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REVIEW

Efficacy of Minimally Invasive Surgical Techniques on Hallux Valgus: A Systematic Review

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ABSTRACT

INTRODUCTION: Hallux valgus is a deformity of the first ray and is one of the most common foot deformities that requires surgery. More than 130 procedures have been described in the literature, all with varying degrees of success. Most of these procedures are performed by open incision. However, the evolution of minimal incision surgery has led to some of these procedures being performed minimally invasively, with no definitive consensus on which technique is more effective. The aim of this study was to systematically search the literature in order to evaluate the efficacy of minimally invasive surgery (MIS) for hallux valgus with respect to surgical outcomes and patient reported outcomes.

METHODS: Medline Complete, PubMed, Cochrane Library, Scopus, SAGE Journals and gray literature were searched. All studies published in English documenting surgical outcomes and patient reported outcomes were included.

RESULTS: The literature search identified 2,558 abstracts which were screened for eligibility and 30 papers were identified as meeting the inclusion criteria. A total of 1,979 patients were treated over all included studies. The surgical outcome measures reported by most papers included hallux valgus angle, distal metatarsal articular angle, and intermetatarsal articular angle. Patient reported outcome measures reported included the American Orthopaedic Foot and Ankle Society Score, pain on a visual analogue scale and subjective patient satisfaction. All complications reported were extracted. Follow up times ranged from 5 months to 10 years, with most papers reporting 12-24 months.

CONCLUSION: This review demonstrates the wide variety of procedures for hallux valgus. Overall, there is no sufficient data to suggest that one minimally invasive procedure is superior to another. We note that a larger number of studies reporting MICA and Reverdin-Isham procedures were present in the literature and the higher complication rate in the Reverdin-Isham compared to MICA. More controlled trials are necessary to further explore patient preference with each procedure, in particular with regard to longer term patient reported outcomes.

Key words: Hallux Valgus; Minimally Invasive Surgery; MIS; Minimally invasive; Hallux Valgus Surgery; Surgical Techniques

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INTRODUCTION

Hallux valgus(HV) is a deformity of the first ray and is one of the most common foot deformities that requires surgery[1]. More than 130 procedures have been described in the literature, all with varying degrees of success[1,2]. Most of these procedures are performed by

open incision[1]. However, the evolution of minimal incision surgery has led to some of these procedures being performed minimally invasively, with no definitive consensus on which technique is more effective[1,3]. A systematic review conducted in 2018 on various minimally invasive surgical techniques indicated potential for three techniques namely Chevron, Akin and Endolog[3]. However, despite these promising results there remains a 13% reported complication rate, without appropriate long term follow up randomised controlled trials[3]. Pain, stiffness, and slow recovery are but a few of the complications that have been reported in up to 15% of patients undergoing open techniques[1]. In comparison, a Cochrane systematic review published in 1999 highlighted that there was no superiority between interventions with regard to open techniques[4]. The excess of surgical techniques highlights that there is no consensus in whether a minimally invasive approach or an open approach is more effective and which of the techniques provides optimum patient outcomes.

What do we know?

There is growing trend for minimally invasive approaches for hallux valgus surgery because of the hypothesized shorter procedure time, reduced scaring and faster recovery time.

What we don't know?

The efficacy for MIS with regard to recovery in the short and long term and the effects on foot/gait biomechanics. Short term results of mostly case series and retrospective studies are available but there is a paucity of evidence with regard to the longer term results.

Percutaneous surgery for the foot and ankle was founded by Stephan Isham in the United States in the 1990s[5]. This subsequently formed a trend for minimally invasive techniques that were promoting smaller scars, less postoperative pain, quicker recovery, decreased time for rehabilitation and reduced risk of infection and wound complications[1,5]. The first generation was thus formed as described by Reverdin/Isham[5]. This technique was a percutaneous extra-articular oblique medial closing wedge osteotomy of the first meta-tarsal head with no further fixation. The second generation Bosch osteotomy was developed to provide more stability and involved a distal transverse osteotomy of the 1st metatarsal stabilized with axial K-wire. However, whilst there were many advocates for this technique many abandoned it due reports of malunion in 61-69% of patients[6]. The complications attributed to both first and second generation techniques were in part due to the lack of fixation which in turn led to the development of the third generation of minimally invasive hallux valgus surgery by Vernois and Redfern, the Minimally Invasive Chevron Akin (MICA) or Percutaneous Chevron Akin osteotomy (PECA). The technique uses a stable method to fixate the distal fragment with one or two screws. Studies have reported no difference with these later MICA/PECA techniques when compared with open approaches[6-9].

A recent Australian study looking at surgeon preference for Hallux Valgus showed a distinct association between choice of procedure and the age of the surgeon, where older surgeons tended to prefer chevron osteotomies and Australian Orthopaedic Foot and Ankle Surgeons were more likely to use scarf osteotomies. The Scarf osteotomy was the preferred procedure for mod-severe HV in more than 50% of the 454 responding surgeons[1,2]. Historically, distal metatarsal osteotomies were reserved for mild-moderate HV, while moderate to severe cases were treated with either proximal osteotomies or metatarso-cuniform arthrodesis combined with other soft tissue procedures[10].

Aim / Hypothesis

The aim of this study was to systematically search the literature in order to evaluate the efficacy of minimally invasive surgery (MIS) techniques for hallux valgus with respect to surgical outcomes and patient reported outcomes. We hypothesised that there is no difference between different MIS techniques with regard to short or long term outcomes.

METHODS

The preferred reporting items for systematic reviews and meta-analyses 2009-2020 (PRISMA) statement was used as a reporting guideline for this study[11,122]. This systematic review was registered with PROSPERO CRD42020203373 Available from: https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42020203373

PICO Research question (PICO)

Research question: "What is the efficacy of Minimally Invasive Surgery techniques for the correction of Hallux Valgus?"-an update of the most current literature.

Table 1 PICO.

Patient/Problem	Adults/Juvenile, Women/Men, Hallux Valgus Deformity, Bunion
Intervention	Minimally Invasive Surgical techniques for Hallux Valgus: Chevron, Scarf/Akin, Basal (Ludloff), Riverdin-Isham, percutaneous, bosch, cresenteric, broomstick osteotomies, Lapidus, bunionectomy
Comparison	Open conventional techniques
Outcome	Primary Outcomes: Hallux Valgus Angle (HVA), Intermetatarsal Angle (IMA), Distal Metatarsal Articular Angle (DMAA)
	Secondary Outcomes: Pain VAS Score, American Foot and Ankle Score (AOFAS), Complications, Satisfaction, Post-op protocol.

Eligibility Criteria for Studies

The inclusion and exclusion criteria were created by discussion among the authors based on the most resent techniques identified in a scoping literature review. It included locating articles from the Cochrane Library, Medline complete, Scopus, SAGE journals and Pubmed as well as Gray Literature. Articles were grouped for synthesis based on procedure type and severity of disease. The last search was run on June 1, 2020 and we considered studies published within the last 10 years in the English language.

Search Strategy

The search strategy consisted of six phases. Firstly, relevant medical databases were chosen for the study and they included: Medline Complete, PubMed, Cochrane Library, Scopus, SAGE Journals and gray literature. Phase two of the search strategy was to develop search terms as MeSH headings and substituted keywords were used if no relevant MeSH headings were identified. In phase three, a librarian expert opinion was sought on the developed MeSH and keyword search nouns. Phase four was to complete the search in all remaining data bases, and upload all included studies into Zotero[13]. This was performed on 01/06/2020 with limits from 2010 until 2020. Due to the steep learning curve and recent advances in surgical techniques we limited our search to 10 years. Phase five, included recording the number of hits returned and to save the study search. Finally phase six, involved removing all duplicates and recording the total number of articles retrieved based on title/abstract. Search terms included: ("Hallux" OR "Hallux Valgus" OR "Metatarsus

Table 2 Eligibility Criteria.

