oxford Foot Questionnaire
MIS	Minimally invasive surgery
MTP	Metatarsophalangeal joint
OC	Open Chevron
PECA	Percutaneous Chevron-Akin
POO	Percutaneous oblique osteotomy
PROMs	Patient-reported outcome measures
RCT	Randomised controlled trial
ROM	Range of motion
RR	Relative risk
SA	Scarf Akin
SF-36 MCS	Short form (36) mental health component summary score
SF-36 PCS	Short form (36) physical component summary score
SD	Standard deviation
SMD	Standardised mean difference
TMT	Tarsometatarsal

VAS	Visual analogue scale

Indications and current treatment

HV is more commonly known as a bunion. The big toe is deviated towards the other toes resulting in a bony protrusion. This deviation occurs at the first metatarsal phalangeal joint. The small sesamoid bones found beneath the first metatarsal also become displaced as the first metatarsal bone drifts away from its normal position, weakening the big toe. Symptoms include damage to the skin over the bunion, pain and weakness of the forefoot when walking, cosmetic concerns, and difficulty with footwear.

In a small number of people, bunion development is associated with underlying genetic conditions affecting the structure of the foot (such as ligamentous laxity syndromes and certain neurological conditions). But in most people the aetiology is not clear. Chronic trivial injury to the joint (for example, caused by some types of footwear) may be the cause. The condition is most common in women and in middle and later life.

Current treatment options include exercises, orthoses (devices to support and align the foot), spacers between the toes to keep them in the correct position, shoe alterations and analgesics to relieve symptoms. Open surgery is considered as standard care when conservative treatments have failed, and severe pain and deformity cause functional impairment. Many different surgical operations are used for treating HV, depending on the nature and extent of the deformity. One commonly used open surgical procedure is distal first metatarsal osteotomy, which divides and repositions the bone of the great toe near to the joint to correct the deformity.

Unmet need

Clinical experts suggest that people with increased frailty, severe HV deformity (defined as HVA 40 degrees or more or IMA 20 degrees or more, or both), poor soft tissues, high risk of wound healing complications and pain management issues may benefit from percutaneous minimally invasive procedures to treat this condition.

What the procedure involves

Surgical correction of HV using percutaneous minimally invasive percutaneous techniques with internal fixation is done as a day case under local or general anaesthesia and in supine position. Low-dose X-ray monitoring or endoscopic images are used. One or more small incisions are made close to the hallux metatarsophalangeal joint of the affected toe. The bunion is then removed and the metatarsal is divided surgically (osteotomy). Motorised high torque low speed burrs and surgical jigs aid the complex reduction and fixation steps of the procedure and implant insertion. Temporary wires may be used to toggle the separated parts of the divided bone into the desired position. The bone fragments are then stabilised using plates, specialised screws, or wires. The temporary wires used for toggling pieces of bone are removed. The small incisions are closed and a dressing is applied. After surgery, a dressing or plaster may be used to support the foot in the corrected position until the divided bone heals. People are usually allowed to put weight on the foot immediately.

The proposed advantages of a percutaneous surgical approach (minimally invasive techniques) are shorter operation time, quicker recovery, less pain, fewer complications, shorter hospital stay, earlier weight-bearing and smaller scars.

Outcome measures

The main outcomes included PROMs: improvement in function and pain, quality of life and patient satisfaction; complications, recurrence rate and reoperations; hallux joint angle correction and maintenance (radiological measures); and radiation exposure time. The measures used are detailed in the following paragraphs.

MOXFQ score

The MOXFQ is a validated measure of health-related quality of life. It has 3 domains: pain, walking or standing, and social interaction, with a maximum score of 100 in each domain. Higher scores signify poorer quality of life.

AOFAS HMI score

The AOFAS HMI score is the most commonly used PROM for first MTP fusion (arthrodesis). It consists of subjective and objective variables classified into 3 major categories: pain, function, and alignment. The scores are divided into categories:

- 90 to 100 – excellent
- 75 to 89 – good
- 50 to 74 – fair
- less than 50 points – poor.

A minimal clinically important difference of 19 points was suggested by Kaufmann (2019).

VAS score

The VAS score is used to assess the intensity of pain. The range of the VAS score was from 0 to 10, with higher scores signifying ‘worst pain’.

Evidence summary

Population and studies description

This interventional procedures overview is based on 1,975 patients from 2 systematic reviews and meta-analyses, 3 RCTs, 3 retrospective cohort studies (1 with propensity score matching) and 3 case series. Of these 1,975 patients, 680 patients had minimally invasive percutaneous surgical techniques with internal fixation (636 MIS Chevron osteotomy procedures, 44 fourth-generation MIS transverse osteotomy Akin procedures, 47 Lapidus TMT fusion), 303 patients had open osteotomy procedures (163 with open scarf Akin osteotomy, 140 with open Chevron osteotomy), 44 patients had open Lapidus TMT fusion and 901 patients had MIS Reverdin-Isham osteotomy (with no fixation). This is a rapid review of the literature, and a flow chart of the complete selection process is shown in figure 1. This overview presents 11 studies as the key evidence in table 2 and table 3, and lists 60 other relevant studies in table 5.

The countries where the procedures were done include Romania, Helsinki, Australia, Singapore, China, Austria, Switzerland, and the UK. The population is comprised of patients above 18 years with HV deformity:

- mild deformity: HVA 15 to 20 degrees or IMA 9 to 14 degrees, or both
- moderate deformity: HVA 20 to 40 degrees or IMA 14 to 20 degrees, or both
- severe deformity: HVA 40 degrees or above, or IMA 20 degrees or above, or both.

The study designs include systematic review and meta-analyses, RCTs, retrospective cohort studies and case series. The follow-up periods range from 1 to 5 years.

The meta-analysis comparing third-generation PECA osteotomy with open SA osteotomy (traditional open surgery) included only 3 studies (1 RCT and 2 cohort studies) with short-term follow up (Ferreira 2021). Another meta-analysis compared 2 MIS techniques, MIS distal Chevron-Akin osteotomy (1 study) with MIS Reverdin-Isham osteotomy (no fixation, 14 studies). The quality of the included studies on MIS Reverdin-Isham osteotomy were low and only 7 studies were used in the meta-analysis. The MIS distal Chevron-Akin osteotomy was done by a single surgeon in 1 centre (Kaufmann 2021).

Two small RCTs (Dragosloveanu 2022, Kaufmann 2019 and 2020) compared third-generation percutaneous MICA and open approaches for Chevron osteotomy (another traditional open surgery). Follow up in these studies ranged from 1 year (Dragosloveanu 2022) to 5 years (Kaufmann 2019 and 2020). All surgeries in both RCTs were done by a single foot and ankle surgeon. In 1 RCT, 17% (8/47) of patients dropped out (2 were lost to follow up and 6 declined continuing in the study; Kaufmann 2019 and 2020). Another small RCT compared MIS scarf osteotomy with open scarf osteotomy. All procedures were done by a single foot and ankle surgeon in both groups. Lesser toe deformities were also treated in 50% of patients in both groups (Torrent 2021).

Two small retrospective cohort studies (Guo 2021, Tay 2022) compared percutaneous MICA and OC osteotomy. One of the small retrospective cohort studies compared POO and internal fixation with OC osteotomy (Guo 2021) in 112 people. The retrospective propensity matched cohort study of 60 patients compared MICA with open SA osteotomy (Tay 2022).

Two case series (1 retrospective and 1 prospective study) assessed third-generation MIS procedures (MICA and PECA). The retrospective study of 92 patients (126 consecutive feet) had more than 60 months follow up. The study was adequately powered and validated clinical outcome measures were used.

But it lacked validated preoperative clinical PROMs. A 40% loss to follow up for radiographs at final follow up was reported (Lewis 2023a). The prospective case series was large (230 patients [333 feet]) and had 2 years follow up. All procedures were done by a single surgeon and validated measures were used to assess PROMs. In-depth analysis of adverse events were reported. There was a lack of long-term radiographic follow up (Lewis 2021).

One small prospective case series of 50 patients with a wide range of HV deformities reported on a fourth-generation META MIS technique with short follow-up period. All procedures were done by a single surgeon (Lewis 2023b).

A retrospective study compared MIS TMT fusion (Lapidus procedure) with the open Lapidus procedure in a single-surgeon practice. The follow-up period was shorter in the MIS group compared with the open procedure (Vieira Cardoso 2022).

Half of the studies are observational studies with some source of bias. Non-validated outcome measure tools, such as the AOFAS and VAS were used in most studies.

Table 2 presents study details.

Figure 1 Flow chart of study selection

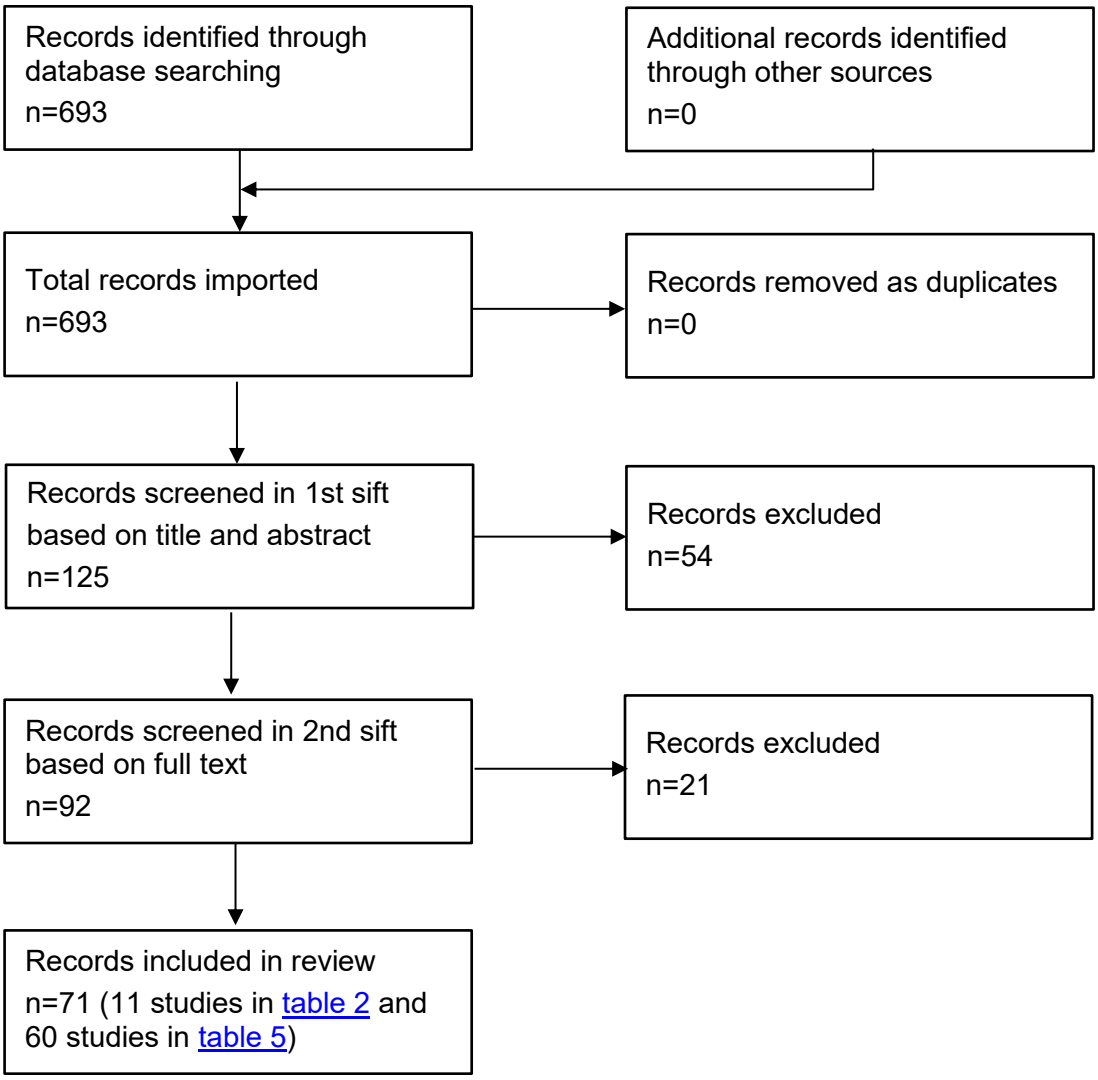

Table 2 Study details

Study no.	First author, date country	Patients and sex (female: male) or gender (women: men) as reported by the study	Age	Study design	Inclusion criteria	Intervention	Follow up
1	Ferreira GF, 2021 Australia, Singapore, and Switzerland	N=235 feet with HV PECA group: n=102 (89:13) Open SA osteotomy group: n=133 (120:13)	PECA: mean 48 to 54 years Open SA osteotomy: mean 48 to 54 years	Systematic review and meta-analysis (n=3 studies including 2 cohort studies and 1 RCT)	HV diagnosis and surgical treatment by the open SA osteotomy and PECA techniques	PECA osteotomy and open SA osteotomy	6 months
2	Kaufmann G, 2021 Austria	N=950 patients MIS or percutaneous chevron osteotomy: 49 patients (57 feet) (52:5) MIS Reverdin-Isham osteotomy: 901 patients (1033 feet) (774:	MIS chevron osteotomy: mean 53 years MIS Reverdin-Isham group: range from 12.5 to 61.5 years	Systematic review and meta-analysis (14 studies;7 included in meta-analysis)	Articles in English or Spanish, assessing MIS, percutaneous chevron distal or oblique osteotomy, MIS Reverdin-Isham method, with a minimum follow up of 6	MIS distal chevron osteotomy (1 case series of 49 patients [57 feet] with mild to moderate HV deformity) 45 feet had phalangeal Akin osteotomy compared with MIS Reverdin-Isham method	MIS chevron osteotomy mean follow up: 58.9 (range 39.0 to 85.4) months MIS Reverdin-Isham method:minimum 6 to 60 months

Study no.	First author, date country	Patients and sex (female: male) or gender (women: men) as reported by the study	Age	Study design	Inclusion criteria	Intervention	Follow up
		60; 4 studies did not report).			months and presenting results in terms of clinical or radiological data were included		
3	Dragosloveanu S, 2022 Romania and Helsinki	N=50 patients with moderate HV Percutaneous MIS chevron osteotomy group: n=24 (24:0) OC osteotomy group: n=26 (24:2)	MIS chevron osteotomy: 49 years OC osteotomy: 55 years	RCT	Patients older than 20 years old, when conservative treatment had failed, with moderate valgus deformity (HVA between 20 and 40 degrees and an IMA between 11 and 16 degrees)	Percutaneous MIS chevron osteotomy (MIS group) compared with OC osteotomy (OC group)	1 year

Study no.	First author, date country	Patients and sex (female: male) or gender (women: men) as reported by the study	Age	Study design	Inclusion criteria	Intervention	Follow up
4	Kaufmann G, 2019, 2020 Austria	N=47 patients with HV MIS chevron osteotomy: n=25 feet (21:4) OC: n=22 feet (19:3)	MIS chevron: 54 years OC: 47 years	RCT	Adults with HV who were scheduled to have distal chevron osteotomy between January 2012 and August 2013. In all, nonoperative treatment had failed before surgery	Percutaneous or MIS chevron osteotomy compared with OC osteotomy	9 months (mean, 67.1 months): 47 feet 5 years: 39 feet
5	Tay A, 2022 Singapore	N=60 patients with symptomatic HV MICA osteotomy group: n=30 (21:9) Open SA osteotomy group: n=30 (26:4)	MICA: mean 51.7 years Open SA osteotomy: mean 52.7 years	Retrospective propensity score matched cohort study	Patients who had primary, unilateral MICA osteotomy for symptomatic HV between 2016 and 2018 for persistent painful bunion with or without metatarsalgia after	MICA osteotomy screw compared with open SA osteotomy (control) Other concomitant procedures were also done in a few cases	24 months