Studies	Participants	Interventions	Comparisons	Outcomes
INCLUSION CRITERIA				
Observational studies; Peer reviewed; Journals; Years: 2010 to present; Language: Published in English, full text available in English.	Adults/Juvenile, Women/Men, Hallux Valgus Deformity	Minimally Invasive Surgical techniques for Hallux Valgus: Chevron, Scarf/Akin, Riverdin-Isham, lapidus, bunionectomy, percutaneous, cheilectomy. Endoscopic/arthroscopic procedure Bosch osteotomy, cresenteric, broomstick osteotomies, Basal (Ludloff) osteotomy, Concurrent procedures. E.g multiple metatarsal osteotomies.	Comparative open techniques	**Primary Outcomes:** Hallux Valgus Angle (HVA) pre-postoperatively; Intermetatarsal Angle (IMA) pre-postoperatively; Distal Metatarsal Articular Angle (DMAA) **Patient Reported Outcomes:** Outcome measures E.g. SF-36 / Foot Function Index / American Orthopaedic Foot and Ankle Score (AOFAS) / Pain – Visual Analogue Scale (VAS); Secondary Outcomes: Complications (Any infection), Satisfaction, Stiffness, Surgery Duration, Irradiation (Exposure during surgery), Cost, Length of stay, Intraoperative blood loss, Time till ambulation
EXCLUSION CRITERIA				
Qualitative Studies, Non-peer reviewed, Narrative Reviews, conference proceesings Editorials, letters, guidelines, Cadaveric studies	Re-do surgeries, Hallux Rigidus or Hallux limitus as primary procedure/ diagnosis; Patients with primary diagnosis as Diabetes Mellitus, Rheumatoid Arthritis or Arthritis at the MTP joint.	Arthrodesis		Subjective reporting; Results other than quantitative.

Varus" OR "Bunion") AND ("minimally invasive" OR "Minimally Invasive Surgical Procedures" OR arthroscop* OR endoscop* OR keyhole OR osteotom* OR percutaneous) AND (Chevron OR "akin osteotomy" OR scarf OR "basal osteotomy" OR ludloff OR "Reverdin-Isham" OR Lapidus OR Bunionectomy OR Cheilectomy or Bosch). The exact search terms and respective databases can be found in our online supplementary material: https://www.crd.york.ac.uk/PROSPEROFILES/203373_STRATEGY_20200821.pdf

Figure 1 below outlines the flow chart of included studies.

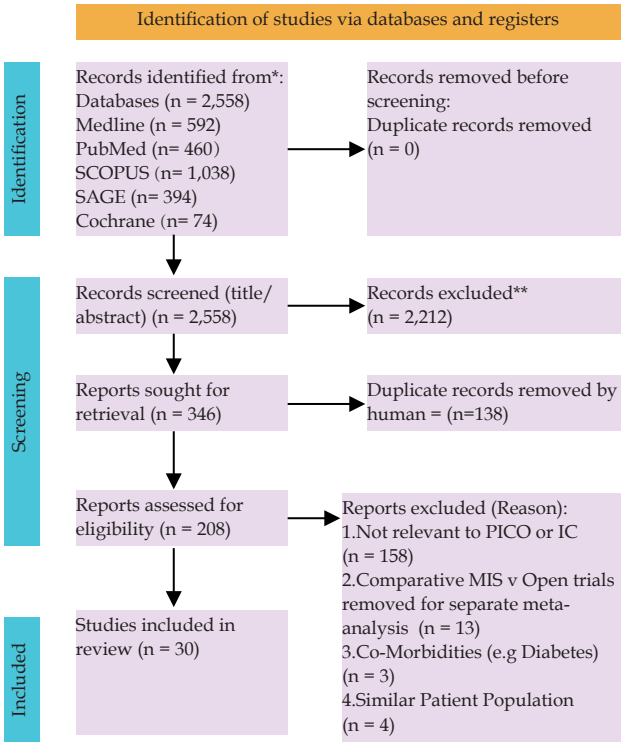

Figure 1 Flow-chart showing the flow of studies through the review[5,7,23–32,9,33-40,16-22].

Selection of the literature

Selection of the literature was performed by systematically searching each database and was first based on title/abstract alone. In order to minimize bias a second independent assessor performed the same search in order to identify any non-relevant or relevant articles by applying the eligibility criteria. Where any discrepancy arose the opinion of an expert was sought. Articles not addressing any of the PICO search terms were excluded. Once all abstracts were retrieved, the full texts were downloaded via Open Athens platform which is provided by the European University Cyprus, School of Medicine. All full texts were then further assessed and any not meeting the inclusion criteria (Table 2) were excluded and a reason was recorded for their exclusion. If full texts were unable to be located, where possible authors were contacted via email, such as with conference proceedings. If any systematic reviews on the same topic arose, they were screened for any additional papers not found in the initial search. These PEARLED articles comprised the gray literature.

Each full text paper downloaded was coded based on their unique Digital Objective Identifier(DOI) or PubMed Identifier and put into a Microsoft excel document with the aforementioned PICO format to ensure suitability and to ensure the study met the inclusion criteria. This process allowed the researcher to have a better overview of the studies which exist in the literature. This process led to further studies being excluded.

Data extraction

Raw data from each included paper was extracted and placed into a Microsoft Excel spreadsheet. Where possible all data provided by each paper was input in order for the reviewer to better appreciate the outcomes assessed by each of the included study's authors. This led to new secondary outcomes being discovered. Both randomized controlled trials, observational studies and non-randomised studies were considered. Synthesis of evidence was applied if at least 2 randomized controlled trials are identified. If less than 4 randomized trials were available, cohort studies were considered, if these applied measures to eliminate confounding bias (e.g. Cox regression analyses, matching).

The prespecified outcomes were both surgical (hallux valgus angle, distal meta-tarsal articular angle and intermetatarsal angle & complications) and patient reported (AOFAS score, VAS, SF-36 & satisfaction). We extracted outcomes for all reported follow up times which ranged from 1 day to 10 years. For the primary analysis on surgical and patient reported outcomes we used final follow up times ranging from 1-10 years. For Secondary analysis patient satisfaction was extracted where possible using a four point scale from Very-satisfied, Satisfied, Not-satisfied & Dissatisfied.

Where possible mean and standard deviations were extracted or estimated from confidence intervals, the P values, or the interquartile range using methods described in the Cochrane Handbook for Systematic Reviews[14]. We extracted all adverse effects/reports and complications for each study without any predefined limits, allowing all patient reported outcomes to be identified. In order for accuracy and detail data extraction was performed by a second independent reviewer, where any discrepancy that arose errors could be rectified.

Data Analysis

Analysis was performed using Microsoft Excel. Where possible mean difference and standard deviations were input as primary outcomes, as well as post operative means and standard deviations. Heterogeneity was assumed based on the variations surgeon technique type and severity of hallux valgus. For this reason subgroup analysis was performed. No formal Higgins's I^2 Heterogeneity statistic was calculated as no meta-analysis was performed[14]. Due to the fact there is a vast array of procedures historically used for Hallux Valgus correction and even though there are negligible differences in how the procedures are performed, we decided to perform subgroup analysis and stratify outcomes based on procedure type and severity of hallux valgus. Pooled estimates were also considered if no particular paper skewed the data in any direction. Additionally, we decided to change our exclusion criteria to exclude Endolog, SERI & Bosch techniques as a recent systematic review was found reporting these techniques[15].

Critical appraisal

Following the search of each data base and full text paper retrieval, critical appraisal and data extraction into a Microsoft excel document was performed. The method for appraising the literature using Critical Appraisal Tools (CATs) was by 2 independent assessors. The reviewers completed the CATs and in person discussed the findings where if any disagreement or discrepancy occurred advice of a third person was sought. The following Critical Appraisal Tools were utilised to appraise each full text paper: Cochrane RoB-2 for randomized clinical trials & ROBINS-I For observational studies. The CATs used are those recommended by the Cochrane Collaboration. This study will not only focus on RCTs, but also observational studies and Non-randomised controlled trials to

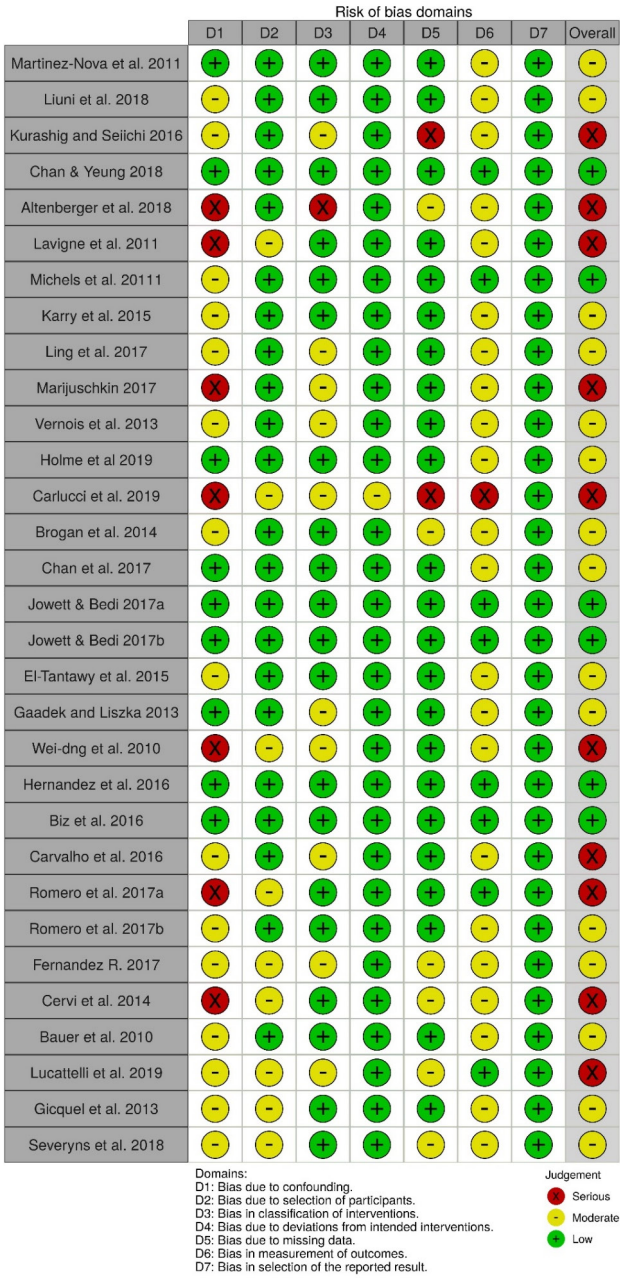

Figure 2A Risk of Bias In Non-randomised studies (ROBINS-I), traffic light plot.

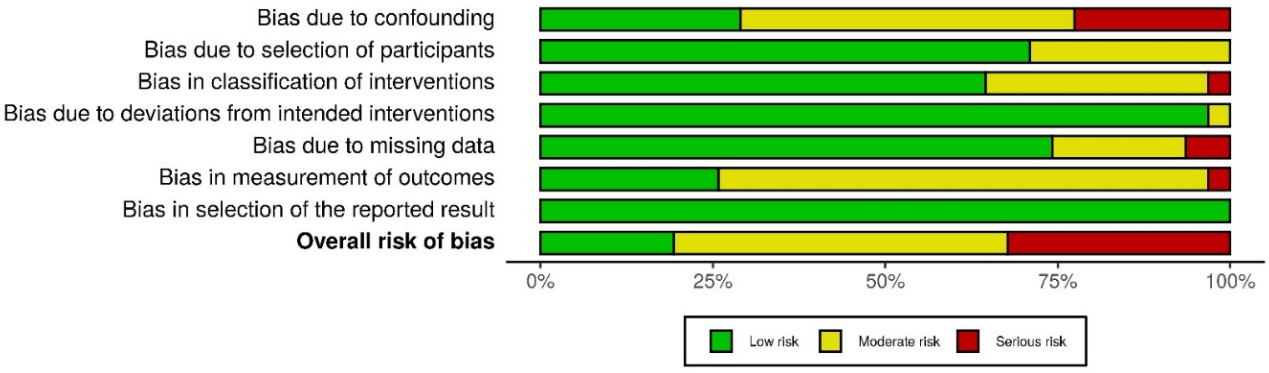

Figure 2B Risk of Bias In Non-randomised studies (ROBINS-I), summary plot.

supplement the paucity of available RCTs on the subject.

RESULTS

The literature search identified 2,558 abstracts that we examined for the efficacy of minimally invasive surgery for primary diagnosis of Hallux Valgus. Among those 2,212 papers were removed due to not being related to the research question. Duplicates were removed from the remaining papers, leaving 208 eligible for full text screening. Predetermined inclusion and exclusion criteria were applied leaving 81 papers of which one was removed from a recent systematic review containing one additional primary study not identified in the original search[41,42]. the length of hospital stay, the American Orthopaedic Foot and Ankle Society (AOFAS Overall the search revealed 30 eligible papers for analysis as seen in table 3a/3b.

All patients in these studies were diagnosed with Primary Hallux Valgus, ranging from mild, moderate or severe. Patients were reported to be free of diabetes, inflammatory conditions such as osteoarthritis, rheumatoid arthritis, infection, septic arthritis or trauma or previous surgeries to the joint. The total number of patients treated in these 30 studies identified was 1,979. Follow up times ranged from 5 months to 10 years, with the majority reporting 12-24 months follow up. This study did not only focus on one procedure, rather the most commonly used including MICA, Chevron, Akin, bunionectomy, Scarf, Reverdin-Isham, lapidus and other variations.

Data extraction was performed on all possible outcomes. However, due to the varied number of outcomes reported by each author only the main will be discussed here. Those being primary hallux valgus angle, intermetatarsal angle, and distal metatarsal articular angles. Patient reported outcomes were consistently reported using the American Foot and Ankle Score (AOFAS) with some studies presenting subjective satisfaction as, very-satisfied to dissatisfied. Primary pain scores on a visual analogue scale (VAS) were also included in order to elucidate a more objective understanding of patient reported outcomes. Data was placed in tables in order to accumulate similar papers with similar outcomes so that the association between the surgery and the outcome may better be elucidated. A separate meta-analysis was performed with fourteen studies that were comparing MIS with open techniques.

Risk of Bias Assessment

The ROBINS-I tool was used as it was developed to assess risk of bias in non-randomised studies that compare health effects of two or more interventions[43]. Risk of bias summaries/graphs for all included studies are present in figure 2a/2b. As seen in figure 2a/2b, 10 out of 30 papers (31 groups) were considered at serious risk of bias overall across 7 domains. 15 studies were considered at moderate risk of bias and only 6 studies were considered at low risk of bias. Bias due to confounding was seen in 25% of the 30 studies. There was also considerable concern regarding the measurement of outcomes. However, as the papers were not blinded controlled clinical trials this issues was inherent and does not effect the data. 70% overall did not cause concern for risk of bias as such all studies were included in the analysis.