Study no.	First author, date country	Patients and sex (female: male) or gender (women: men) as reported by the study	Age	Study design	Inclusion criteria	Intervention	Follow up
					conservative treatment for at least 3 months		
6	Guo CJ, 2021 China	N=112 feet (99 patients with HV) MIS (POO) group: n=48 feet (41 patients; 45:3) OC osteotomy group: n=64 feet (58 patients; 61:3)	MIS (POO) group: mean 60.9 years OC group: mean 60.6 years	Retrospective cohort study	Patients above 18 years with painful HV and failed conservative treatment; and HV correction had operative treatment via POO or OC osteotomy techniques	Intervention: POO Control: OC osteotomy Akin osteotomy done in 50 (15 in POO and 35 in OC group) Weil osteotomy in 39 (16 in POO and 23 in OC group)	2 years
7	Lewis T, 2023a Australia, 3 centres	N=92 patients with HV deformity (126 feet; 87:5) Included for analysis (n=53, 78 feet [51:2])	Mean age: 60.4 years	Retrospective observational study	People aged over 16 presenting with a painful HV deformity (HVA more than 15 degrees) who had isolated primary third-	PECA by a single surgeon No additional concomitant procedures were done	Mean follow up was 66.8 (range 60 to 88) months

Study no.	First author, date country	Patients and sex (female: male) or gender (women: men) as reported by the study	Age	Study design	Inclusion criteria	Intervention	Follow up
					generation PECA with at least 60 months follow up		
8	Lewis T, 2023b UK 2 centres	N=44 patients with HV deformity (n=47 feet [38:6])	Mean 55.4 years	Prospective case series	People aged 16 and over, who had primary correction of HV, of all radiological severities and congruent and incongruent deformities, with first TMT joint instability or a diagnosis of generalised hyper-mobility, who had additional forefoot procedures	Fourth-generation MIS only in 40% patients 60% had additional concomitant procedures (23 lesser toe proximal and distal interphalangeal joint deformity corrections, 3 bunionette corrections at little toe, 1 K-wire fixation for dislocated second toe, and 1 case of lesser	Mean 1.3 years (range 1.0 to 2.3).

Study no.	First author, date country	Patients and sex (female: male) or gender (women: men) as reported by the study	Age	Study design	Inclusion criteria	Intervention	Follow up
						metatarsal distal osteotomies for metatarsalgia in rheumatoid arthritis)	
9	Lewis T, 2021	N=230 patients (333 feet with HV deformity [214:16]) Mild: HVA 15 to less than 20 degrees and IMA 9 to 14 degrees, 7.8% (n=25) Moderate: HVA 20 to less than 40 degrees and IMA 14 to less than 20 degrees, 65.5% (n=209) Severe: HVA 40 degrees or more and IMA 20 degrees or more, 26.6% (n=85)	Mean age 55 years (range, 23.5 to 84.9 years)	Prospective case series	Patients over 16 who had primary correction of HV (of any deformity severity) were included. Patients who had additional forefoot procedures (such as hammer-toe correction or distal metaphyseal metatarsal osteotomy) were included	Third-generation MICA by a single surgeon 69 patients (138 feet) had bilateral procedures on same day	Mean follow up was 2.5 years (range, 2.0 to 5.5 years)

Study no.	First author, date country	Patients and sex (female: male) or gender (women: men) as reported by the study	Age	Study design	Inclusion criteria	Intervention	Follow up
10	Torrent J, 2021 Spain	N=58 patients MIS SA osteotomy group: n=30 (28:2) Open SA osteotomy group: n=28 (28:2)	MIS SA osteotomy: mean 60.7 years Open SA osteotomy: mean 64.2 years	RCT	Indication of scarf osteotomy as the treatment for HV deformity, failed conservative treatment for at least 6 months	Minimally invasive scarf osteotomy compared with open scarf osteotomy	21 (range, 12 to 38) months
11	Vieira Cardoso D, 2022 Switzerland	N=91 patients MIS Lapidus procedure: N=47 (43:4) Open Lapidus procedure: N=44 (38:6)	MIS group: mean 58 years Open group: mean 62 years	Retrospective cohort study	Patients over 18 who had MIS (between 2018 to 2019) or open first TMT fusion surgical procedure (between 2015 to 2017) to treat moderate to severe HV deformities were reviewed	MIS TMT fusion (Lapidus procedure) compared with open TMT fusion (Lapidus procedure)	MIS group mean 29 (range, 14 to 47) months Open group mean 82 (range, 31 to 82) months

Table 3 Study outcomes

First author, date	Efficacy outcomes	Safety outcomes
Ferreira GF, 2021	**Clinical outcomes** **Pain (assessed using VAS)** **Day 1 after surgery** (2 studies) (PECA [n=54] versus open SA [n=83]), SMD -1.68 points (95% CI -2.09 to -1.27, p<0.01, I^2=87%) **At last clinical visit** (3 studies) (PECA [n=102] versus open SA [n=133]), SMD -0.14 points (95% CI -0.49 to 0.20, p=0.81, I^2=0%) **Function** (assessed using AOFAS score at 6 months) (n=3 studies) PECA [n=102] versus open SA [n=133]), SMD 4.97 points (95% CI 3.55 to 6.39, p=0.14, I^2=48%, **Radiological outcomes** **Difference in HVA** (3 studies) (PECA [n=102] versus open SA [n=133]), SMD -0.80 degrees (95% CI -1.07 to -0.52, p=0.03, I^2=70%) **Difference in IMA** (3 studies) (PECA [n=102] versus open SA [n=133]), SMD -0.53 degrees (95% CI -0.93 to -0.13, p<0.01, I^2=93%)	**Complications** (3 studies) (PECA [n=102] versus open SA [n=133]), RR 1.51 (95% CI 0.80 to 2.86, p=0.36, I^2=3%) PECA group reported complications with the screws, in some cases being necessary to remove them (actual number not reported). In the open SA group, complications included metatarsalgia and wound complications. **Radiation exposure time** (assessed using the mean fluoroscopy duration in seconds; 2 studies). PECA group [n=54] versus open SA group [n=83]). Exposure to radiation was higher in the PECA group (SMD 35.53 seconds, 95% CI 31.75 to 35.31, p<0.01, I^2=87%)
Kaufmann G, 2021 Austria	**Radiographic outcomes** MIS distal chevron osteotomy (1 study) IMA (degrees) • Preoperative=13.3 • 6 weeks=6.2	–

First author, date	Efficacy outcomes	Safety outcomes
	• 12 weeks=6.2 • 9 months=5.9 • Mean 58.9 months=6.1 <u>HVA (degrees)</u> • Preoperative=29.9 • 6 weeks=8.9 • 12 weeks=8.1 • 9 months=7.7 • Mean 58.9 months=8.4 <u>DMAA (degrees)</u> • Preoperative=20.9 • 6 weeks=8.7 • 12 weeks=7.6 • 9 months=5.5 • Mean 58.9 months=6.8 <u>MIS Reverdin-Isham osteotomy</u> <u>IMA (degrees)</u> Mean postoperative IMA=11.6 Three studies reported a correction of 3 degrees and 3 studies less than 3 degrees. In the meta-analysis of 7 studies, mean postoperative IMA was 11.6 degrees.	

First author, date	Efficacy outcomes	Safety outcomes
	Sufficient correction of IMA was not achieved with the MIS Reverdin-Isham osteotomy. MIS distal chevron osteotomy versus MIS Reverdin-Isham osteotomy Radiographic outcomes (HVA, IMA and DMAA) were statistically significantly better with the MIS distal chevron osteotomy than with the MIS Reverdin-Isham osteotomy in mild to moderate HV deformity correction ($p<0.05$). **Clinical outcomes** MIS distal chevron osteotomy (1 study) VAS (0-10) • Preoperative=5.6 • 6 weeks=1.4 • 12 weeks=0.8 • 9 months=0.9 • Mean 58.9 months=0.5 AOFAS (0-100) • Preoperative=64.4 • 6 weeks=84.2 • 12 weeks=90.2 • 9 months=92.2 • Mean 58.9 months=95.3	

First author, date	Efficacy outcomes	Safety outcomes
	ROM of the first MTP joint (degrees) • Preoperative=1.5 • 6 weeks=1.1 • 12 weeks=1.4 • 9 months=1.5 • Mean 58.9 months=1.6 MIS Reverdin-Isham osteotomy Improved AOFAS and VAS scores were seen in studies. ROM was reported in 3 Reverdin-Isham studies and showed a slight reduction. MIS distal chevron osteotomy versus MIS Reverdin-Isham osteotomy Clinical outcomes were comparable with both techniques. **Recurrence (radiographic analysis)** MIS distal chevron osteotomy (in 1 study at 58.9 months follow up) IMA above10 degrees (n=2 feet) HVA above 20 degrees (n=5 feet) Reverdin-Isham osteotomy A significant number of the Reverdin-Isham studies showed radiographic recurrence for IMA and HVA.	

First author, date	Efficacy outcomes	Safety outcomes
Dragosloveanu S, 2022	**Clinical outcomes** **Pain (assessed using VAS), mean (SD)** • Preoperative: MIS osteotomy group=7.6 (1.2), OC osteotomy group=7.1 (1.8); p=0.257 • Discharge: MIS=2.5 (0.8), OC=4.5 (1.4); p<0.001 • 3 weeks: MIS=1.4 (0.5), OC=2.8 (0.9); p<0.001 • 6 weeks: MIS=0.4 (1), OC=2.0 (0.8); p<0.001 • 6 months: MIS=0.2 (0.8), OC=0.8 (0.6); p=0.004 • 12 months: MIS=0.2 (0.6), OC=0.4 (0.7); p=0.285 **Function (AOFAS score), mean (SD)** • Preoperative: MIS=65.7 (3.8), OC=61.4 (4.5); p=0.134 • 6 months: MIS=85.6 (4.1), OC=79.4 (3.6); p=0.125 **Radiological outcomes, mean (SD)** **HVA** • Preoperative: MIS=32.5 (2.5), OC=31.9 (4.3); p=0.553 • 6 months: MIS=9.6 (2.4), OC=9.5 (1.8); p=0.867 • 12 months: MIS=8.8 (3.1), OC=8.9 (2.3); p=0.896 **IMA, mean (SD)** • Preoperative: MIS=15.1 (1.8), OC=15.6 (1.9); p=0.345	**Screw removal** (after 3 months, because of soft tissue irritation, pain caused by screw prominence) • MIS osteotomy group: 12.5% (3/24) • OC osteotomy group: 3.8% (1/26) **Metatarsalgia** after 6 months OC group: 3.8% (1/26) **Average radiological exposure time** MIS group (15.5 [5.6] seconds) versus OC group (1.8 [3.8] seconds) (p<0.001)

First author, date	Efficacy outcomes	Safety outcomes
	• 6 months: MIS=7.9 (1.4), OC group=7.6 (1.1); p=0.401 • 12 months: MIS=7.2 (1.8), OC=6.4 (1.5); p=0.093	
Kaufmann 2019, 2020	**Clinical outcomes** **Pain (assessed by VAS, median)** • Preoperative: MIS osteotomy group=5, OC osteotomy group=6, p=0.829 • 6 weeks: p=0.95 • 12 weeks: MIS group=1, OC group=1, p=0.144 • 9 months: MIS group=1, OC group=0, p=0.744 • 5 years: MIS group=0, OC group=0, p=0.322 **Function (AOFAS score, median)** • Preoperative: MIS group=65, OC group=66.5, p=0.932 • 12 weeks: MIS group=85, OC group=83.5, p=0.237 • 9 months: MIS group=85, OC group=90, p=0.943 • 5 years: MIS group=95, OC group=95, p=0.235 **Radiological outcomes** **IMA** • Preoperative: MIS group=14, OC group=15.15, p=0.201 • 12 weeks: MIS group=7.7, OC group=7.4, p=0.898	**Adverse events** **MIS group:** Screw removal (because of soft tissue irritation and pain by K-wire) 48% (12/25) feet. **OC group:** Screw removal (1 because of local pain and soft tissue irritation and another because of patient wish), 9% (2/22) of feet. Hallux varus n=1

First author, date	Efficacy outcomes	Safety outcomes
	• 9 months: MIS group=6.8, OC group=5.85, p=0.502 • 5 years: MIS group=7.4, OC group=6 **HVA** • Preoperative: MIS group=26.4, OC group=28.25, p=0.957 • 12 weeks: MIS group=8.8, OC group=9.15, p=0.873 • 9 months: MIS group=6.9, OC group=8.5, p=0.839 • 5 years: MIS group=9.8, OC group=10.3, p=0.967 **DMAA** • Preoperative: MIS group=22.5, OC group=24.5, p=0.247 • 12 weeks: MIS group=7.1, OC group=8.2, p=0.322 • 9 months: MIS group=4.1, OC group=5.5, p=0.061 • 5 years: MIS group=5.9, OC group=7.5, p=0.396 **ROM of the first MTP joint** Preoperative p=0.910 • Less than 30 degrees: MIS group=4%, OC group=4.5%	

First author, date	Efficacy outcomes	Safety outcomes
	• 31 to 75 degrees: MIS group=40%, OC group=50% • More than 75 degrees: MIS group=56%, OC group=45.5% 6 weeks follow up p=0.075 • Less than 30 degrees: MIS group=8%, OC group=32% • 31 to 75 degrees: MIS group=88%, OC group=64% • More than 75 degrees: MIS group=4%, OC group=4.5% 12 weeks follow up p=0.653 • Less than 30 degrees: MIS group=0%, OC group=9.1% • 31 to 75 degrees: MIS group=84%, OC group=73% • More than 75 degrees: MIS group=16%, OC group=18% 9-month follow up p=0.910 • Less than 30 degrees: MIS group=0%, OC group=5% • 31 to 75 degrees: MIS group=60%, OC group=67% • More than 75 degrees: MIS group=33%, OC group=35% 5 years follow up p=0.496	

First author, date	Efficacy outcomes	Safety outcomes
	• Less than 30 degrees: MIS group=0%, OC group=0% • 31 to 75 degrees: MIS group=37%, OC group=50% • More than 75 degrees: MIS group=63%, OC group=50% **Patient satisfaction** **9 months** • Very satisfied: MIS group=62.5%, OC group=70%, p=0.736 • Satisfied: MIS group=25%, OC group=15% • Do not know: MIS group=4.2%, OC group=0% • Not satisfied: MIS group=8.3%, OC group=15% **5 years** • Very satisfied: MIS group=89%, OC group=70% • poor satisfaction: n=2 in the OC group, (1 developed partial osteonecrosis of the lateral metatarsal head, and 1 had a recurrence of HV) **Recurrence:** **MIS group** Recurrence of HVA less than 25 degrees, 8% (2/25) **OC group** Recurrence of HVA less than 25 degrees, 9% (2/22) Recurrence of HV with an HVA of more than 30 degrees, n=1	