Results of individual studies

This systematic review includes 30 papers, with 1,979 participants across all studies and 2,324 feet. 167 were male and 1,689 female. The age range on included patients was from mean 17 to 87, with only one study by Romero et al. 2017 including patients as young as seventeen. Follow up times varied across all studies, with the majority reporting 12 monthly data. Most studies provided data on preoperative and postoperative outcomes for hallux valgus angles, intermetatarsal angle, distal metatarsal articular angle, AOFAS score, satisfaction, complications and subjective pain scores. Only 30 papers that met our inclusion criteria were present in the literature. The techniques described are generally understood to be of use for different severities of hallux valgus and clinical outcomes. As such we have attempted to elucidate if one technique is superior of the other with regards to both surgical and patient reported outcomes. As seen in tables 4-7 the analysis included subgroups based on type of procedure, that being Akin, Chevron, Scarf, Reverdin-Isham etc and severity, mild, moderate or severe.

Surgical outcomes (Radiological Analysis)

As demonstrated in table 4 stratified analysis based on operative technique and hallux valgus severity is displayed. For all outcomes pre, post and mean difference with ranges were recorded respectively where possible. All values represent final follow up times.

Hallux Valgus Angle

The majority of papers reported hallux valgus angles within normal range at final follow up (i.e < 15 degrees)[44]. Mean differences can be seen for each operative procedure. When considering MICA procedure type, seven studies with 650 participants achieved an overall range of -18.1 degrees to -26.4 degrees decrease in HVA. Only one study by Vernois et al. 2013 reported some patients to have a post operative HVA up to 25.6 degrees (Mod-Severe HV patient population), the remaining studies all reported final follow up mean HVA to be less than 15 degrees. When attempting to analyse differences with respect to severity, the moderate to severe group had the largest HVA change -18.1 to -26.4 of the studies imploring the MICA technique (Table 4a/4b).

Notably a study by Lavigne et al. 2011 involving Chevron + Akin + Bunionectomy in severe cases, an average of -27 mean difference was reported. Only one study by El-Tantawy et al 2015 reported a mean difference in HVA to be -30 degrees using a Minimally invasive Distal Metatarsal osteotomy technique.

Ten papers using the Reverdin-Isham technique were identified. When comparing the subgroup analysis of Reverdin-Isham to Chevron it can be seen that the changes in HVA are larger for the Chevron technique, in mild to moderate cases, but larger for Reverdin-Isham in moderate to severe cases (Table 4a/4b).

Intermetatarsal Angle

With regard to IMA, there appears to be a greater number of studies reporting a post operative IMA < 9 degrees (Normal)[44]. Most of the studies imploring the Reverdin-Isham techqnique report an IMA at final follow up to be >9 degrees. For the MICA studies the overall difference between pre and post operative scores ranged from -3.7 to -7.44 degrees. For the Reverdin Isham studies the range was -0.87 to -8.5 degrees.

The two studies reporting the greatest decrease in IMA was one by El-Tantawy et al 2015, -14.46 degrees, and Michels et al. 2011 using a Lapidus technique combined with chevron and distal soft tissue release, they achieved -10.6 degrees. Both achieving normal mean range at post operative follow up.

Distal Metatarsal Articular Angle

Of the studies that reported DMAA, El-Tantawy et al 2015 using a minimally invasive distal metatarsal osteotomy reported the largest decrease being -12.4 degrees. The studies involving Reverdin-Isham procedures reported some patients to gain up to 5.7 degrees.

Table 3a Included Studies categorised based on technique and severity [7, 9, 26–28, 47, 16–19, 21–23, 25]

Authors	Year	Study Design	LOE	Severity	Intervention Summary	Consent	Age-Range (Mean)	M	F	Incision Length (mm) / number of incisions	N=	Feet	follow up (m/yrs)	lost FU
Martinez-Nova et al. 2011	2011	Prospective Cohort	III-2	Mild	A + DSTR + B		54.7 (12.5); Controls 52.3 (11.8)	0	177	3mm	79	79	28	-
Liuni et al. 2018	2018	Case Series	IV	Mild-severe	A + DSTR + B (Bianchi system)	YES	64 (28-82)	3	55	2mm, 5mm, 3mm if A as well.	52	58	25	-
Chan & Yeung 2018	2018	Case Series	IV	Mod-Severe	BCWO + B + MCP.	Yes	58.9 (R 41-71)	7	16	10mm, small stab incision for B and medial plication, small incision for osteotomy an screw.	23	23	21.5 (R 12-38)	-
Kurashig and Seiichi 2016	2016	Case Series	IV	Severe	Basal / PCWO + A		70.8 (9.5)(R 56-87)	0	15	5mm for B, DSTR 1.5mm, PCWO Kwire insertion and 5mm incision, 5mm for A osteotomy	15	17	22.1 (6.9)(R 12-34)	-
Altenberger et al. 2018	2018	Case Series	IV	Mild-Mod	C + A + B		-	-		-	43	43	12	-
Karry et al. 2015	2015	Case Series	IV	Mild-Mod	C percutaneous + DSTR + MCP + A (13)		48 (R 22-67)	0	20	3mm, stab incision for STR, + 3mm for A,	20	23	27.9 (R 18-36)	-
Michels et al. 20111	2011	Case Series	IV	Moderate	C + DSTR + Arthroscopic L and W		62	0	5	MIS mentioned only	5	5	12	-
Lavigne et al. 2011	2011	Case Series	IV	Severe	C + A + B bilateral.		60 (R 42-44)	0	6	3mm	6	6	4	-
Ling et al. 2017	2017	Retrospective Case Series	IV	Mild-Mod	DSTR + MCP (Endoscopic)		48.4(15.7)	15	70	5 incisions (2-3mm)	97	85	up to 10 years	12
Marijuschkin 2017	2017	Case Series	IV	Mod-Severe	LU (Proximal OO)		66.9 (29-78)			-	14	15	18 (R 12-36)	-
Brogan et al. 2014	2014	Case Series	IV	Mild-Mod	MICA + DSTR		54 (10.9)	1	45	5 / x3(one stab incision for guide wire (nail) and x1 for guidewire (Oblique)	35	45	9.1 (3) (R6-17)	-
Chan et al. 2017	2017	Case Series	IV	Mild-Mod	MICA + DSTR	Ethics Yes	50.7 (13.1)(R 36.1-70.7)			3mm/ x3 incisions B 5 mm incision.	8	13	24	-
Carlucci et al. 2019	2019	Case Series	IV	Moderate	MICA		M 58 (IQR 52-65)	2	36	-	-	38	12	-
Jowett & Bedi 2017 (a)	2017	Cohort Study - prospective	III-2	Mild-severe	MICA Group A	Ethics Yes	55 (25-81)	2	76	stab incision	53	53	24 (R 18-38)	-
Jowett & Bedi 2017 (b)	2017	Cohort Study - prospective	III-2	Mild-severe	MICA Group B					-	53	53	24 (18-38 range)	-
Vernois et al. 2013	2013	Case Series retrospective	IV	Mod-Severe	MICA			20	321	3mm	341	408	R 12-36	-
Holme et al 2019	2019	Case Series	IV	Mod-Severe	MICA	YES				smilar to standard MICA. 3mm	40	40	12	-

Mean (SD) M=Median R=Range IQR = Interquartile range; Akin (A), Bunionectomy (B), Chevron (C), Distal Minimally Invasive Metatarsal Osteotomy (DMMO), Distal Soft Tissue Release (DSTR), Lapidus (L), Lateral Soft Tissue Release (LSTR), Ludloff (LU), Medial Capsule Plication (MCP), Minimally Invasive Chevron + Akin (MICA), Minimally Invasive Distal Metatarsal Osteotomy (MIDMO), Mitchel-Kramer (M-K), Oblique Osteotomy (OO), Percutaneous Extra-articular Reverse-L Chevron (PERC), Proximal Basal Closing Wedge Osteotomy (PBCWO), Reverdin-Isham (R-I), Weil Osteootomy (W)

Table 3b Included Studies categorised based on technique and severity [5, 24, 38–40, 29–33, 35–37]

Authors	Year	Study Design	LOE	Severity	Intervention Summary	Consent	Age-Range (Mean)	M	F	Incision Length (mm) / number of incisions	N=	Feet	follow up (m/yrs)	lost to FU
El-Tantawy et al. 2015	2015	Case Series	IV	Severe	MIDMO - priximally and distally	YES	43.90(7.7)(R 37-51)	9	6	stab-20mm - x5 incisions	15	20	22.6 (R 16-30)	
Gaadek and Liszka 2013	2013	Case Series	IV	Mild-Mod	Mitchel-Kramer		45.7	18	41	15mm		59	18	5 excluded
Wei-dng et al. 2010	2010	Case Series	IV	Mild-severe	Oblique osteotomy + bunionectomy + concomittant for metatarsalgia		47 (R 13-75)	4	75	10mm curved	79	150	R 5.3-13.2 years	-
Hernandez et al. 2016	2016	Case Series	IV	Moderate	PERC + Akin + LSTR	YES	48 (R17-69)	3	35	-	38	45	59.1 (R 45.9 - 75.2)(R 3.5 -6.25 years)	-
Carvalho et al. 2016	2016	Retrospective Case Series	IV	Mild-Mod	Reverdin-Isham + Akin + Bunionectomy + concomittent metatarsalgia		60.1 (R 30-86)	2	59	-	61	93	26	-
Romero et al. 2017	2017	Case Series	IV	Mild-Mod	Reverdin-Isham + Akin + Bunionectomy + DMMO for concomittent metatarsalgia.	Yes	55.3 (12.4) (R 17-77)	7	82	-	89	89	58	-
Bauer et al. 2010	2010	Case Series	IV	Mild-Mod	Reverdin-Isham + bunionectomy		57 (R 23 -87)	6	76	3-5mm	82	104	24	-
Lucattelli et al. 2019	2019	Case Series	IV	Mild-Mod	Reverdin-Isham + Bunionectomy		46.9 (F) 51.8 (Males)	18	177	3mm, small dorsal incision for LSTR,	195	195	35.6 mean. radiographs at 1m, 3m, and 6m	-
Severyns et al. 2018	2018	Case Series	IV	Mild-Mod	Reverdin-Isham. No fixation.	Ethics Yes	51.5 (R 13.5-80.1)	5	43	3mm	48	57	60.1 (R 12-132)	-
Biz et al. 2016	2016	case series - prospective	IV	Mild-severe	Reverdin-Isham , Akin and LSTR	Yes	51 (15.5) (R 26-78)	5	75	2-5mm - x4 incisions	80	80	3, 12 and 48m	0
Gicquel et al. 2013	2013	Case Series	IV	Mild-Severe	Reverdin-Isham Osteotomy + Bunionectomy		12.5 (R 8.1-15.7)			-	18	33	31.5 months (R 14.1 - 58.2)	7
Romero et al. 2017	2017	Case Series	IV	Mod-Severe	Reverdin-Isham + Akin + Bunionectomy + DMMO for concomittent metatarsalgia.	Yes	56 (12.6)	7	125	Not mentioned	126	132	57.3 (R 24-112)	108/126 completed 2 yr FU
Fernandez R. 2017	2017	Case Series	IV	Mod-Severe	Reverdin-Isham + Akin + Bunionectomy + Weill osteotomy (all except 7); no fixation		61.9 (9.3) (R 20-75)	4	46	3mm, stab incision for STR, + 3mm Akin,	46	50	24 (R 12-51)	2
Cervi et al. 2014	2014	Case Series	IV	Mod-Severe	Reverdin-Isham + Bunionectomy		55 (R 25-85	29	184	3 tiny incisions	213	213	R 5-29	-
Totals:								167	1689		1974	2324		

Mean (SD) M=Median R=Range IQR = Interquartile range; Akin (A), Bunionectomy (B), Chevron (C), Distal Minimally Invasive Metatarsal Osteotomy (DMMO), Distal Soft Tissue Release (DSTR), Lapidus (L), Lateral Soft Tissue Release (LSTR), Ludloff (LU), Medial Capsule Plication (MCP), Minimally Invasive Chevron + Akin (MICA), Minimally Invasive Distal Metatarsal Osteotomy (MIDMO), Mitchel-Kramer (M-K), Oblique Osteotomy (OO), Percutaneous Extra-articular Reverse-L Chevron (PERC), Proximal Basal Closing Wedge Osteotomy (PBCWO), Reverdin-Isham (R-I), Weil Osteootomy (W)

Table 4a Stratified Radiological Outcomes according to operative technique and severity of HV deformity.

Intervention	Authors	Study Design	LOE	Severity	feet n=	HVA Pre	HVA Post	HVA Diff	IMA Pre	IMA Post	IMA Diff	DMAA Pre	DMAA post	DMAA Diff
A + DSTR + B	Martinez-Nova et al. 2011	Prospective Cohort	III-2	Mild	79	24.1(3.7)	11 (1.7)	-13.1	11.8 (0.5)	9.4 (0.5)	-2.4			
A + DSTR + B	Liuni et al. 2018	Case Series	IV	Mild-severe	58	34.0 (9)	10.6 (6)	-23.4	13.5 (3)	8.0 (2)	-5.5	14.6 (6)	4.2 (3)	-10.4
	Totals				137			(-13.1 - -23.4)			(-2.4 - -5.5)			-10.4
PBCWO	Chan & Yeung 2018	Case Series	IV	Mod-Severe	23	39.4 (R 29-58.3)	14.7 (R 0.1-23.2)	-24.7	14.9 (R 6.7-22.4)	6.6 (R 0.9-14.8)	-8.3			
PBCWO	Kurashig and Seiichi 2016	Case Series	IV	Severe	17	46.5 (4.0) (R 40-55)	18.9 (6.7)	-27.6	18.6 (3.5) (R 13 to 25)	9.9 (4.4)	-8.7			
	Totals				40			(-24.7 - -27.6)			(-8.3 - -8.7)			-
C+A+B	Altenberger et al. 2018	Case Series	IV	Mild-Mod	43	32 (9)	9(8)	-23	13.6 (4)	4 (3)	-9.6			
C+DSTR+MCP	Karry et al. 2015	Case Series	IV	Mild-Mod	23	31.68 (R 17-39)	14.39 (R 5-24.5)	-17.29	13.77 (R 8.5-20.9)	7.98 (R 4.4-14.5)	-5.79	6.30 (R 3.8-10)	5.40 (R 2.9-9.2)	-0.9
C+DSTR+L+W	Michels et al. 20111	Case Series	IV	Moderate	5	42.6	17	-25.6	17.8	7.2	-10.6			
C+A+B	Lavigne et al. 2011	Case Series	IV	Severe	6	43	16	-27	22	11	-11			
	Totals				77			(-17.29 - -27)			(-5.79 - -11)			-0.9
DSTR+MCP	Ling et al. 2017	Retrospective Case Series	IV	Mild-Mod	85	25.8 (8.63)	11.2 (4.03)	-14.6	13.5 (3.48)	9.5 (3.55)	-4			
	Totals				85			-14.6			-4			-
LU	Marijuschkin 2017	Case Series	IV	Mod-Severe	15	39.7 (30-51)	18 (R 8-28)	-21.7	18.6 (R 17-22)	13.8 (7 - 17)	-4.8			
	Totals				15			-21.7			-4.8			-
MICA +DSTR	Brogan et al. 2014	Case series	IV	Mild-Mod	45	30.54	10.41	-20.13	14.55	7.11	-7.44			
MICA +DSTR	Chan et al. 2017	Case Series	IV	Mild-Mod	13	30.4 (5.9)	10.9 (7.2)	-19.5	13.9 (3.5)	10.2 (3.3)	-3.7			
	Mild-Mod Stratified Total							(-19.5 - -20.13)			(-3.7 - -7.44)			-
MICA	Carlucci et al. 2019	Case Series	IV	Moderate	38			-						
MICAa	Jowett & Bedi 2017 (a)	Cohort Study - prospective	III-2	Mild-severe	53	28.7(8.1)	10.6(5.4)	-18.1	13.6(3.3)	8.1(3.6)	-5.5			
MICAb	Jowett & Bedi 2017 (b)	Cohort Study - prospective	III-2	Mild-severe	53	30.7(5.7)	9.9(4.01)	-20.8	14.4 (1.8)	7.1(1.8)	-7.3			
	Mild-Severe Stratified Total							(-18.1 - -20.8)			(-5.5 - - 7.3)			
MICA	Vernois et al. 2013	Case Series retrospective	IV	Mod-Severe	408	33.7 (9) (R 14.5-70.7)	7.3(5.6) (R 0.2-25.6)	-26.4	14.5(3.5) (R 5.3-22.2)	5.5(2.4) (R 0.2-11.6)	-9	-	9.2(6)	-
MICA	Holme et al 2019	Case Series	IV	Mod-Severe	40	31.7 (R 12-57)	12.1 (1-43)	-19.6	13.2 (range 6-24)	6.7 (2-13)	-6.5			
	Mod-Severe Stratified Total							(-19.6 - -26.4)			(-6.5 - -9)			
	Totals				650			(-18.1 - -26.4)			(-3.7 - -9.0)			(-0.9 - -10.4)