First author, date	Efficacy outcomes	Safety outcomes
Tay A, 2022	**Clinical outcomes** **Pain (assessed using VAS score), mean (SD)** • Preoperative: MICA group=5.5, open SA group=5.6; p=0.958 • Early post operative: MICA=2.0(2.0), open SA=3.4(2.6); p=0.029 • 6 months: MICA=1.2, open SA group=1.2; p=0.990 • 24 months: MICA=1.1, open SA group=0.5; p=0.290 **Function (assessed using AOFAS, mean)** • Preoperative: MICA=54.3, open SA=53.2; p=0.800 • 6 months: MICA=79.8, open SA=79.3; p=0.920 • 24 months: MICA=83.3, open SA=86.5; p=0.432 **Quality of life** **SF-36 MCS, mean** • Preoperative: MICA=56.8 SD 10.6, open SA=54.8 SD 10.3; p=0.462 • 6 months: MICA=55.3, open SA=55.9; p=0.820 • 24 months: MICA=56.0 SD 10.7, open SA=55.2 SD 11.1; p=0.756 **SF-36 PCS** • Preoperative: MICA=40.9 SD 9.3, open SA=43.9 SD 9.7; p=0.215 • 6 months: MICA=50.5 SD 9.1, open SA=48.9; p=0.550	Open SA osteotomy group Readmission on day 10 for acute myocardial infarction (treated medically) n=1

First author, date	Efficacy outcomes	Safety outcomes
	• 24 months: MICA=50.6 SD 9.1, open SA=51.9 SD 7.1; p=0.538 **Radiological outcomes** **HVA, mean (degrees)** • Preoperative: MICA=23.5, open SA=23.7; p=0.915 • 24 months: MICA=7.7, open SA=9.3; p=0.375 **IMA (degrees)** • Preoperative: MICA=13.5, open SA=13.6; p=0.899 • 24 months: MICA=7.5, open SA=7.8; p=0.134 **Patient satisfaction** • 6 months: MICA=87% (26/30), open SA=73% (22/30), p=0.197 • 24 months: MICA=80% (24/30), open SA=87% (26/30), p=0.488	
Guo CJ, 2021	**Quality of life** **Clinical foot-specific (MOXFQ score), mean (SD)** <u>Walking and standing score</u> • Preoperative: POO group=50.3 (8.59), OC group=49.8 (10.4); p=0.24 • 2 years: POO group=13.5 (7.83), OC group=15.2 (8.08); p=0.23 <u>Social interaction score</u> • Preoperative: POO group=56.9 (10.7), OC group=58.6 (9.22); p=0.41	**Complication rate** POO group 8.3% (4/48) versus OC group 12.5% (8/64), p=0.48 **POO group:** • Screw removal (because of irritation after 3 months), n=1 • Revision surgery (on day 6 because of screw displacement after weight-bearing), n=1 • Paraesthesia of the medial of first metatarsal, n=1

First author, date	Efficacy outcomes	Safety outcomes
	• 2 years: POO group=13.3 (10.9), OC group=17.6 (16.8); p=0.40 Pain score • Preoperative: POO group=51.6 (9.87), OC group=49.8 (10.4); p=0.16 • 2 years: POO group=15.8 (13.3), OC group=22.7 (17.3); p=0.06 **Clinical outcomes** **Function (assessed using AOFAS HMI), mean (SD)** • Preoperative: POO group=46.4 (10.1), OC group=43.7 (15.1); p=0.64 • 1 year: POO group=86.5 (10.7), OC group=88.2 (10.8); p=0.4 • 2 years: POO group=85.2 (13.8), OC group=79.5 (23.7); p=0.66. **Pain (assessed using VAS score), mean (SD)** • Preoperative: POO group=7.63 (1.06), OC group=7.29 (1.42), p=0.07 • 2 weeks: POO group=2.00 (0.98), OC group=5.51 (1.45), p=0.00 • 1 year: POO group=2.00 (0.99), 2.56 (2.88), p=0.53 • 2 years: POO group=1.55 (1.11), 2.56 (2.88), p=0.37 Compared with preoperative scores, both groups showed statistically significant improvement in all the	• Stiffness of the first MTP joint, n=1 **OC group:** • Wound problem, n=1 • Screw irritation, n=2 • Second metatarsalgia, n=2 • Paraesthesia of the medial of first metatarsal, n=1 • Stiffness of the first MTP joint, n=2

First author, date	Efficacy outcomes	Safety outcomes
	domains at 2 year follow up (p<0.001), but no statistically significant difference was noted between the groups. **Radiologic outcomes, mean (SD)** **HVA (degrees)** • Preoperative: POO group=35.9 (10.0), OC group=34.3 (8.85); p=0.38 • 1 year: POO group=12.5 (2.22), OC group=14.1 (6.78); p=0.12 • 2 years: POO group=17.9 (9.31), OC group=14.8 (7.83); p=0.06 **IMA (degrees)** • Preoperative: POO group=13.2 (3.31), OC group=13.7 (2.53); p=0.46 • 1 year: POO group=7.61 (1.63), OC group=6.89 (3.06); p=0.14 • 2 years: POO group=6.94 (1.53), OC group=6.97 (2.95); p=0.95 Compared with preoperative outcomes, both groups demonstrated statistically significant differences in the HVA and IMA at the final follow up (p<0.05)	
Lewis T, 2023a	**Radiological outcomes (n=78 feet)** **IMA, mean degrees (SD)** • Preoperative=12.8 (2.9) • 6 months=5.9 (2.4) • More than 60 months=6.0 (2.6), p<0.001 **HVA, mean degrees (SD)**	**Reoperations** (for removal of prominent screws) 4% (5/126) in patients who had more than 60 months follow up

First author, date	Efficacy outcomes	Safety outcomes
	• Preoperative=28.2 (8.1) • 6 months=6.7 (4.6) • More than 60 months=7.8 (5.1), p<0.001 **Clinical outcomes (n=78 feet), mean (SD)** **Quality of life** **Clinical foot-specific (MOXFQ score) at more than 60 months** • Walking/standing=6.8 (17.7) • Social interaction=11.2 (20.1) • Pain=11.8 (19.6) • Index=10.1 (17.0) **General health-related QoL (EuroQoL-5D-5L: EQ-VAS score)** at ≥60-months=92.0 (10.2) **VAS-pain scores** at ≥60-months=6.3 (14.9) **Recurrence** (HVA more than 15 degrees at final follow-up radiographs)=8% (6/78) Of these, only 1 foot (1.3%) had an HVA more than 20 degrees and 3 of the 6 feet had a severe preoperative deformity (HVA more than 40 degrees). **Patient satisfaction** (at 60 months and over follow up) • 77% reported 'highly satisfied' • 27% reported 'satisfied'	
Lewis T, 2023b	**Clinical outcomes, mean (SD)**	**Complications**

First author, date	Efficacy outcomes	Safety outcomes
	MOXFQ (n=47 feet) (scale from 0 to 100, 0 best possible score) Pain • Preoperative mean=53.7 (23.0) • Postoperative (12 month) mean=15.0 (20.4), p<0.001 Walking and standing • Preoperative mean=53.9 (25.1) • Postoperative (12 month) mean=13.6 (20.5), p<0.001 Social interaction • Preoperative mean=52.1 (22.4) • Postoperative (12 month) mean=9.9 (15.3), p<0.001 Index Preoperative mean=53.4 (21.0) Postoperative (12 month) mean=13.1 (17.5), p<0.001 **EuroQol-5D-5L** (scale from 0 to 100, 100 best possible score) **VAS** • Preoperative mean=69.8 (17.8) • Postoperative (12 month) mean=84.1 (15.0), p<0.001 **Index**	• Superficial infections (treated with antibiotics), n=1 • First metatarsal lateral wall fracture (asymptomatic), n=1 • Prominent screw removal (3 akin, 2 metatarsal), n=5 • Scar revision (because of prominent bone swarf), n=1

First author, date	Efficacy outcomes	Safety outcomes
	• Preoperative mean=0.556 (0.237) • Postoperative (12 month) mean=0.799 (0.233), p<0.001 **VAS pain** (scale 0 to 100, 0 best possible score) • Preoperative mean=45.6 (23.3) • Postoperative (12 month) mean=14.7 (21.0), p<0.001 **Recurrence of deformity** (between 6 week and 6 months HVA increased from 11 to 17 degrees): n=1; no progression between 6 months and 2 years noted. **Radiological outcomes (final follow up at 1.5 years [SD 0.5], n=42 feet), mean (SD)** **HVA (degrees)** • Preoperative 32.7 (8.8) • Final follow up 7.9 (5.0) • Change -24.8 (8.2), p<0.001 **IMA (degrees)** • Preoperative 14.0 (3.6) • Final follow up 4.2 (2.5) • Change -9.8 (3.6), p<0.001 **DMAA (degrees)**	

First author, date	Efficacy outcomes	Safety outcomes
	• Preoperative 18.5 (6.4) • Final follow up 5.6 (3.5) • Change -12.9 (6.1), p<0.001	
Lewis T, 2021	**Clinical outcomes** **PROMs in 87.7% (292/333); (200 patients, 292 feet)** **MOXFQ score, mean (SD)** Walking and standing • Preoperative 38.7 (23.4) • 24 months 6.5 (14.6); change -32.2 (25.5), p<0.001 Social interaction • Preoperative 48.0 (22.3) • 24 months 6.6 (13.5); change -41.3 (24.7), p<0.001 Pain • Preoperative 44.5 (21.0) • 24 months 9.4 (15.8); change -35.1 (23.7), p<0.001 Index • Preoperative 42.8 (19.8) • 24 months 7.4 (13.2); change -35.4 (21.9), p<0.001 EQ-5D-5L Index • Preoperative 0.75 (0.14)	**Adverse events** **Overall adverse-event rate 21.3%** **Grade 3** (needing surgical intervention or unplanned hospital admission) rate 7.8% (• Osteotomy site displacement: bone-screw interface failure (fracture/screw cutout), 1.8% (n=6) • Osteotomy site displacement: delayed union/malunion/non-union, 1.2% (n=4) • Symptomatic prominent screw(s), 2.4% (n=8) • Prominent bone, 1.2% (n=4) • Deep infection needing surgical debridement and washout, 1.2% (n=4) • All-cause screw removal rate, 6.3% (n=21) **Grade 2 (**treatable and no surgical intervention needed) • Additional intraoperative fixation (for example, Kirschner wire, additional screw), 1.8% (n=6) • Symptomatic osteotomy site displacement, 0.3% (n=1) • Symptomatic delayed union, 1.5% (n=5)

First author, date	Efficacy outcomes	Safety outcomes
	• 24 months 0.90 (0.13); change 0.17 (0.16), p<0.001 EQ-VAS • Preoperative 83.5 (14.9) • 24 months 84.2 (16.9); change 0.8 (18.5), p=0.563 VAS-pain • Preoperative 31.4 (22.7) • 24 months 8.4 (16.4); change -22.9 (26.4), p<0.001 **Radiographic outcomes (in 95.8% 222/230 patients, 319/333 feet)** IMA, (degrees), **mean (SD)** • Preoperative 15.3 (3.6) • 6 weeks 5.7 (3.2); mean deformity correction 9.6 (3.8), p<0.001 HVA, degrees, **mean (SD)** • Preoperative 32.9 (10.2) • 6 weeks 8.7 (5.2) (mean deformity correction 24.1 [9.7]), p<0.001 **Recurrence** Symptomatic recurrence of HV deformity 0.9% (n=3)	• Transfer metatarsalgia and sesamoid pain, 0.9% (n=3) • Intraoperative conversion to open surgery, 0.6% (n=2) **Grade 1** (minor complications) • Delayed wound healing, 0.6% (n=2) • Superficial cellulitis (treated with oral antibiotics), 4.5% (n=15) • Transient neurapraxia, 0.9% (n=3) • Flexor hallucis longus tendon injury, 1.5% (n=5)

First author, date	Efficacy outcomes	Safety outcomes
Torrent J, 2021	**Radiological outcomes** **HVA, degrees; mean (range)** • Preoperative: MIS scarf group=32.9 (21 to 48), open scarf group=33.3 (25 to 45); p=0.764 • Final follow up: MIS scarf group=12.7 (4 to 19), open scarf group=10.5 (3 to 19); p=0.08 **IMA, degrees; mean (range)** • Preoperative: MIS scarf group=15.3 (13 to 19), open scarf group=14.7 (11 to 19); p=0.212 • Final follow up: MIS scarf group=7.3 (3 to 12), open scarf group=7.5 (4.5 to 12); p=0.793 **DMAA, degrees; mean (range)** • Preoperative: MIS scarf group=10.7 (1 to 20), open scarf group=10.7 (2 to 21); p=0.991 • Final follow up: MIS scarf group=2.8 (1 to 6), open scarf group=3 (1 to 8); p=0.803 **Clinical outcomes** **Function (assessed by AOFAS), mean** • Preoperative: MIS scarf group=41 (IQR 10), open scarf group=39 (IQR 14) • Final follow up: MIS scarf group=84 (IQR 16), open scarf group=82 (IQR 15) In both groups, there was a statistically significant improvement at follow up compared with preoperative scores (p<0.001). There were no statistically significant differences between groups. **Pain (assessed by VAS scores), mean (range)**	**Complications** **MIS Group:** • Screw removal because of irritation and screw prominence/dorsal protrusion, 3.3% (1/30) • Recurrences of HVA (no revision surgery), 7% (2/30) **Open Group:** Hypertrophic scar formation 7% (2/28) **Radiation exposure, mean** MIS scarf 34 versus open scarf 2.4 mGy/cm^2 (p<0.001)

First author, date	Efficacy outcomes	Safety outcomes
	24 hours: MIS scarf group=2.3 (0 to 7), open scarf group=3.7 (0 to 8); p=0.03 **Mean operative time, minutes** • MIS=16.7 (range 12 to 25) • Open=26.1 (range 21 to 34)	
Vieira Cardoso D, 2022	**Radiographic outcomes** HVA (degrees)**, mean (SD)** • Preoperative: MIS group=34.4 (9.0), open group=37.4 (6.3), p=0.091 • Postoperative: MIS group=14.5 (8.0), open group=11.9 (6.2), p=0.084 IMA (degrees), mean (SD) • Preoperative: MIS group=15.8 (4.6), open group=17.2 (4.9), p=0.141 • Postoperative: MIS group=6.4 (3.2), open group=4.8 (3.6), p=0.034 DMAA (degrees), mean (SD) • Preoperative: MIS group=20.4 (12.7), open group=24.0 (10.5), p=0.131 • Postoperative: MIS group =10.3 (7.7), open group=11.0 (5.3), p=0.187	**Overall complications** 5 in MIS group versus 12 in open group (p=0.42) **Wound healing complications:** 0 in MIS group versus 4 in open group (p=0.051) **Non-union (needed revision):** 0 in MIS group versus 4 in open group (p=0.051) **Neurovascular complications** 3 in MIS group versus 1 in open group (p=0.617) **Deformity recurrence (needed revision)** 2 in MIS group versus 3 in open group (p=0.617) **Hardware-related pain** 8 in the MIS group versus 9 in the open group **Surgery for hardware removal** 6 in the MIS group (at mean 33.5 months), 3 in the open group (at mean 85 months, p=0.487)

Procedure technique

All studies detailed their procedure technique with variations in surgical technique, implants placed and additional surgery. The most common approach used in 6 studies (Dragosloveanu 2022, Kaufmann 2019 and 2021, Guo 2021, Tay 2022, Lewis 2023a) was the third-generation MIS percutaneous distal chevron osteotomy (also known as MICA or PECA techniques). It is an extra-articular metatarsal osteotomy that involves sliding manoeuvre of the first metatarsal head and internal fixation with at least 1 or 2 screws. Different screws were used in studies (such as headless cannulated screws with flat and square ends, and fully threaded MICA screws with a chamfered head design). MICA procedure with a new generation MICA screw was used in 1 of the studies (Tay 2022). Different fixation methods in different zones (such as dorsal-to-plantar) were used in studies. POO was used in 1 study to avoid excessive shortening of the first metatarsal and provide intrinsic stability (Guo 2021).

A fourth-generation MIS surgery with a distal META, combined with 3D reduction manoeuvre and fixed using 2 screws for early weight-bearing and biomechanical stability was used in 1 study (Lewis 2023b).

MIS scarf osteotomy is another third-generation extra-articular osteotomy used in 2 studies (Ferreira 2021, Torrent 2021), in which the osteotomy is fixed with 1 or 2 headless screws introduced through a dorsal percutaneous approach. The procedure was done under a midfoot nerve block and no tourniquet with the use of intraoperative fluoroscopy.

MIS Reverdin-Isham osteotomy is another specific MIS HV correction technique used in 1 study as a comparator (Kaufmann 2021). This procedure involves an intra-articular medial based closing wedge osteotomy of the metatarsal head without addressing the IMA and without any internal fixation.

Two main traditional techniques assessed as comparators in included studies were OC osteotomy and open SA osteotomy. In OC osteotomy, a V-shaped osteotomy was done through a 4 to 5 cm incision. In open SA osteotomy a Z-shaped diaphyseal osteotomy of the first metatarsal was usually done and needs fixation with 2 screws.

Another technique, the Lapidus procedure either as an MIS or open procedure, was reported in 1 study. This involves removing the cartilage from the first TMT joint and the medial cuneiform, correcting the deformity and fusing of the bones by hardware.

In most of the studies, some patients had additional adjunct procedures such as Akin or Weil osteotomy together with HV correction.

Efficacy

Functional improvement

Five studies on MIS techniques (PECA or MICA) compared with open SA or OC osteotomy showed similar functional improvement at follow up, which ranged from 6 months to 5 years.

MICA or PECA compared with OC osteotomy

The RCT of 47 patients reported that the functional AOFAS score improved from baseline for both the MIS and OC osteotomy groups. The median score improved from 65 at baseline to 95 at 5 years in the MIS group, and from 66.5 to 95 in the OC osteotomy group. The difference between the groups was not statistically significant at any of the follow-up intervals (Kaufmann 2019 and 2020).

The retrospective cohort study of 112 feet (99 patients) reported that the AOFAS HMI scores improved significantly in POO and OC osteotomy groups postoperatively ($p<0.001$). There was no statistically significant difference

between the groups at 1 year (86.5 [SD 10.7] for POO and 88.2 [SD 10.8] for OC, p=0.40) and 2 years follow up (85.2 [SD 13.8] for POO and 79.5 [SD 23.7 for OC], p=0.66; Guo 2021).

The systematic review of 3 studies (n=235 feet) comparing PECA with open SA osteotomy reported that the mean difference in the AOFAS score between the groups was small (4.97 points [95% CI 3.55 to 6.39], p=0.14, I^2=48%) at 6 months follow up (Ferreira 2021).

The RCT of 50 patients reported improvements in the AOFAS score for both MIS and OC osteotomy groups. There were no statistically significant differences between the groups, either before surgery (MIS group 65.7 [SD 3.8] compared with OC group 61.4 [SD 4.5]; p=0.134), or at 6-month follow up (MIS group 85.6 [SD 4.1] compared with OC group 79.4 [SD 3.6] p=0.125; Dragosloveanu 2022).

MIS scarf osteotomy compared with open scarf osteotomy

The RCT of 58 patients compared MIS scarf osteotomy (n=30) with open scarf osteotomy (n=28). It reported that in both groups the AOFAS scores showed a significant improvement at final follow up (mean 21 months) compared with preoperative scores (MIS scarf group from 41 to 84 and open scarf group from 39 to 82, p<0.001) without significant differences between groups (Torrent 2021).

Pain improvement

Six studies on MIS techniques (PECA or MICA) compared with open SA or OC osteotomy showed similar improvement in pain at follow up, which ranged from 6 months to more than 5 years.

MICA or PECA compared with OC osteotomy

The RCT of 47 patients reported that VAS pain score improved from baseline for both the MIS and OC osteotomy groups but was not significantly different between the groups at any of the follow-up intervals (6 weeks [p=0.95], 12 weeks

[p=0.14], 9 months [0.74]), and 5 years (p=0.32) follow up (Kaufmann 2019 and 2020).

In the retrospective observational study of 92 patients (126 feet) who had treatment with PECA, an analysis of data in 53 patients (78 feet) reported a mean postoperative VAS pain score (ranging from 0 to 10, where 0 is the best possible score) of 6.3 (SD 14.9) at more than 60-month follow up (Lewis 2023a).

In the prospective case series of 233 patients (333 feet), the quality-of-life PROMs analysed in 200 patients (n=292 feet) reported that the VAS pain score improved from 31.4 (SD 22.7) preoperatively to 8.4 (SD 16.4) at 24-month follow up (p<0.001; Lewis 2021).

The propensity matched cohort study of 60 patients compared MICA with open SA osteotomy. It reported that the first 24-hour postoperative VAS score was significantly lower in the MICA group compared with the open SA group (2.0 [SD 2.0] compared with 3.4 [SD 2.6], p=0.029). But there was no significant difference in clinical or radiological outcomes between the groups at 6 months (p=0.990) and 24 months (p=0.290; Tay 2022).

The retrospective cohort study of 112 feet (99 patients) reported that the VAS scores in the POO group during the follow-up period were 2.00 (SD 0.98) at 2 weeks, 2.00 (SD 0.99) at 1 year and 1.55 (SD 1.11) at 2 years. In the OC group the VAS scores were 5.51 (SD 1.45) at 2 weeks, 2.56 (SD 2.88) at 1 year and 2.56 (SD 2.88) at 2 years. The VAS scores between POO and open groups showed no statistically significant difference at 1-year (p=0.53) and 2-year (0.37) follow up. But the POO group showed statistically significantly lower VAS scores 2 weeks after surgery (p<0.001; Guo 2021).

The RCT of 50 patients found significant improvements in the VAS scores for MIS and OC osteotomy groups. The VAS showed significantly better

postoperative results for the MIS group at discharge (2.5 [SD 0.8] compared with 4.5 [SD 1.4], p<0.001), 3 weeks (1.4 [SD 0.5] compared with 2.8 [SD 0.9], p<0.001), 6 weeks (0.4 [SD 1] compared with 2.0 [SD 0.8], p<0.001), and 6 months (0.2 [SD 0.8] compared with 0.8 [SD 0.6], p=0.004). At 12 months, the pain level was comparable between both groups (0.2 [SD 0.6] compared with 0.4 [SD 0.7], p=0.285; Dragosloveanu 2022).

The systematic review of 3 studies (n=235 feet) compared PECA with open SA osteotomy. It reported that the mean difference in the VAS pain scale (ranging from 1 to 10) between the groups was -1.68 points (95% CI -2.09 to -1.27, p<0.01, I^2=87%; 2 studies) 1 day after surgery. The mean difference at last clinical visit decreased between the groups (SMD -0.14 points, 95% CI -0.49 to 0.20, p=0.81, I^2=0%; 3 studies; Ferreira 2021).

MIS scarf osteotomy compared with open scarf osteotomy

The RCT of 58 patients comparing MIS scarf osteotomy (n=30) with open scarf osteotomy (n=28) reported that the mean postoperative VAS for pain at 24 hours was significantly lower in the MIS scarf group compared with the open scarf group (2.3 compared with 3.6, p=0.03; Torrent 2021).

Range of motion

The RCT of 47 patients reported no significant differences in ROM of the first metatarsophalangeal joint (categorised into 3 classes: less than 30 degrees, 30 to 70 degrees, and more than 75 degrees) between the MIS and OC osteotomy groups at all follow-up periods (6 weeks, p=0.075; 12 weeks, p=0.653; 9 months, p=0.910; and 5 years, p=0.496; Kaufmann 2019 and 2020).

Quality of life

Two studies on MIS techniques (MICA or POO) compared with open SA or OC osteotomy showed similar improvement in quality of life at follow up.

A retrospective cohort study of 112 feet (99 patients) compared POO and OC osteotomy. It reported that the clinical foot-specific postoperative MOXFQ scores in all domains (walking or standing, social interaction and pain) significantly improved in both groups. But there was no significant difference in the improvement of any domain between POO and open groups at 2-year follow up (Guo 2021).

The propensity matched cohort study of 60 patients compared MICA and open SA osteotomy. It reported improvement in both the mean SF-36 PCS scores (from 40.9 [SD 9.3] to 50.6 [SD 9.1], p<0.001) and the mean SF-36 MCS scores (from 56.8 [SD 10.6] to 56.0 [SD 10.7], p<0.001) at 24-month follow up in the MICA group. The scores also improved for the scarf osteotomy group (mean SF-36 PCS from 43.9 [SD 9.7] to 51.9 [SD 7.1], p<0.001; and mean SF-36 MCS from 54.8 [SD 10.3] to 55.2 [SD 11.1], p<0.001). But the scores were not significantly different between the groups (PCS p=0.538, MCS p=0.756; Tay 2022).

In the retrospective observational study of 92 patients (126 feet) who had treatment with PECA, an analysis of data in 53 patients (78 feet) reported that the clinical foot-specific mean MOXFQ index score (where 0 is the best possible score) at more than 60-month follow up was 10.1. The mean general health-related quality of life PROM (assessed using EuroQoL-5D-5L: EQ-VAS, where 100 is the best possible score) at more than 60-month follow up was 92.0 (Lewis 2023).

In the prospective case series of 233 patients (333 feet), the quality-of-life PROMs were analysed in 200 patients (n=292 feet). It reported significant improvement in MOXFQ scores in each domain (reduced from 44.5 [SD 21.0] preoperatively to 9.4 [SD 15.8] at 24 months for pain [p<0.001], from 38.7 [SD 23.4] to 6.5 [SD 14.6] for walking and standing [p<0.001], and from 48.0 [SD

22.3] to 6.6 [SD 13.5] for social interaction [p<0.001]); EQ-5D-5L score improved from preoperative mean 0.75 [SD 0.14] to 0.90 [SD 0.13] at 24 months (p<0.001) with the exception of the EQ-VAS (from preoperative score mean 83.5 [SD 14.9] to 84.2 [SD 16.9] at 24 months, p=0.563; Lewis 2021).

In the prospective case series of 50 patients who had fourth-generation MIS with META there was a significant improvement in all MOXFQ domain scores, with the index domain improving from 53.4 to 13.1 (p<0.001). There was also a statistically significant improvement in general health-related quality of life EQ-5D-5L index and EQ-VAS scores (p<0.001; Lewis 2023).

Patient satisfaction

Two studies on MIS techniques (MICA or POO) compared with open SA or OC osteotomy showed similar patient satisfaction rates at follow up.

In the RCT of 47 patients, patient satisfaction (measured using a scale ranging from very satisfied to not satisfied) was comparable in both MIS and OC osteotomy groups at 9-month follow up (very satisfied: 62.5% compared with 70%, p=0.736). At 5 years, 89% of the patients in the MIS and 70% in the OC osteotomy group were very satisfied. Two patients in OC osteotomy group, reported poor satisfaction. One of these patients had developed partial osteonecrosis of the lateral metatarsal head, and 1 had a recurrence of hallux valgus (Kaufmann 2019 and 2020).

The propensity matched cohort study of 60 patients comparing MICA and open SA osteotomy reported that satisfaction rates were similar at 6 months (MICA group 87% [26/30]) compared with the open SA group 73% [22/30], p=0.197) and 24-month follow up (MICA group 80% [24/30] compared with the open SA group 87% [26/30], p=0.488; Tay 2022).

In the retrospective observational study of 92 patients (126 feet) who had treatment with PECA, an analysis of data in 53 patients (78 feet) reported that at more than 60-month follow up, 77% patients were highly satisfied and 23% patients were satisfied with the procedure (Lewis 2023).

Recurrence

In the RCT of 37 patients comparing MIS chevron osteotomy with OC osteotomy, 8% (2/25) of patients in the MIS group (25) and 9% (2/22) of patients in the OC group had recurrence of hallux valgus with an HVA of less than 25 degrees. One patient in the OC group had recurrence of hallux valgus with an HVA of more than 30 degrees (Kaufmann 2019 and 2020).

The prospective case series of 230 patients (333 feet) reported symptomatic recurrent HV after the procedure in 3 feet (0.9%). Two of these were because of under-correction by the chevron osteotomy and failure of the akin osteotomy screw because of cutout. The third was because of soft tissue stretching over a prolonged time (Lewis 2021).

In the retrospective observational study of 92 patients (126 feet) who had treatment with PECA, an analysis of data in 53 patients (78 feet) reported a radiographic recurrence rate (defined as HVA more than 15 degrees) of 8% (6/78 feet) at more than 60 months follow up. Of these, only 1 foot had an HVA more than 20 degrees and 3 of the 6 feet had a severe preoperative deformity (HVA more than 40 degrees; Lewis 2023).

Recurrences of HVA (no revision surgery) was reported in 7% (2/30) of patients in the MIS scarf osteotomy group in the RCT of 58 patients (Torrent 2021).

In the retrospective cohort study of 91 patients who had TMT Lapidus procedure, deformity recurrence (needing revision) was reported in 2 patients in the MIS group and 3 patients in the open group (p=0.617; Vieira Cardoso 2022).

Hallux joint angle correction

There are normal for X-ray measurements: HVA less than 15 degrees; IMA less than 9 degrees; and DMAA less than 10 degrees.

Nine studies on MIS techniques (MICA/PECA/META) reported statistically significant improvement in HVA, IMA and DMAA from preoperative values at follow up. Six of these studies compared MIS techniques (PECA or MICA) with open SA or OC osteotomy and showed similar radiographic correction.

MICA or PECA compared with OC osteotomy

A systematic review of 3 studies (n=235 feet) compared PECA osteotomy (n=102) with open SA osteotomy (n=133). It reported that the final mean difference in the HVA was 0.80 degrees (95% CI -1.07 to -0.52, p=0.03, I^2=70%) and the mean difference in the IMA was 0.53 (95% CI -0.93 to -0.13, p<0.01, I^2=93%), at the last radiographic evaluation (Ferreira 2021).

A RCT of 50 patients comparing percutaneous MIS chevron osteotomy (n=26) with OC osteotomy (n=26) reported improvements in both groups regarding the IMA and HVA at 12-month follow up. But, it did not find any statistically significant differences between the groups (IMA: 7.2 SD 1.8 compared with 6.4 SD 1.5; p=0.093; HVA: 8.8 SD 3.1 compared with 8.9 SD 2.3; p= 0.896; Dragosloveanu 2022).

A RCT of 47 patients comparing MIS chevron osteotomy (n=25) with OC osteotomy (n=22) reported statistically significant correction of the hallux deformity using both techniques. The IMA improved from 14 to 6.8 degrees in the MIS group and from 15.1 to 5.8 degrees in the OC group. The HVA improved from 26.4 to 6.9 degrees in the MIS group and from 28.3 to 8.5 degrees in the OC group. No statistically significant differences were seen between the groups

at all follow-up periods (6 weeks, 12 weeks, 9 months and at 5 years; Kaufmann 2019 and 2020).