Mean (SD) M=Median R=Range IQR = Interquartile range; Akin (A), Bunionectomy (B), Chevron (C), Distal Minimally Invasive Metatarsal Osteotomy (DMMO), Distal Soft Tissue Release (DSTR), Lapidus (L), Lateral Soft Tissue Release (LSTR), Ludloff (LU), Medial Capsule Plication (MCP), Minimally Invasive Chevron + Akin (MICA), Minimally Invasive Distal Metatarsal Osteotomy (MIDMO), Mitchel-Kramer (M-K), Oblique Osteotomy (OO), Percutaneous Extra-articular Reverse-L Chevron (PERC), Proximal Basal Closing Wedge Osteotomy (PBCWO), Reverdin-Isham (R-I), Weil Osteootomy (W), Hallux valgus Angle (HVA), Intermetatarsal Angle (IMA), Distal Metatarsal Articular Angle (DMAA)

Table 4b: Stratified Radiological Outcomes according to operative technique and severity of HV deformity.

Intervention	Authors	Study Design	LOE	Severity	feet n=	HVA Pre	HVA Post	HVA Diff	IMA Pre	IMA Post	IMA Diff	DMAA Pre	DMAA post	DMAA Diff
MIDMO	El-Tantawy et al. 2015	Case Series	IV	Severe	20	45.80 (3.726)	14.86 (2.8)	-30.94	22.66(3.1)	8.20(3.265)	-14.46	20.3(10.8)	7.9(2.7)	-12.4
	Totals				20			-30.94			-14.46			-12.4
M-K	Gaadek and Liszka 2013	Case Series	IV	Mild-Mod	59	33.9	14.2	-19.7	14.8	9.7	-5.1			
	Totals				59			-19.7			-5.1			-
OO+B	Wei-dng et al. 2010	Case Series	IV	Mild-severe	150	33.28 (9.59)	12.31 (4.64)	-20.97	11.75 (2.89)	6.80(1.95)	-4.95			
	Totals				150			-20.97			-4.95			-
A+LSTR+PERC	Hernandez et al. 2016	Case Series	IV	Moderate	45	26.2 (4.9) (R 16-40)	9.6 (3.1) (R 4-18)	-16.6	11.8 (2.7) (R 6-18)	7.9(2.1) (R 3-11)	-3.9			
	Totals				45			-16.6			-3.9			-
R-I+A+B	Carvalho et al. 2016	Retrospective Case Series	IV	Mild-Mod	93	33.3	19.3	-14	13.85	13	-0.85	14.8	7.05	-7.75
R-I+A+B+DMMO	Romero et al. 2017	Case Series	IV	Mild-Mod	89	29.6(6.2); M 30 (R 25-35)	19.8(10.0); M 21 (R 12.5-26)	-9.8	12.4(3.4); M 12 (R 10-15)	10.6(2.9); M 11 (R 9-12.5)	-1.8	17.1(6.2); M 17 (R13-21)	22.8(9.1); M 23 (R 15-30)	5.7
R-I+B	Bauer et al. 2010	Case Series	IV	Mild-Mod	104	M 30 (IQR 25—32)	M 15 (IQR 11—18)	-	14 (12—15)	11 (9—13)	-3	15 (R 12—18)	7 (4—10)	-8
R-I+B	Lucattelli et al. 2019	Case Series	IV	Mild-Mod	195			-						
R-I	Severyns et al. 2018	Case Series	IV	Mild-Mod	57	29.3 (7.1)	15.4(6.4)	-13.9	13.5 (3.1)	12 (2.8)	-1.5	14.1(6.9)	7.7 (5.7)	-6.4
	Mild - Mod Stratified Total							(-9.8 - -14)			(-0.85 - -3)			(-8 - +5.7)
R-I+A+LSTR	Biz et al. 2016	case series - prospective	IV	Mild-severe	80	26.40(6.75) (R 10-47.5)	13.9 (6.25) (R 0-34)	-12.5	12.90(2.83) (R 7.50 - 20.00)	9.0(2.04) (R 5-14)	-3.9	10.12 (4.26) (R 3.5 - 26)		-
R-I +B	Gicquel et al. 2013	Case Series	IV	Mild-Severe	33	28.06 (6.30) (R 18-42)	19.45(8.52); (R6 - 38)	-8.61	13.61 (2.59) (R 10-18)	12.74(2.70) (R 8-18)	-0.87	15.97(5.74) (R 0-28)	8.97(8.17) (R-4 to 28)	-7
	Mild-Severe Stratified Total							(-8.61 - -12.5)			(-0.87 - -3.9)			-7
R-I+A+B+DMMO	Romero et al. 2017	Case Series	IV	Mod-Severe	132	34.3(9.3)	22.5(11.1)	-11.8	13.1 (3.5)	10.7 (3.1)	-2.4	18.5(7.3)	23.6 (9.7)	5.1
R-I+A+B+W	Fernandez R. 2017	Case Series	IV	Mod-Severe	50	39.2(7.2)	10.8 (6.4)	-28.4	16.9(2.0)	8.4(3.1)	-8.5	16.3(7.8)	8.9 (6.2)	-7.4
R-I+B	Cervi et al. 2014	Case Series	IV	Mod-Severe	213			-						
	Mod-Severe Stratified Total							(-11.8 - -28.4)			(-2.4 - -8.5)			(-7.4 - +5.1)
	Totals				1046			(-8.61 - -28.4)			(-0.87 - -8.5)			(-8 - +5.7)
	Overall totals				2324			(-8.61 - -30.94)			(-0.87 - -14.46)			(-12.4 <0< +5.7)

Mean (SD) M=Median R=Range IQR = Interquartile range; Akin (A), Bunionectomy (B), Chevron (C), Distal Minimally Invasive Metatarsal Osteotomy (DMMO), Distal Soft Tissue Release (DSTR), Lapidus (L), Lateral Soft Tissue Release (LSTR), Ludloff (LU), Medial Capsule Plication (MCP), Minimally Invasive Chevron + Akin (MICA), Minimally Invasive Distal Metatarsal Osteotomy (MIDMO), Mitchel-Kramer (M-K), Oblique Osteotomy (OO), Percutaneous Extra-articular Reverse-L Chevron (PERC), Proximal Basal Closing Wedge Osteotomy (PBCWO), Reverdin-Isham (R-I), Weil Osteootomy (W), Hallux valgus Angle (HVA), Intermetatarsal Angle (IMA), Distal Metatarsal Articular Angle (DMAA)

Table 5a Stratified Clinical Outcomes according to operative technique and severity of HV deformity.