A propensity matched cohort study of 60 patients comparing MICA osteotomy with open SA osteotomy reported that HVA improved from 23.5 to 7.7 degrees postoperatively, and IMA improved from 13.5 to 7.5 degrees postoperatively for the MICA group. For the open SA osteotomy group, HVA improved from 23.7 to 9.3 degrees postoperatively, and IMA improved from 13.6 to 7.8 degrees postoperatively. There was no statistically significant difference between the groups (Tay 2022).

A retrospective cohort study of 112 feet (99 patients) compared percutaneous oblique osteotomy (POO) and OC osteotomy. It reported that the HVA in the POO group reduced from 35.9 SD 10.0 degrees preoperatively to 12.5 SD 2.22 degrees at 1 year ($p<0.05$) and to 17.9 SD 9.31 degrees at 2 years follow up ($p<0.05$). In the OC group, HVA decreased from 34.3 SD 8.85 degrees preoperatively to 14.1 SD 6.78 degrees at 1 year ($p<0.05$) and 14.8 SD 7.83 degrees at 2 years follow up ($p<0.05$). Similar results were reported for IMA at follow-up periods ($p<0.05$). When comparing both groups, HVA (at 1 year, $p=0.12$ and 2 years, $p=0.06$) and IMA (at 1 year, $p=0.14$ and 2 years, $p=0.95$) showed similar results (Guo 2021).

In a retrospective observational study of 92 patients (126 feet) who had treatment with PECA, an analysis of data in 53 patients (78 feet) reported a change in HVA from mean 28.2 degrees preoperatively to 7.8 degrees at more than 60 months follow up (mean change −20.3 SD 7.0; $p<0.001$) and change in the IMA from mean 12.8 degrees preoperatively to 6.0 degrees at more than 60 months follow up (mean change −6.8 SD 3.0, $p<0.001$; Lewis 2023).

In a prospective case series of 233 patients (333 feet), radiographic outcomes analysed in 200 patients (n=319 feet) reported significant reduction in the IMA

(from mean preoperative 15.3 SD 3.6 to 5.7 SD 3.2 degrees at 6 weeks, p<0.001) and HVA (from mean preoperative 32.9 SD 10.2 to 8.7 SD 5.2 at 6 weeks, p<0.001; Lewis 2021).

In a prospective case series of 50 patients who had fourth-generation MIS with META there was a significant improvement in HVA (32.7 to 7.9 degrees, p<0.001), IMA (14.0 to 4.2 degrees, p<0.001) and DMAA (18.5 to 5.6 degrees, p<0.001) at mean follow up of 1.53 SD 0.51 years (Lewis 2023).

MIS scarf osteotomy compared with open scarf osteotomy

A RCT of 58 patients comparing MIS scarf osteotomy (n=30) with open scarf osteotomy (n=28) reported that radiologic measurements were similar in both groups at final follow up (mean 21 months: HVA p=0.08, IMA p=0.79, and DMAA p=0.80) but showed significant improvement from preoperative measures (Torrent 2021).

MIS distal chevron osteotomy compared with MIS Reverdin-Isham osteotomy

A systematic review and meta-analysis comparing MIS distal chevron osteotomy with MIS Reverdin-Isham osteotomy reported that radiographic outcomes were significantly better in the MIS chevron osteotomy group (IMA p<0.05, HVA and DMAA p<0.05; Kaufmann 2021).

MIS Lapidus procedure compared with open Lapidus procedure

A retrospective cohort study of 91 patients comparing first tarsometatarsal (TMT) fusion (Lapidus procedure) using MIS (n=47) and open (n=44) techniques reported that radiographic outcomes (IMA, HVA, DMAA) significantly improved from preoperative measures at postoperative follow up (mean 29 months for MIS and 82 months for open group). When compared between both the groups, the

IMA was significantly lower in the open group (4.8 SD 3.6 degrees compared with 6.4 SD 3.2 degrees, p<0.05; Vieira Cardoso 2022).

Safety

Complications

The systematic review of 3 studies (n=235 feet) comparing PECA with open SA osteotomy reported a higher rate of complications in the PECA group (RR 1.51, 95% CI 0.80 to 2.86, p=0.36, I^2=3%). Complications with the screws were reported in the PECA group, some of which were removed (actual number not reported). Complications in the open SA group included metatarsalgia and wound complications (Ferreira 2021).

The propensity matched cohort study of 60 patients comparing MICA and open SA osteotomy reported that there were no complications in either group. All cases achieved complete fusion of the osteotomy at the last radiological evaluation (Tay 2022).

The retrospective case study of 112 feet (99 patients) reported there was no statistical significance between the POO and OC osteotomy group in terms of complications rates (8.3% [4/48] compared with 12.5% [8/64], p=0.48; Guo 2021).

The prospective case series of 230 patients (n=333 feet) reported an overall complication rate of 21% at 24-month follow up. Grade 3 complications needing intervention or hospital admission were reported in 7.8% (n=26) of patients. These include hardware problems (prominent screws in 8 patients; bone screw interface failure [fracture or screw cutout] in 6 patients); delayed union or malunion, or no union, in 4 patients; prominent bone in 4 patients; deep infection in 4 patients. Grade 2 complications needing no additional intervention or hospital admission were reported in 6% (n=20) of patients. These include additional

intraoperative fixation in 6 patients; intraoperative conversion to open surgery in 2 patients; symptomatic osteotomy site displacement in 1 patient, symptomatic delayed union in 1 patient, transfer metatarsalgia in 3 patients, and recurrence in 3 patients (Lewis 2021).

The RCT of 58 patients comparing MIS scarf osteotomy with open scarf osteotomy reported that there were no major complications in either group (Torrent 2021).

The retrospective study of 91 patients who had first TMT fusion (Lapidus procedure) using MIS or open techniques reported that overall complications were higher in the open group compared with the MIS group, but this was not significantly different (5 in MIS group compared with 12 in the open group, p=0.42; Vieira Cardoso 2022).

Metatarsalgia

In the RCT of 50 patients, metatarsalgia after 6 months was reported in 1 patient in the OC osteotomy group (n=26). Shortening of the first metatarsal during the osteotomy could be the reason for this complication (Dragosloveanu 2022). Two cases of second metatarsalgia were also reported in the OC osteotomy group (64 feet) in the retrospective cohort study of 99 patients (with 112 feet; Guo 2021).

Reoperations and hardware removal

In the RCT if 50 patients, soft tissue irritation and pain caused by screw prominence (needing hardware removal after 3 months) was reported in 13% (3/24) of patients in the MIS osteotomy group compared with 1 patient in the OC osteotomy group (n=26). Authors state that the reason for tissue irritation could be the oblique insertion and slight protrusion of the screw head (Dragosloveanu 2022).

In the RCT of 47 patients, substantial soft-tissue irritation caused by the Kirschner wire needing removal was reported in 64% (16/25) of patients in the MIS group, whereas screw removal was needed in 18% (4/22) of patients in the OC osteotomy group. In response to these results, authors recommended using a cannulated oblique-headed compression screw for fixation during MIS chevron osteotomy (Kaufmann 2019 and 2020). Screw removal because of irritation after 3 months was reported in 1 patient in the POO group (n=41 patients, 48 feet) in the retrospective cohort study of 99 patients (Guo 2021).

In the RCT of 58 patients, screw removal because of irritation and screw prominence or dorsal protrusion was reported in 1 patient in the MIS scarf osteotomy group (n=30; Torrent 2021).

Reoperations for removal of prominent screws were reported in 4% (5/126) of patients at more than 60 months follow up in the retrospective observational study of 92 patients (126 feet) who had treatment with PECA (Lewis 2023a). The all-cause screw-removal rate needing revision was 6.3% (n=21 feet) in the case series of 230 patients (n=333 feet) at 2 years follow up (Lewis 2021).

One patient in the POO group (n=41) had a revision surgery at day 6 because of screw displacement after initial weight-bearing on the first day after surgery in the retrospective cohort study of 99 patients (Guo 2021).

Surgery for hardware removal was reported in 6 patients in the MIS group (at mean 33.5 months) and 3 patients in the open group (at mean 85 months, p=0.487) in the retrospective study of 91 patients who had the TMT Lapidus procedure (Vieira Cardoso 2022).

Wound complications and non-union

Wound healing and non-union rates were higher in the open group compared with the MIS group in the retrospective study of 91 patients who had the TMT

Lapidus procedure (wound healing: 0 in the MIS group compared with 4 in the open group, p=0.051; non-union (needing revision): 0 in MIS group compared with 4 in the open group, p=0.051; Vieira Cardoso 2022).

Exposure to radiation

The systematic review of 3 studies (n=235 feet) compared PECA with open SA osteotomy. It reported that exposure to radiation during the surgical procedure was higher in the PECA group, with a mean of 35.53 seconds (95% CI 31.75 to 35.31, p<0.01, I^2=87%; Ferreira 2021).

The RCT of 50 patients reported that the average radiological screen time was significantly longer for the MIS group (15.5, SD 5.6 seconds) compared with the OC osteotomy group (1.8, SD 3.8 seconds; p<0.001; Dragosloveanu 2022).

The RCT of 58 patients comparing MIS scarf osteotomy with open scarf osteotomy reported that radiation exposure was 14 times higher in the MIS scarf group compared with the open scarf group (mean 34 mGy/cm^2 compared with 2.4 mGy/cm^2, p<0.001; Torrent 2021).

Other events

Other events such as paraesthesia of the medial of first metatarsal (n=1), stiffness of the first MTP joint (n=1), flexor hallucis longus tendon injury (n=5), superficial cellulitis (n=15), delayed wound healing (n=2) and transient neurapraxia (n=3) were reported in the MIS groups in the included studies. Neurovascular complications and hardware-related pain were reported in both the MIS and open technique groups in the retrospective study of 91 patients who had first TMT Lapidus procedure (Vieira Cardoso 2022). One of the patients in the OC osteotomy group had developed partial osteonecrosis of the lateral metatarsal head (Kaufmann 2019 and 2020).

Anecdotal and theoretical adverse events

Expert advice was sought from consultants who have been nominated or ratified by their professional society or royal college. They were asked if they knew of any other adverse events for this procedure that they had heard about (anecdotal), which were not reported in the literature. They were also asked if they thought there were other adverse events that might possibly occur, even if they had never happened (theoretical).

They listed the following anecdotal adverse events:

- patient dissatisfaction because of recurrent deformity.

They listed the following theoretical adverse events:

- avascular necrosis of the metatarsal head
- non-union due to the large corrections
- tendon damage
- complex regional pain syndrome.

Five professional expert questionnaires for this procedure were submitted. Find full details of what the professional experts said about the procedure in the specialist advice questionnaires for this procedure.

Validity and generalisability

- Studies on percutaneous techniques with internal fixation only have been considered in this overview of evidence. Variation in osteotomy techniques, hardware/cutting tools, insertion aids, fixing devices (screws, wires, sutures) were reported as they have been changed with time. Studies compared different MIS procedures to different conventional open surgical procedures. Few small RCTs performed compared different surgical procedures.
- Follow-up in studies ranged from 1 to 5 years.

- In all studies correction was indicated after failure of conservative treatment with progressive deformity.
- Studies included patients with mild (HVA 15 to less than 20 degrees, IMA 9 to 14 degrees), moderate (HVA 20 to less than 40 degrees, IMA 14 to less than 20 degrees) and severe (HVA 40 degrees or more or IMA 20 degrees or more) hallux valgus deformity. Small case series for correction of severe hallux valgus deformity also demonstrated deformity correction and significant improvements in clinical outcomes 3 years following surgery (these studies are included in table 5).
- There is a learning curve with percutaneous hallux valgus surgery. There is some published evidence suggesting that adequate training and experience is required (these studies are in table 5).
- Procedures were done only by consultant trauma and orthopaedic surgeons sub-specialising in foot and ankle surgery.
- Patients who have this procedure should be entered into the national BOFAS Registry via the Adult Foot and Ankle pathway. This dataset collects PROMS on both open and MIS techniques for hallux valgus correction. One specialist adviser stated that 18% (137/766) of procedures logged onto the database were minimally invasive metatarsal osteotomies.

Related NICE guidance

Interventional procedures

- NICE's interventional procedures guidance on Synthetic cartilage implant insertion for first metatarsophalangeal joint osteoarthritis (hallux rigidus) IPG 727 (2022) (Recommendation: special arrangements)
- NICE's interventional procedures guidance on Metatarsophalangeal joint replacement of the hallux IPG 140 (Nov 2005) (Recommendation: normal arrangements)

Professional societies

- British Orthopaedic Association (BOA)
- British Orthopaedic Foot & Ankle Society (BOFAS)
- The Royal College of Podiatry
- British Society of Rheumatology
- The Society of Chiropodists & Podiatrists
- The British Chiropody and Podiatry Association
- Association of Foot and Ankle Physiotherapists & AHPs.

Company engagement

NICE asked companies who manufacture a device potentially relevant to this procedure for information on it. NICE received 1 completed submission. This was considered by the IP team and any relevant points have been taken into consideration when preparing this overview.

References

1. Ferreira GF, Borges VQ, Moraes LVdM et al. (2021) Percutaneous Chevron/Akin (PECA) versus open scarf/Akin (SA) osteotomy treatment for hallux valgus: A systematic review and meta-analysis. PLoS ONE 16(2): e0242496. https://doi.org/10.1371/journal.pone.0242496
2. Kaufmann G, Weiskopf D, Liebensteiner M et al. (2021) Midterm Results Following Minimally Invasive Distal Chevron Osteotomy: Comparison With the Minimally Invasive Reverdin-Isham Osteotomy by Means of Meta-analysis. in vivo 35: 2187-2196.
3. Dragosloveanu S, Popov VM, Cotor DC et al. (2022) Percutaneous Chevron Osteotomy: A Prospective Randomized Controlled Trial. Medicina (Kaunas). 58(3):359.
4. Kaufmann G, Dammerer D, Heyenbrock F et al. (2019) Minimally invasive versus open chevron osteotomy for hallux valgus correction: a randomized controlled trial. Int Orthop. 43(2):343-350.
5. Kaufmann G, Mörtlbauer L, Hofer-Picout P et al. (2020) Five-Year Follow-up of Minimally Invasive Distal Metatarsal Chevron Osteotomy in

Comparison with the Open Technique: A Randomized Controlled Trial. J Bone Joint Surg Am.102 (10):873-879.

6. Tay AYW, Goh GS, Koo K et al. (2021) Third-Generation Minimally Invasive Chevron-Akin Osteotomy for Hallux Valgus Produces Similar Clinical and Radiological Outcomes as Scarf-Akin Osteotomy at 2 Years: A Matched Cohort Study. Foot & Ankle International, 43(3):321-330.
7. Guo CJ, Li CG, Li XC et al. (2021) Hallux Valgus Correction Comparing Percutaneous Oblique Osteotomy and Open Chevron Osteotomy at a 2-year Follow-up. Orthop Surg. 13(5):1546-1555.
8. Lewis TL, Robinson PW, Ray R et al. (2023a) Five-Year Follow-up of Third-Generation Percutaneous Chevron and Akin Osteotomies (PECA) for Hallux Valgus. Foot Ankle Int. 44(2):104-117.
9. Lewis TL, Ray R, Miller G, Gordon DJ. (2021) Third-Generation Minimally Invasive Chevron and Akin Osteotomies (MICA) in Hallux Valgus Surgery: Two-Year Follow-up of 292 Cases. J Bone Joint Surg Am. 7;103 (13):1203-1211.
10. Lewis TL, Lau B, Alkhalfan Y et al. (2023b) Fourth-Generation Minimally Invasive Hallux Valgus Surgery With Metaphyseal Extra-Articular Transverse and Akin Osteotomy (META): 12 Month Clinical and Radiologic Results. Foot Ankle Int. 44 (3):178-191.
11. Torrent J, Baduell A, Vega J et al. (2021) Open vs Minimally Invasive Scarf Osteotomy for Hallux Valgus Correction: A Randomized Controlled Trial. Foot Ankle Int. 42(8):982-993.
12. Vieira Cardoso D, Veljkovic A, Wing K et al. (2022) Cohort Comparison of Radiographic Correction and Complications Between Minimal Invasive and Open Lapidus Procedures for Hallux Valgus. Foot Ankle Int. 43 (10):1277-1284.

Methods

NICE identified studies and reviews relevant to minimally invasive percutaneous surgical techniques with internal fixation for correcting hallux valgus from the medical literature. The following databases were searched between the date they started to 14.02.2024: MEDLINE, EMBASE, Cochrane Library and other databases. Trial registries and the internet were also searched (see the literature search strategy). Relevant published studies identified during consultation or resolution that are published after this date may also be considered for inclusion.

The following inclusion criteria were applied to the abstracts identified by the literature search.

- Publication type: clinical studies were included with emphasis on identifying good quality studies. Abstracts were excluded if they did not report clinical outcomes. Reviews, editorials, and laboratory or animal studies, were also excluded and so were conference abstracts, because of the difficulty of appraising study methodology, unless they reported specific adverse events that not available in the published literature.
- Patients with hallux valgus.
- Intervention or test: minimally invasive percutaneous surgical techniques with internal fixation.
- Outcome: articles were retrieved if the abstract contained information relevant to the safety, efficacy, or both.

If selection criteria could not be determined from the abstracts the full paper was retrieved.

Potentially relevant studies not included in the main evidence summary are listed in the section on other relevant studies.

Find out more about how NICE selects the evidence for the committee.

Table 4 literature search strategy

Databases	Date searched	Version/files
MEDLINE ALL (Ovid)	14/02/2024	1946 to February 13, 2024
EMBASE (Ovid)	14/02/2024	1974 to February 13, 2024
Cochrane Database of Systematic Reviews – CDSR (Cochrane Library)	14/02/2024	Issue 2 of 12, February 2024
Cochrane Central Database of Controlled Trials – CENTRAL (Cochrane Library)	14/02/2024	Issue 2 of 12, February 2024

International HTA database (INAHTA)	14/02/2024	-

Trial sources searched

- Clinicaltrials.gov
- ISRCTN
- WHO International Clinical Trials Registry

Websites searched

- National Institute for Health and Care Excellence (NICE)
- NHS England
- Food and Drug Administration (FDA) - MAUDE database
- Australian Safety and Efficacy Register of New Interventional Procedures – Surgical (ASERNIP – S)
- Australia and New Zealand Horizon Scanning Network (ANZHSN)
- General internet search

The following search strategy was used to identify papers in MEDLINE. A similar strategy was used to identify papers in other databases.

MEDLINE search strategy

The MEDLINE search strategy was translated for use in the other sources.

1 Hallux Valgus/ 4009
2 (Hallux* adj4 (valgus* or abduct*)).tw. 4003
3 (Metatars* adj4 primus* adj4 varus*).tw. 166
4 Bunion/ 215
5 Bunion*.tw. 926
6 (Toe* adj4 (deformit* or malform*)).tw. 946
7 or/1-6 5990
8 Osteotomy/ 33724
9 Osteotom*.tw. 40619
10 8 or 9 51838
11 Percutaneous*.tw. 175328
12 10 and 11 712
13 Surgical Procedures, Minimally Invasive/ 30209
14 (Minimal* adj4 invasive* adj4 (surg* or tech* or procedur* or incision* or correct* or treat* or therap* or method*)).tw. 64155
15 (Bosch adj4 (surg* or tech* or procedur* or incision* or correct* or treat* or therap* or method*)).tw. 77
16 (Minimally adj4 invasive adj4 Chevron adj4 Akin).tw. 39

17 (MICA adj4 (surg* or tech* or procedur* or incision* or correct* or treat* or therap* or method*)).tw. 296
18 (Percutaneous adj4 Chevron adj4 Akin adj4 Osteotom*).tw. 8
19 (PECA adj4 (surg* or tech* or procedur* or incision* or correct* or treat* or therap* or method*)).tw. 40
20 (Metaphyseal adj4 Extra adj4 Articular adj4 Transverse adj4 Akin adj4 Osteotom*).tw. 1
21 (META adj2 (surg* or tech* or procedur* or incision* or correct* or treat* or therap* or method*)).tw. 13566
22 (distal adj4 (metatarsal or chevron) adj4 osteotom*).tw. 473
23 (Minimal adj4 invasive adj4 scarf adj4 osteotom*).tw. 0
24 Arthroscopy/ 28798
25 Arthroscop*.tw. 40197
26 fracture fixation, internal/ 42489
27 "internal fixation".tw. 22804
28 (Osteosynthes* or Osteo synthes*).tw. 13711
29 (SERI adj4 (surg* or tech* or procedur* or incision* or correct* or treat* or therap* or method*)).tw. 37
30 or/12-29 195120
31 7 and 30 883
32 (PROstep or (MICA adj4 implant*)).tw. 11
33 31 or 32 894
34 Animals/ not Humans/ 5162935
35 33 not 34 893
36 limit 35 to ed=20230630-20240229 23
37 limit 35 to dt=20230630-20240229 41

38 36 or 37 47

Other relevant studies

Other potentially relevant studies to the IP overview that were not included in the main evidence summary (tables 2 and 3) are listed in table 5.

Table 5 additional studies identified

Article	Number of patients and follow up	Direction of conclusions	Reason study was not included in main evidence summary
Alimy AR, Polzer H, Ocokoljic A et al. (2023) Does Minimally Invasive Surgery Provide Better Clinical or Radiographic Outcomes Than Open Surgery in the Treatment of Hallux Valgus Deformity? A Systematic Review and Meta-analysis. Clinical orthopaedics and related research. 481, 6, 1143-1155.	Systematic Review and Meta-analysis 7 studies (395 feet), consisting of 6 RCTs and 1prospective comparative study, were included. MIS versus open surgery.	This meta-analysis found that hallux valgus treated with minimally invasive surgery did not result in improved clinical or radiologic outcomes compared with open surgery. Methodologic shortcomings of the studies in this meta-analysis likely inflated the apparent benefits of minimally invasive surgery, such that in reality it may be inferior to the traditional approach.	Includes a variety of techniques, such as the Bosch and SERI osteotomy, mini-SCARF and MICA osteotomy.
Baumann AN, Walley KC, Anastasio AT et al. (2023) Learning curve associated with minimally invasive surgery for hallux valgus: A systematic review. Foot Ankle Surg. 29(8):560-565.	Systematic review (6 studies included).	An average of 35.5 surgeries (range 27 - 40) are needed to reach the plateau phase for MIS for HV. The learning phase of the learning curve of MIS for HV has a significant increase in operating time and fluoroscopy usage but not associated with decreased outcomes or high complication rates.	Learning curve

Balesar VV, Bruin LL, van Liebergen M et al. (2024) MICA procedure vs open chevron osteotomy for hallux valgus correction: A prospective cohort study. Foot Ankle Orthop. 9(1):24730114231224725.	Prospective cohort study N=104 68 patients, (42 patients underwent MICA surgery and 26 patients underwent open chevron osteotomy). Follow-up 1 year.	Both groups showed significant improvement in HVA, IMA, and DMAA at the 1-year follow-up. Our findings show that both clinical and radiologic outcomes of the MICA technique are comparable to the conventional open technique. No significant differences were found in clinical outcomes (VAS, AOFAS, MOXFQ, FFI, and FAOS), complication rate, and operative times.	Larger studies with longer follow-up included in table 2.
Bia A, Guerra-Pinto F, Pereira BS et al. (2018) Percutaneous osteotomies in hallux valgus: a systematic review. J Foot Ankle Surg; 57:123–130.	Systematic review n=18 studies (1534 procedures for percutaneous HV surgery on 1397 patients). 14 were level IV, 2 were level III, and 2 were level II.	Overall, the average angle correction of the HV deformity improved postoperatively. Regarding the complications, although some investigators revealed no major complications, others described deformity recurrence in 7.8%, stiffness of the first metatarsophalangeal joint in 9.8%, malunion in 4% to 8.7%, and infection rates ranging from 1.9% to 14.3%.	Different types of MIS -mainly those with temporary or no fixations were included in the analyses.
Bertolo F, Pautasso A, Cuocolo C et al. (2021). The Endolog technique for moderate to severe hallux valgus treatment: Clinical and radiographic analysis of 194 patients. Foot Ankle Surg. 27(1):46-51. doi: 10.1016/j.fas.2020.02.001. Epub 2020 Feb 5. PMID: 32085948.	Retrospective study 194 feet (144 moderate and 50 severe HV) underwent HV correction using Endolog procedure.	OFAS scores significantly improved from 31.0 points preoperatively to 88.5 at 24 months. Even all radiographic measurements significantly improved during 2 years' follow-up. Only 6 patients experienced complications: 4 cases of HV recurrence and 2	Larger studies with longer follow-up included in table 2.

		cases of intolerance device-related pain.	
Boksh K, Qasim S, Khan K, Tomlinson C, Mangwani J. (2018) A Comparative Study of Mini-Scarf Versus Standard Scarf Osteotomy for Hallux Valgus Correction. J Foot Ankle Surg. 57(5):948-951.	N=37 Prospective non-randomised study 16 mini-scarf versus traditional 21 scarf osteotomy 12 weeks post-operative follow-up.	The medial sesamoid position had improved in all patients, with similar satisfaction between the 2 procedures (p =.43). The results of the present study have shown that the mini-scarf osteotomy for mild to moderate hallux valgus is as effective as the standard approach, with the potential benefit of a smaller scar and less soft tissue disruption.	Higher level evidence included in table 2.
Brogan K, Lindisfarne E, Akehurst H, et al. (2016) Minimally invasive and open distal chevron osteotomy for mild to moderate hallux valgus. Foot Ankle Int; 37:1197–1204.	Retrospective cohort study N=81 feet 49 minimally invasive versus and 32 open distal chevron osteotomies. Follow-up 24 months	Clinical and radiologic postoperative scores in all domains were substantially improved in both groups but there was no statistically significant difference in improvement of any domain between open and MIS groups. There were no significant differences in complications between the two groups.	Larger and higher quality studies included in table 2.
Brogan K, Voller T, Gee C et al. (2014) Third-generation minimally invasive correction of hallux valgus: technique and early outcomes. International Orthopaedics (SICOT) 38:2115–2121.	Case series N=45 feet underwent a third-generation MIS distal chevron osteotomy 6 month follow-up	There were significant improvements in all three domains of the MOXFQ ($p<0.001$) There was also significant improvement in all radiographic parameters ($p<0.001$). Mean HVA decreased from 30.54° to 10.41°, and the mean IMA decreased from 14.55° to 7.11°. Shortening of the first metatarsal had no effect on clinical outcomes. There was a	Higher quality studies included in table 2.

		very low rate of complications.	
Caravelli S, Mosca M, Massimi S et al. (2018) Percutaneous treatment of hallux valgus: What's the evidence? A systematic review. Musculoskelet Surg 102:111–117	Systematic review 4 papers, a total of 464 hallux valgus has been treated with a properly percutaneous distal first metatarsal osteotomy.	There are different aspects that the foot and ankle non-experienced surgeon must consider about percutaneous surgery: limitation of the tools, radio-exposure, lack of direct visual control of the osteotomy and higher costs and patient risk due to surgical time.	Different types of MIS -mainly those with temporary fixations were included in the analyses.
Carvalho P, Viana G, Flora M et al. (2016) Percutaneous hallux valgus treatment: unilaterally or bilaterally. Foot and Ankle Surgery: Official Journal of the European Society of Foot and Ankle Surgeons.;22(4):248-253.	Retrospective case series N= 93 feet (61 patients) with hallux valgus had percutaneous osteotomy. 29 had unilateral and 32 had bilateral surgery. Mean follow-up was 24 to 28 months.	The similar results obtained in both groups suggest that the simultaneous bilateral percutaneous surgery gives equivalent results to the unilateral surgery.	More comprehensive studies included in table 2.
de Carvalho KAM, Baptista AD, de Cesar Netto C, Johnson AH, Dalmau-Pastor M. Minimally Invasive Chevron-Akin for Correction of Moderate and Severe Hallux Valgus Deformities: Clinical and Radiologic Outcomes With a Minimum 2-Year Follow-up. *Foot & Ankle International*. 2022;43(10):1317-1330	Retrospective study including 70 feet with HV operated using the MICA technique. 2 years follow-up.	MICA technique is an effective procedure for correcting moderate to severe HV, with a low rate of recurrence and an acceptable rate of complications. Patients undergoing the surgical procedure in our series showed a significant reduction in radiographic parameters and a significant improvement in clinical scores, maintaining these results over time.	Larger studies included in table 2.