Authors	Study Design	LOE	Severity	No of Feet	Pain VAS Pre	Pain VAS Post	Pain VAS Diff	AOFAS Pre	AOFAS Post	AOFAS Diff
Martinez-Nova et al. 2011	Prospective Cohort	III-2	Mild	79				68.5 (10.6)	86.6 (8.5)	18.1
Liuni et al. 2018	Case Series	IV	Mild-severe	58	6.7 (1.1)	0.59 (1.1)	-6.11	28.6 (14.1)	91.7 (10.6)	63.1
Totals				137			-6.11			18.1-63.1
Chan & Yeung 2018	Case Series	IV	Mod-Severe	23				39 (R 12-50)	81 (R 70-93)	42
Kurashig and Seiichi 2016	Case Series	IV	Severe	17						
Totals				40			-			42
Altenberger et al. 2018	Case Series	IV	Mild-Mod	43	-	-		-	-	
Karry et al. 2015	Case Series	IV	Mild-Mod	23				59.26 (R 49-75)	88.35 (R 75-100)	29.09
Michels et al. 20111	Case Series	IV	Moderate	5				38.6	89.4	50.8
Lavigne et al. 2011	Case Series	IV	Severe	6	?	0 in 5/6	-	34	84	50
Totals				77			-			29.09-50.8
Ling et al. 2017	Retrospective Case Series	IV	Mild-Mod	85	6.53	0.51	-6.02	-	93.5 (8.27)	-
Totals				85			-			-
Marijuschkin 2017	Case Series	IV	Mod-Severe	15				43	86.6	43.6
Totals				15			-			43.6
Brogan et al. 2014	Case series	IV	Mild-Mod	45						
Chan et al. 2017	Case Series	IV	Mild-Mod	13	5.1 (1.7)	0	-5.1	59 (13.1)	93.7 (8.0)	34.7
Carlucci et al. 2019	Case Series	IV	Moderate	38				58.23 (9.02)	97.15 (4.72)	38.92
Mild-Mod Stratified Total							-			34.7-38.92
Jowett & Bedi 2017 (a)	Cohort Study - prospective	III-2	Mild-severe	53				55 (11.3)	85 (9.3)	30
Jowett & Bedi 2017 (b)	Cohort Study - prospective	III-2	Mild-severe	53				57 (8.6)	89 (10.9)	32
Mild-Severe Stratified Total							-			30-32
Vernois et al. 2013	Case Series retrospective	IV	Mod-Severe	408						
Holme et al 2019	Case Series	IV	Mod-Severe	40				48.2 (R 24-72)	93.4 (60-100)	45.2
Mod-Severe Stratified Total							-			45.2
Totals				650			-			30-45.2

Mean (SD) M=Median R=Range IQR = Interquartile range; Akin (A), Bunionectomy (B), Chevron (C), Distal Minimally Invasive Metatarsal Osteotomy (DMMO), Distal Soft Tissue Release (DSTR), Lapidus (L), Lateral Soft Tissue Release (LSTR), Ludloff (LU), Medial Capsule Plication (MCP), Minimally Invasive Chevron + Akin (MICA), Minimally Invasive Distal Metatarsal Osteotomy (MIDMO), Mitchel-Kramer (M-K), Oblique Osteotomy (OO), Percutaneous Extra-articular Reverse-L Chevron (PERC), Proximal Basal Closing Wedge Osteotomy (PBCWO), Reverdin-Isham (R-I), Weil Osteootomy (W), American Orthopedic Foot And Ankle Scale (AOFAS), Visual Analog Scale for Pain (VAS).

Patient reported outcomes (Table 5a/5b)

American Foot and Ankle Society Score (AOFAS): With regard to the AOFAS subgroup of mild to moderate severity, MICA appears to have a larger difference (34.7-38.9), compared to Reverdin-Isham (33.3-34.9). Of the other techniques, the combined Chevron + Distal soft tissue release, bunionectomy and Akin also had one of the higher differences 29.09 to 50.8 points. Also, with excellent post operative AOFAS scores all above 84. Whilst the largest difference was reported by Liuni et al. 2018 to be 63.1 points on average, this was an Akin, DSTR and bunionectomy procedure in 68 patients. The more severe studies for MICA showed a range difference from 30-45.2 and Reverdin-Isham 33.05 to 45.0 points.

Pain VAS: Only 7 of the 31 papers reported PAIN on a VAS scale as seen in Table 5a/5b. Three studies using the Reverdin-Isham technique reported changes from -4.4 to -4.7. One study using MICA + DSTR reported a change in -5.1 points on the PAIN VAS scale at final follow up.

Complications (Table 6): An overall complication rate of 15.8% was found (table 6). Our results indicate a significantly larger complication rate in the Reverdin Isham studies (22%) compared to the MICA studies(7.4%). However, this appears to be attributed to one large study by Vernois et al. 2013 involving 408 feet with 371 patients, which when excluded increased the complication rate from 7 to 15%.

Satisfaction (Table 7): Seventeen studies reported on subjective patient reported outcomes, either as excellent, good, not satisfied or dissatisfied, as seen in Table 7. Of the MICA procedures (4 studies & 554 feet), 93% were satisfied, but only 5% indicated they believed the result was excellent. Of Reverdin-Isham studies (8 studies with 916 feet), 87.8% of patients were satisfied, and 13% indicated the results were excellent. The remaining studies were individual and satisfaction levels ranged from 82%-100%.

DISCUSSION

The purpose of this review was to determine the efficacy of minimally invasive surgery techniques for hallux valgus. Moreover, to elucidate if one technique provides any superior benefit over another in terms of both surgical and patient reported outcomes. Although the data presented here are mostly observational case series we aim to provide an overview of the available evidence. Meta-analysis was not possible due to the large number of procedures and heterogeneity of included studies. There were also considerably concerns regarding confounding and potential for bias in the measurements of the outcomes.

Table 5b Stratified Clinical Outcomes according to operative technique and severity of HV deformity.

Authors	Study Design	LOE	Severity	No of Feet	Pain VAS Pre	Pain VAS Post	Pain VAS Diff	AOFAS Pre	AOFAS Post	AOFAS Diff
El-Tantawy et al. 2015	Case Series	IV	Severe	20				44.8 (5.5)	93.2(2.95)	48.4
Totals				20			-			48.4
Gaadek and Liszka 2013	Case Series	IV	Mild-Mod	59	8.9	2.6	-6.3	37	90.7	53.7
Totals				59			-6.3			52.7
Wei-dng et al. 2010	Case Series	IV	Mild-severe	150				?	84.20(4.32)	-
Totals				150			-			-
Hernandez et al. 2016	Case Series	IV	Moderate	45				62.5 (R 30-80)	97.1 (75-100)	34.6
Totals				45			-			34.6
Carvalho et al. 2016	Retrospective Case Series	IV	Mild-Mod	93				?	86.8 (29-100)	-
Romero et al. 2017	Case Series	IV	Mild-Mod	89	6.3 (1.5); M 7 (IQR 5-8)	1.6 (2.3); M 0 (IQR 0-3)	-4.7	52.2(11.2); M 52 (IQR 47-59)	87 (13.9); M 90 (R 79-100)	34.8
Bauer et al. 2010	Case Series	IV	Mild-Mod	104				M 49 (IQR 44—52)	87.5 (R 67—93.5)	-
Lucattelli et al. 2019	Case Series	IV	Mild-Mod	195				54.7	89.6	34.9
Severyns et al. 2018	Case Series	IV	Mild-Mod	57				55.9 (15.5)	89.2 (9.8)	33.3
Mild-Mod Stratified Total							-4.7			33.3-34.9
Biz et al. 2016	case series - prospective	IV	Mild-severe	80				54.1(8.3) (R 39-85); M 52	87.15(12.83) (R 52–100)	33.05
Gicquel et al. 2013	Case Series	IV	Mild-Severe	33					80.7	-
Romero et al. 2017	Case Series	IV	Mod-Severe	132	6.3 (1.5)	1.9(2.4)	-4.4	50.6 (11.2)	85.9(13.8)	35.3
Fernandez R. 2017	Case Series	IV	Mod-Severe	50				47.6 (6.0)	89.9 (10.2)	42.3
Cervi et al. 2014	Case Series	IV	Mod-Severe	213				45	90	45
Mild-Severe Stratified Total							-4.4			33.05-45
Totals				1046			(-4.4 - -4.7)			33.3 - 45
Overall totals				2324			(-4.4 - -6.11)			18.1-63.1