Castellini JLA, Grande Ratti MF, Gonzalez DL. (2022) Clinical and Radiographic Outcomes of Percutaneous Third-Generation Double First Metatarsal Osteotomy Combined With Closing-Wedge Proximal Phalangeal Osteotomy for Moderate and Severe Hallux Valgus. Foot & Ankle International 43(11) 1438–1449	Retrospective case series N= 156 percutaneous double first metatarsal osteotomy (PEDO) and first phalanx osteotomy in 128 patients. median follow-up was 22.6 months.	Clinical and radiographic parameters improved significantly, with a minimum of 12 months of follow-up in moderate and severe hallux valgus. The satisfaction rate was 97% in the total sample. Recurrence rate (HVA ≥20 degrees) was 7.7%. Hallux varus (HVA<0 degrees) occurred in 5.8%, acute osteomyelitis in 1.3%, partial avascular necrosis in 0.6%, screw removal in 0.6%, and reoperation in 1.9%. No non-union was observed.	Higher level evidence included in table 2.
Choi JY, Kim BH. & Suh JS (2021). A prospective study to compare the operative outcomes of minimally invasive proximal and distal chevron metatarsal osteotomy for moderate-to-severe hallux valgus deformity. *International* Orthopaedics (SICOT) 45, 2933–2943.	Prospective cohort study MIS distal chevron metatarsal osteotomy (DCMO, n=23) versus MIS-proximal chevron metatarsal osteotomy (PCMO, n=20) for moderate-to-severe hallux valgus deformity. Follow-up 2 years.	Compared with MIS-DCMO, MIS-PCMO resulted in significantly greater correction of the HVA ($P < 0.001$) and IMA ($P = 0.01$), along with Meary's angle improvement ($P < 0.001$); however, the DMAA worsened ($P = 0.01$). Furthermore, a significantly greater change was found in the relative second metatarsal length in the MIS-DCMO group ($P = 0.01$). No significant between-group differences were noted in the correction of the medial sesamoid position ($P = 0.445$).	More comprehensive studies included in table 2.
Diaz Fernandez R (2019) Use of a percutaneous osteotomy with plate fixation in hallux valgus correction. Foot and ankle surgery: official journal of	Case series N=24 patients with painful hallux valgus deformities	The mean correction achieved improved for AHV from 36.57 to 12.22 °, for IMA from 13.8 to 7.08 and for DMAA from 13.98 to	Larger studies with longer follow-up included in table 2.

the European Society of Foot and Ankle Surgeons. 25 (2),106-112.	had percutaneous osteotomy. Follow-up 6 to 12 weeks.	6.07. Clinically, scores on the AOFAS scale improved from a 45.8 to 91.29 . 2 cases (8.3%) exhibited delayed healing. Plate had to be removed in 3 cases (12.5%).	
Flaherty A, Chen J. (2024) Minimally invasive chevron akin osteotomy for hallux valgus correction. JBJS Essent Surg Tech. 14(1):e22.00021.	Review and technical description	Outcomes following minimally invasive chevron Akin hallux valgus correction have been shown to be equivalent to traditional open correction, with reported recurrence rates of <1% and excellent or good patient satisfaction in >90% of patients.	Review
Frigg A, Zaugg S, Maquieira G, Pellegrino A. (2019) Stiffness and range of motion after minimally invasive chevron-akin and open scarf-akin procedures. Foot Ankle Int. 40(5):515–25.	Prospective cohort (non-randomised, comparative) study N=48 PECA versus 50 open Scarf Akin technique. Follow-up 2 years.	MICA showed no advantages over scarf other than a shorter scar. The observed gain in extension could be related to the increased shortening of the first metatarsal because of the size of the burr.	Study included in systematic review added to table 2.
Kim J, Oh M, Kyeong TH et al. (2024) Radiographic comparison of open and minimally invasive distal chevron metatarsal osteotomy in patients with hallux valgus. J Foot Ankle Surg. S1067-2516(24)00031-0.	Retrospective comparative study n=65 feet with hallux valgus (33 open and 32 MIS distal chevron osteotomy-modified method that added percutaneou	The MIS group showed shorter operation time ($p<0.001$) and hospitalization period ($p=0.034$) than the open surgery group. Radiographic measurements revealed comparable outcomes of MIS compared with open surgery. Additionally, adding percutaneous K-wire fixation during MIS had an advantage in correcting distal	Larger studies with longer follow-up included in table 2.

	s K-wire fixation and headless screws). Follow up 1 year.	metatarsal articular angle compared with open surgery.	
Lu J, Zhao H, Liang X et al. (2020) Comparison of Minimally Invasive and Traditionally Open Surgeries in Correction of Hallux Valgus: A Meta-Analysis. The journal of foot and ankle surgery. 59, 4, 801-806.	Meta-analysis N=11 studies with 1166 patients treated with MIS and 1035 patients treated with traditionally open surgery.	The pooled data (OR 6.28, 95% CI 3.20 to 12.32, Z = 5.35, p <.01) indicated that patients treated with MIS had a significantly higher rate of excellent-good radiographic angular results than did patients treated with open surgery. However, the incidences of complications (OR 0.67, 95% CI 0.24 to 1.91, Z = 0.75, p =.45), recovery time (standard mean difference –3.09, 95% CI –7.98 to 1.80, Z = 1.24, p =.22), and patient-reported satisfaction (OR 2.76, 95% CI 0.72 to 10.65, Z = 1.48, p =.14) were similar between patients with hallux valgus treated with MIS and patients treated with open surgery.	Different types of MIS -mainly those with temporary fixations were included in the analyses.
Fukushi JI, Tanaka H, Nishiyama T et al (2022) Comparison of outcomes of different osteotomy sites for hallux valgus: A systematic review and meta-analysis. Journal of Orthopaedic Surgery 30(2) 1–8.	Systematic review and meta-analysis of RCTs. N=10 studies with a total of 793 feet in the qualitative synthesis.	For the management of mild to moderate HV deformity, we found no significant clinical and radiological differences between patients treated with scarf and chevron osteotomies. Further controlled trials comparing different sites of osteotomies for moderate to severe HV deformity are needed.	Only one RCT with percutaneou s technique included. All other studies are open/mini osteotomies.

Di Giorgio L, Touloupakis G, Simone S et al. (2013) The Endolog system for moderate-to-severe hallux valgus. Journal of Orthopaedic Surgery; 21(1):47-50.	Case series N=25 patients underwent minimally invasive surgery using the Endolog system. Mean follow-up 18.2 months.	The mean hallux valgus angle (HVA), the intermetatarsal angle (IMA), and the proximal articular set angle (PASA) and the mean AOFAS score improved significantly after surgery (all p<0.0001). Periosteal reaction was noted by week 4, and callus formation after 3 months. There were no delayed or non-union or other complications.	Higher quality studies included in table 2.
Harrasser N, Hinterwimmer F, Baumbach SF et al. (2023) The distal metatarsal screw is not always necessary in third-generation MICA: a case-control study. Arch Orthop Trauma Surg.143(8):4633-4639.	Case-control study n=55 MICA procedures (50 patients with hallux valgus deformities) 22 with two screws (MICA2), 33 with one screw (MICA1) 12 months follow-up	Fixation of the first MTH with a single bicortical screw in MICA with moderate lateralization of MTH shows stable anchoring and good clinical results. The routine use of a second metatarsal screw can be omitted.	Variation of the MICA procedure
Herrera-Perez M, De Prado-Serran M, Gutierrez-Morales MJ et al. (2018) Increased rates of delayed union after percutaneous Akin osteotomy. Foot and ankle surgery: official journal of the European Society of Foot and Ankle Surgeons, 24 (5), 411-416.	Case series N=24 had minimally invasive (percutaneous) Akin osteotomy. Mean follow-up 17.6 months.	The average time to fusion in our series was 4.69 months (2–11): 17 of the 26 osteotomies (65.4%) were considered radiographically healed at an average time of 2,94 months (2–5), whereas 9 patients (34.6%) sustained a delayed union and healed at an average of 8 months (7–11).	Larger studies with longer follow-up included in table 2.
Holme TJ, Sivaloganathan SS, Patel B et al. (2020)	Case series	At 12 months, the MOXFQ score improved	Higher quality

Third-Generation Minimally Invasive Chevron Akin Osteotomy for Hallux Valgus. Foot & Ankle International, 41(1) 50–56.	N=40 patients undergoing third-generation MICA Follow up 12 months.	and the AOFAS score improved, with 70% of patients reporting excellent outcomes and 30% good ones. Hallux valgus angles improved from 32 degrees to 12 degrees, and intermetatarsal angles improved from 13 degrees to 7 degrees. There were 4 cases of Akin screw removal for soft tissue irritation. There were no other complications, including recurrence.	studies included in table 2.
Jowett CRJ, Bedi HS. (2017) Preliminary Results and Learning Curve of the Minimally Invasive Chevron Akin Operation for Hallux Valgus. J Foot Ankle Surg. 56(3):445-452.	Case series n=78 consecutive feet underwent minimally invasive Chevron Akin (MICA) for symptomatic hallux valgus. Follow-up mean of 25 (range 18 to 38) months.	The mean AOFAS score improved from 56 preoperatively to 87 postoperatively ($p < 0.001$). The mean hallux valgus and intermetatarsal angles preoperatively were 29.7° and 14.0°. The postoperative angles were 10.3° and 7.6° ($p < 0.001$). The patients were satisfied in 87% of cases (92/106). The incidence of reoperation was 14% (15/106). They display a steep associated learning curve, and the learning curve is comparable to that for open hallux valgus surgery.	Learning curve Higher level evidence included in table 2.
Karry LK-L, Siu-Wah K, Yuen-Hon C. (2015) Percutaneous Chevron Osteotomy in Treating Hallux Valgus: Hong Kong Experience and Mid-Term Results. Journal of Orthopaedics, Trauma and	Case series N= 23 percutaneous chevron osteotomies with screw fixation in 20 patients.	At 18 months, the mean hallux valgus angle (HVA) was corrected from 31.68° to 14.39°, mean intermetatarsal angle (IMA) from 13.77° to 7.98° and mean American Orthopaedic	Higher quality studies included in table 2.

Rehabilitation 19 (1), 25-30.	Follow-up 18 months	Foot and Ankle Society (AOFAS) score from 59.26 to 88.35. There were 4 cases of medial plication stitch impingement and 4 cases with screw impingement but no other complications.	
Lai MC, Rikhraj IS, Woo YL et al. (2018) Clinical and radiological outcomes comparing percutaneous chevron-akin osteotomies vs open scarf-akin osteotomies for hallux valgus. Foot Ankle Int; 39(3):311–7.	Retrospective analysis of prospective data. 29 feet had PECA and 58 feet had open Scarf Akin osteotomies. Follow-up 24 months.	Both groups showed comparable clinical and radiological outcomes at 24 months. The percutaneous group demonstrated less pain and shorter length of operation. there were no complications in percutaneous group, but 3 wound complications were reported in the open group.	Higher quality studies included in table 2. Study included in systematic review added to table 2.
Lee M, Walsh J, Smith MM et al. (2017) Hallux valgus correction comparing percutaneous chevron/Akin (PECA) and open SCARF/Akin osteotomies. Foot Ankle Int; 38:838–846.	Prospective RCT N=50 25percutaneous Chevron/Akin (PECA) versus 25 open SCARF/Akin osteotomies Follow-up 6 months.	Both groups showed significantly improved clinical and radiological results. The PECA group showed significantly lower pain level (visual analogue scale) in the early postoperative phase. No serious complications were observed in either group.	Study included in systematic review added to table 2.
Lewis TL, Robinson PW, Ray R et al. (2023) The Learning Curve of Third-Generation Percutaneous Chevron and Akin Osteotomy (PECA) for Hallux Valgus. The Journal of Foot & Ankle Surgery 62, 162−167.	Retrospective review of the first 58 consecutive PECA cases of a single surgeon.	Technical proficiency was reached after 38 cases. Operation time and radiation exposure significantly decreased after this transition point ($p < .05$). There was no difference in complication rate or radiographic deformity correction	Studies reporting similar outcome included in table 2.

		regardless of position along the learning curve (p >.05). In conclusion, the mean number of cases required to reach technical proficiency in third generation PECA is 38 cases. The complication rate does not correlate to the number of cases performed.	
Lewis TL, Ray R, Robinson P, Dearden PMC, Goff TJ, Watt C, Lam P. Percutaneous Chevron and Akin (PECA) Osteotomies for Severe Hallux Valgus Deformity With Mean 3-Year Follow-up. Foot Ankle Int. 2021 Oct;42(10):1231-1240.	Retrospective review of 50 patients (59 feet) with HVA >40 degrees or IMA >20 degrees had PECA. Mean follow-up 3.1 years.	Mean postoperative MOXFQ index score was 15.1. There was a statistically significant improvement (*P* <.001) in both IMA and HVA after surgery (IMA 17.5-5.1 degrees; HVA 44.1-11.5 degrees). 76.8% reporting they were highly satisfied. The hallux valgus recurrence rate was 7.5%.	Studies with longer follow-up included in table 2.
Lewis TL, Ray R, Gordon DJ. (2022) Minimally invasive surgery for severe hallux valgus in 106 feet. Foot Ankle Surg. 28(4):503-509.	Case series N=106 feet (78 patients) had MICA with screw fixation. Follow-up 2 years	At 2 years follow-up, the MOXFQ score significantly improved for the Pain, Walking and Standing and Social Interaction domains from 39.2 to 7.5, 38.2 to 5.9 and 48.6 to 5.5, respectively (p < 0.001). Pre- and 6 week post-operative radiographic data was available for all 106 feet. Mean IMA improved from 18.2° to 6.3° (p < 0.001) whilst mean HVA improved from 45.3° to 10.9° (p < 0.001). The complication rate was 18.8% and the screw removal rate was 5.6%.	Studies with longer follow-up included in table 2.

Lewis TL, Ray R, Gordon DJ. (2002) Time to maximum clinical improvement following minimally invasive chevron and Akin osteotomies (MICA) in hallux valgus surgery. Foot Ankle Surg. 28(7):928-934.	Case series N=202 feet had third-generation MICA Follow-up 2 years	Most of the PROM improvement with MICA is gained by 6 months post-operatively but further significant improvement can be seen up to 2 years. Those patients who have not improved at 6 months, are likely to do so with time.	Larger studies with longer follow-up included in table 2.
Lim WSR, Rikhraj IS, Koo KOT (2021). Simultaneous bilateral hallux valgus surgery: Percutaneous or conventional? Early results of a matched study from a tertiary institution. Foot Ankle Surg. 27(4):377-380. doi: 10.1016/j.fas.2020.04.014. Epub 2020 May 6. PMID: 32499145	Retrospective case series N=52 feet (26 patients) undergoing bilateral MIS surgery were matched by severity of deformity to 52 feet (26 patients) undergoing simultaneous conventional open surgery.	There were no significant differences in pre-operative function or pain between both groups. Post-operatively, the mean hallux valgus angle (HVA) was significantly lower in the MIS group. (HVA MIS – 8.6; Open – 11.8, *P* = 0.013). There were no significant differences in post-operative outcome and patient satisfaction between both groups.	Larger studies with longer follow-up included in table 2.
Liuni FM, Berni L, Fontanarosa A et al. (2020) Hallux valgus correction with a new percutaneous distal osteotomy: Surgical technique and medium term outcomes. Foot Ankle Surg. 26(1):39-46.	Case series N=58 cases had PBS (Percutaneous Bianchi System) for mild, moderate or severe hallux valgus deformity.	AOFAS scores improved from 28.6 at preoperative assessment to 91.7 at latest follow-up. The VAS pain score improved from 6.7 before surgery to 0.6 at latest follow-up. The mean HVA, IMA, DMAA significatively decreased from the preoperative assessment to the latest follow-up.	Larger studies included in table 2.
Liszka H, Gądek A. (2020) Percutaneous Transosseous Suture Fixation of the Akin Osteotomy and Minimally	103 minimally invasive chevron (MIC) Akin	The minimally invasive chevron osteotomy with transosseous suture stabilization of the Akin osteotomy was a safe	Variation of the procedure.

Invasive Chevron for Correction of Hallux Valgus. Foot Ankle Int. 241(9):1079-1091.	osteotomies, with screw stabilization (group A, n=54), and percutaneous transosseous suture (group B, n=49). Follow-up 1 year	method with good functional results that were comparable to the outcomes achieved when using screw fixation.	
Lucas y, Hernandez J, Golanó P et al. (2016) Treatment of moderate hallux valgus by percutaneous, extra-articular reverse-L chevron (PERC) osteotomy. Bone Joint J; 98-B:365–373.	Prospective case series N=38 patients who underwent 45 extraarticular reverse-L Chevron (PERC) osteotomies. Mean follow-up of 59.1 months (45.9 to 75.2).	The AOFAS score increased from 62.5 (range, 30 to 80) preoperatively to 97.1. There was a statistically significant decrease in the hallux valgus angle and the intermetatarsal angle. With a mean preoperative hallux valgus and intermetatarsal angle of 26 degrees and 11 degrees, respectively, these patients presented mainly mild deformities.	Larger and higher quality studies included in table 2.
Miranda MAM, Martins C, Cortegana IM et al. (2021) Complications on Percutaneous Hallux Valgus Surgery: A Systematic Review. 60, 3, 548-554.	Systematic review 16 studies were included and 1157 procedures reported for percutaneous HV on 1246 patients.	The mean angle correction of HV deformity improved postoperatively. Reported complications vary among the studies. The highest complication rate was joint stiffness in 18.47% of cases, followed by HV recurrence and shortening of M1, both in 15.2%, material intolerance in 10.1%, osteoarthritic changes in 9.1%, infection in 7.6%, and transfer metatarsalgia in 5.4%.	different surgical approaches, and fixation devices used those with temporary fixation or no fixation were also included.

Mizher R, Rajan L, Kim J et al. (2024). Does the presence of asymptomatic flatfoot deformity impact the clinical and radiographic outcomes of the minimally invasive chevron and akin bunionectomy? Foot Ankle Int. 10711007231220553.	Retrospective cohort study N=104 patients had MICA. (42 patients with flatfoot versus 62 with normal arch). Follow-up 1 year.	Study indicates that minimally invasive chevron and Akin bunionectomy leads to improved clinical and radiographic hallux valgus outcomes without impacting radiographic flatfoot parameters. Therefore, the MIS bunionectomy may be an effective option for hallux valgus correction in patients with mild, flatfoot.	Larger studies with longer follow-up included in table 2.
Malagelada F. Minimally invasive surgery for hallux valgus: a systematic review of current surgical techniques. Int Orthop 2018;43:625–637	Systematic review N=23 studies 2279 procedures in 1762 patients	There is some evidence that Chevron and Akin showed the most potential for improvement of the HVA and the Endolog for the IMA. An overall complication rate of 13% was obtained among studies. Randomized controlled trials and long-term follow up are needed to assess the efficacy of MIS techniques.	Different surgical techniques assessed- Bosch, MIS Chevron-Akin, Reverdin-Isham, Endolog system, and techniques involving distal soft tissue release and fixation.
Maffulli N, Longo UG, Marinozzi A et al. (2011) Hallux valgus: effectiveness and safety of minimally invasive surgery. A systematic review. Br Med Bull 97: 149-167.	Systematic review	Given the limitations of the case series, extensive clinical heterogeneity, it is not possible to determine clear recommendations regarding the systematic use of minimally invasive surgery for hallux valgus correction, even though preliminary results are encouraging. Studies of higher levels of evidence, concentrating on large adequately powered	Different MIS techniques were included.

		randomized trials, should be conducted.	
Madi NS, Braunstein J, Fletcher AN et al. (2023) Early outcomes of third-generation minimally invasive chevron–akin (MICA) osteotomy for symptomatic hallux valgus deformity. *Foot & Ankle Specialist*. 0(0) May 26	Case series N=91 feet had MICA for HV deformity. Mean follow-up 6.3 months.	Patients showed significant improvement in VAS and radiographic outcomes at final follow-up, with a mean improvement of 10.70°, 2.39°, and 5.30 mm for the HVA, IMA, and bony foot width, respectively. Two patients required revision surgery for non-union and removal of symptomatic hardware. One patient had a second metatarsal fracture treated nonoperatively.	Larger studies with longer follow-up included in table 2.
Merc, M., Fokter, S.K. & I, I.S. (2023) Learning curve in relation to radiation exposure, procedure duration and complications rate for Minimally Invasive Chevron Akin (MICA) osteotomy. *BMC Musculoskelet Disord* **24**, 575. https://doi.org/10.1186/s12891-023-06706-1	Retrospective study of MICA procedure performed by a single surgeon. N=100	Results demonstrate surgeon's comfort with MICA to minimize operative time and radiation exposure after 30 cases. The plateau is achieved later for complications. Findings impose lag between surgeon feeling comfortable with procedure and a decrease in complications.	Learning curve
Mikhail CM, Markowitz J, Di Lenarda L, Guzman J, Vulcano E. (2022) Clinical and Radiographic Outcomes of Percutaneous Chevron-Akin Osteotomies for the Correction of Hallux Valgus Deformity. Foot Ankle Int. 43(1):32-41.	Retrospective cohort study N=248 patients (274 feet) had minimally invasive chevron-Akin (MICA). Follow-up 12.9 months.	The mean preoperative intermetatarsal angle (IMA) and hallux valgus angle (HVA) were 13.4 and 29.1 degrees, respectively. The postoperative IMA and HVA were 4.9 and 8.9 degrees, respectively. The mean Foot Function Index (FFI) score part A was 92 preoperatively and 43 postoperatively. Patient satisfaction was	Higher level evidence included in table 2.

		91.6%. The mean postoperative 5 mg oxycodone pill consumption was 2.2.	
Marciano G, Ashinsky BG, Mysore N et al. (2024) Fracturing the lateral hinge improves radiographic alignment and does not affect clinical outcomes of the minimally invasive akin osteotomy. Foot Ankle Int. 45(1):52-59.	Cohort study N=98 patients with hallux valgus who underwent first metatarsal osteotomy and percutaneous Akin osteotomy stabilized by permanent, rigid screw fixation. Follow-up 1 year.	In a percutaneous surgical cohort with correction maintained by rigid screw fixation, fracture of the lateral cortex is associated with improved postoperative radiologic alignment without detriment to patient-reported outcomes.	More comprehensive studies included in table 2.
Neufeld SK, Dean D, Hussaini S. (2021) Outcomes and Surgical Strategies of Minimally Invasive Chevron/Akin Procedures. Foot Ankle Int. 42(6):676-688.	Retrospective analysis treating surgeon's first 94 MICA procedures. Average patient follow-up was 11.2 months.	The MICA osteotomy was a safe and reproducible technique, associated with rapid improvement in pain scores, early weightbearing, and significant deformity correction. Complication rates and patient satisfaction scores were similar between the first and second half of patients ($P > .05$), suggesting the learning curve was not a factor.	Similar outcomes reported in studies added to table 2.
Palmanovich E, Ohana N, Atzmon R et al. (2020) MICA: A Learning Curve. The Journal of Foot and Ankle Surgery. 59 (4), 781-783	Case series N= 50 patients using the minimally invasive Chevron and Akin	Results showed that surgery duration decreased from >2 hours in the first cases to a mean of 45 minutes in the third year. This learning curve plateaued by the 21st patient. The number	Larger studies included in table 2.

	procedure over the course of 3 years.	of intraoperative fluoroscopy used decreased substantially over the first 27 surgeries, at which point the learning curve plateaued. In summary, it took about 27 procedures for an inexperienced surgeon to acquire the skill of performing minimally invasive Chevron and Akin osteotomy.	
Palmanovich E, Ohana N, Tavdi A, et al. (2023) A modified minimally invasive osteotomy for hallux valgus enables reduction of malpositioned sesamoid bones. Arch Orthop Trauma Surg. 143(10):6105-6112.	N=53 patients open chevron osteotomy (n = 19), minimally invasive V-shaped osteotomy (n = 18), and a modified straight minimally invasive osteotomy (n = 16). Postoperative follow-up.	When compared to open chevron and V-shaped osteotomies, the modified osteotomy resulted in significantly lower postoperative sesamoid position scores (3.74, 4.61, and 1.44, respectively, P < 0.001). Furthermore, the mean change in postoperative sesamoid position score was greater (p < 0.001).	Modified MIS osteotomy technique Higher level studies included in table 2.
Patnaik S, Jones NJ, Dojode C, et al. (2021). Minimally invasive hallux valgus correction: Is it better than open surgery? Foot (Edinb). 50:101871. doi: 10.1016/j.foot.2021.101871. Epub Oct 22. PMID: 35219131.	Retrospective case series N=54 27 MIS or 27 open chevron osteotomy for hallux valgus correction Mean follow-up 25.9 months.	Results show MIS chevron osteotomy provides better radiographic correction of the IM angle but functional outcomes for all parameters were comparable to the open technique. It can therefore be considered at least equivalent to standard open surgery when compared using	Larger studies with longer follow-up included in table 2.

		validated Patient Reported Outcome Measures (PROMs).	
Redfern, D (2020). Minimally Invasive Chevron Akin (MICA) for correction of hallux valgus. Techniques in Foot & Ankle Surgery 19(3):p 132-141.	Review	MICA technique continues to gain in popularity among surgeons worldwide as a reliable technique for the surgical treatment of hallux valgus. This article provides an update of surgical techniques as described by the originators and review of current literature on the topic.	General review
Siddiqui NA, Mayer BE, Fink JN. (2021) Short-Term, Retrospective Radiographic Evaluation Comparing Pre- and Postoperative Measurements in the Chevron and Minimally Invasive Distal Metatarsal Osteotomy for Hallux Valgus Correction. The Journal of Foot & Ankle Surgery, 60 (6), 1144−1148.	Retrospective radiographic review of chevron (n=30) and MIDMO (n=31) osteotomies Mean follow-up was 26.6 months for chevron and 18.7 months for MIDMO osteotomies.	Postsurgical retrospective radiographic review demonstrated chevron and MIDMO procedures provide comparable radiographic correction of IMA, HAA, and TSP.	Higher quality studies included in table 2.
Slullitel G, López V, Álvarez V et al. (2022) Refined Minimally Invasive Distal First Metatarsal Osteotomy for Moderate Hallux Valgus Treatment: The BC Procedure. J Foot Ankle Surg.61(5):1052-1055	Prospective case series N= 63 patients who underwent the modified distal metatarsal osteotomy (DMO) BC technique for mild and moderate	The mean AOFAS score improved from a median of 47.4 points preoperatively to a median of 88 points postoperatively ($p < .05$). First MTPJ ROM did not change from preoperative period (mean 32.5°) to the postoperative period (mean 31.8°) ($p > .65$). All osteotomies went on to bony healing in the 6-week follow-up visit. Fifty-	Higher level evidence included in table 2.

	hallux valgus. Mean follow-up was 36.5 (range 23.4-59.8) months.	two (82%) of patients were either very satisfied or satisfied with the procedure (p <.05).	
Singh MS, Khurana A, Kapoor D, et al. (2020) Minimally invasive vs open distal metatarsal osteotomy for hallux valgus - A systematic review and meta-analysis. J Clin Orthop Trauma. 11(3):348-356.	Systematic review and meta-analysis. N= 9 studies were included.	Most available studies are either randomized control trials, or prospective cohort studies providing good level of evidence. Radiological analysis showed similar correction with both MIS and open osteotomies. In functional analysis results were different with open techniques providing better results in terms of AOFAS score. (p < 0.0001). VAS score and complication rate were similar in both groups.	Different MIS techniques were included in the analysis (Bosch, SERI/Kramer, mini scarf, percutaneous Chevron +Akin)
Tan CY, Thevendran G. Perspectives and trends for minimally invasive surgery for hallux valgus deformity in the Asia Pacific region. J Orthop Surg (Hong Kong). 2023 May-Aug;31(2):10225536231180332.	Survey in 11 countries	MIS hallux valgus surgery is gaining popularity in the Asia Pacific region, with surgeons adopting this practice. MIS surgery is still not the most popular alternative and shows that surgeons are still circumspect when it comes to MIS surgery.	Survey
Toepfer A, Strässle M. (2022) 3rd generation MICA with the "K-wires-first technique" - a step-by-step instruction and preliminary results. BMC Musculoskelet Disord. 18;23(1):66.	Case series N=50 consecutive MICAs in 47 patients were performed with the K-wires-first technique.	There was one intraoperative conversion to an open surgical bunion correction corresponding to a 2% conversion rate respectively (1/50). On 3 feet (2 patients), removal of the Chevron screws was performed after 7, 9, and 12 months due to	Modified MICA technique

	12 months follow-up.	prominent and disturbing screw heads at the level of the medial cortex, accounting for a revision rate of 6% (3/50). The IMA decreased after MICA by a mean of 10.8° from 16.2° to 5.4° and the HVA by a mean of 22.1° from 30.6° to 8.5°, demonstrating MICA's high potential for correction.	
Toepfer A, Strassle M. (2022) The percutaneous learning curve of 3rd generation minimally-invasive Chevron and Akin osteotomy (MICA). Foot and Ankle Surgery 28 1389–1398.	Case series N= first 50 consecutive MICA procedures with the "K-wires-First technique".	Although the learning curve of 3rd generation MICA is flat and requires specific training and intensive practice, the rate of complications is not elevated compared to other percutaneous hallux valgus techniques. The learning curve showed a continuous improvement regarding surgery time and use of fluoroscopy. After 40 procedures, the surgery time consistently dropped under 45 min and required less than 100 fluoro-shots. The modified surgical technique may help reduce Chevron screw mal-positioning when using large C-arm fluoroscopy for this procedure.	Learning curve Studies reporting similar outcomes included in table 2.
Trnka HJ, Krenn S and Schuh R. (2013) Minimally invasive hallux valgus surgery: a critical review of the evidence. Int Orthop 37(9): 1731- 1735.	Systematic review N=21 papers (1750 patients).	The majority of papers are level IV studies. Reported complications seem to be less than one may see in one's own clinical practice. This possible bias may be related to the fact that	Different MIS techniques were included in the analysis.

		most studies are published by centres performing primarily minimally invasive hallux valgus surgery.	
Trnka HJ, (2021) Percutaneous, MIS and open hallux valgus surgery. EFORT Open Rev;6:432-438.	Review	Review distinguishes the first, second and third generation minimal incision surgery techniques and reports that minimally invasive and percutaneous hallux valgus correction lead to similar clinical and radiological results as the open chevron or SCARF osteotomies. Third generation minimally invasive Chevron osteotomies present similar clinical and radiological outcomes. Training is vital to avoid unnecessary complications and to minimize the surgeon's learning curve.	Review
Vernois J, Redfern DJ.(2016) Percutaneous surgery for severe hallux valgus. Foot Ankle Clin; 21:479–493.	Case series N=100 feet treated with a percutaneous Chevron osteotomy.	Radiological analysis revealed a correction of the intermetatarsal angle from 14.5° to 5.5° at the last follow-up. The mean hallux valgus angle was corrected from 33.7° preoperatively to 7.3° at the last follow-up. Patient-reported satisfaction rate was 95% good/excellent results.	Higher level evidence included in table 2.
Xu, Y., Guo, Cj., Li, Xc. *et al.* (2022) Radiographic and clinical outcomes of minimally invasive surgery versus open osteotomies for the correction of hallux valgus. *International*	Retrospective comparative study. N=27 patients (31 feet) had	Although open osteotomies were superior than MIS in HVA and IMA, MIS showed advantages in correcting DMAA. MIS provided equivalent functional	Larger studies included in table 2.

Orthopaedics (SICOT) **46**, 1767–1774.	MIS for hallux valgus. 30 patients (31 feet) had open osteotomies. Mean follow-up 25 to 26.1 months.	outcomes compared to open surgery.	
Yousaf A, Saleem J, Al-Hilfi L et al. (2023) Third-Generation Minimally Invasive Chevron Akin Osteotomy for Hallux Valgus: Three-Year Outcomes. Indian Journal of Orthopaedics. 57:1105–1111	Cohort study N=33 patients underwent third-generation MICA surgery. Follow-up 3 years.	Third-generation MICA demonstrates promising patient satisfaction scores post-operatively, and we have shown these improvements are sustained over a minimum three-year follow-up period.	Higher quality studies included in table 2.
Yoon YK, Tang ZH, Shim DW et al. (2023) Minimally Invasive Transverse Distal Metatarsal Osteotomy (MITO) for hallux valgus correction: early outcomes of mild to moderate vs severe deformities. Foot Ankle Int. 44(10):992-1002.	Retrospective comparative study N=116 patients had minimally invasive distal metatarsal transverse osteotomy (MITO). Follow-up median 29 months.	This study showed that short-term radiographic results for patients with either mild to moderate or severe HV treated with MITO were favourable. Overall clinical outcomes were comparable to those of conventional treatments. In this series, we found MITO with screw fixation to be a satisfactory surgical option for patients with mild to severe HV deformities.	More comprehensive studies included in table 2.