Mean (SD) M=Median R=Range IQR = Interquartile range; Akin (A), Bunionectomy (B), Chevron (C), Distal Minimally Invasive Metatarsal Osteotomy (DMMO), Distal Soft Tissue Release (DSTR), Lapidus (L), Lateral Soft Tissue Release (LSTR), Ludloff (LU), Medial Capsule Plication (MCP), Minimally Invasive Chevron + Akin (MICA), Minimally Invasive Distal Metatarsal Osteotomy (MIDMO), Mitchel-Kramer (M-K), Oblique Osteotomy (OO), Percutaneous Extra-articular Reverse-L Chevron (PERC), Proximal Basal Closing Wedge Osteotomy (PBCWO), Reverdin-Isham (R-I), Weil Osteootomy (W), American Orthopedic Foot And Ankle Scale (AOFAS), Visual Analog Scale for Pain (VAS).

From our review there is no convincing evidence that one procedure offers any substantial benefit over another. We note that the overall complication rates were surprising, indicating a substantial difference between MICA surgery and the Reverdin-Isham technique. However, when assessing the sub group analysis the difference only existed due to one large study by Vernois et al. 2013. If we removed this study from the analysis as perhaps Vernois et al only reported the major complications, we see a 7 to 15% complication rate in the MICA, compared to the stated 22% for Reverdin-Isham procedures. This is more in line with previous reports of complication rates with MICA surgery. However, here in lies a fundamental factor often reported in using MIS techniques, it relies on surgeon expertise.

The Reverdin-Isham technique also appears to have a much larger range of complications compared with MICA as seen in table 6. In particular fractures of the 1st MTJ and delayed healing are but a few. As previously reported there appears to be a significant learning curve which makes the interpretation of studies more difficult, again why we chose to limit our study to the last 10 years[45,46]. To illustrate an example of the learning curve, a study by Jowet et al reported two consecutive groups of 53 patients, where the complications rate improved from 26% to 15%[26].

We expected to see a larger difference between surgical techniques. In particular with regard to patient reported outcomes, we expected there to be an obvious trend in favour of the more commonly used procedures. However, in fact our data indicates little difference between techniques. We note there may be an appreciable difference between the MICA technique alongside distal soft tissue releases compared with the Reverdin Isham technique. This also was the case for patient reported satisfaction. Although negligible, 93.86% of patients in MICA studies (554 feet) reported being satisfied with their outcome, while only 87.8% reported satisfaction with the Reverdin Isham procedure (916 feet). This difference may be considered negligible and related to surgeon preference, as the Australian study noted that surgeons tend to choose the MICA procedure these days as well as being more comfortable with said procedure[2]. Some of the other techniques were found to have larger AOFAS post-operative means and mean differences. These techniques are promising and should be explored further.

CONCLUSION

Overall, there is no sufficient data to suggest that one minimally invasive procedure is superior to another. Moreover, there appears to be negligible differences between the latest procedures used over the last 10 years. However, we do note that a larger number of MICA and Reverdin-Isham studies were present in the literature and the higher complication rate in the Reverdin-Isham compared to MICA. More controlled trials are necessary to further explore patient preference with each procedure, in particular with regard to longer term patient reported outcomes.

Table 6 Complications Single Arm Studies categorised based on operative technique and severity of HV deformity; Mean (SD) M=Median R=Range IQR = Interquartile range;

			Arthritic changes	Burn (Skin)	CRPS	Decreased ROM <30 deg	infection deep	Delayed consolidation	Delayed weight bearing	Delayed healing	DMAA Hypercorrection	DVT	fracture of metatarsal 2-5	fracture of 1st metatarsal/p1	Hallux Varus	Hematomas	Metatarsalgia	Neuroma	Ongoing pain	Osteotomy displaced	Paresthesia	Radio Recurrence	Revision surgery	plication stich removal	Screw removal	Stiffness	infection superficial	Troughing	wound dehisence	Total	Total %	Grouped Totals
Intervention	Authors	feet n=																														
A + DSTR + B	Martinez-Nova et al. 2011	79														11	2				3						7			23	29	
A + DSTR + B	Liuni et al. 2018	58				3											5				1									9	16	23.4
PBCWO	Chan & Yeung 2018	23																			1						1			2	9	
PBCWO	Kurashig and Seiichi 2016	17		1																	2				3	1				7	41	22.5
C+A+B	Altenberger et al. 2018	43																												-	-	
C+DSTR+MCP	Karry et al. 2015	23																						4	4					8	35	
C+DSTR+L+W	Michels et al. 20111	5																	1											1	20	
C+A+B	Lavigne et al. 2011	6																												0		11.7
DSTR+MCP	Ling et al. 2017	85																			5	3	1			4	1			14	16	16
LU	Marijuschkin 2017	15						2									1					1						1		5	33	33
MICA +DSTR	Brogan et al. 2014	45																	1						1					2	4	
MICA +DSTR	Chan et al. 2017	13																		2*	1		2			1	1			5	38	12.1
Mild-Mod																																
MICA	Carlucci et al. 2019	38											1				5						1		1		2			10	26	
MICAa	Jowett & Bedi 2017 (a)	53																					1		12		1			14	26	
MICAb	Jowett & Bedi 2017 (b)	53												1											6		1			8	15	22.2
Mild-Severe																																
MICA	Vernois et al. 2013	408															1						7							8	2	
MICA	Holme et al 2019	40																							4					4	10	2.7
Mod-Severe																																Overall = 7.4%
Intervention	Authors	feet n=																												0	-	
MIDMO	El-Tantawy et al. 2015	20																	2							2	7			11	55	55
M-K	Gaadek and Liszka 2013	59																									1			1	2	2
OO+B	Wei-dng et al. 2010	150																			4									4	3	3
A+LSTR+PERC	Hernandez et al. 2016	45						1		1													1		4					7	16	16
R-I+A+B	Carvalho et al. 2016	93						3														18				3	0			24	26	
R-I+A+B+DMMO	Romero et al. 2017	89																				12								12	13	
R-I+B	Bauer et al. 2010	104			2						6			5			2					3				2				20	19	
R-I+B	Lucattelli et al. 2019	195						5				2					2		5*			7					2	2		20	10	
R-I	Severyns et al. 2018	57								10		1					4				3	2								20	35	17.8
Mild - Mod																																
R-I+A+LSTR	Biz et al. 2016	80				1				2											1	5				16				25	31	
R-I +B	Gicquel et al. 2013	33							7										9		4									20	60	39.8
Mild-Severe																																
R-I+A+B+DMMO	Romero et al. 2017	132	6														12	3					14				9			44	33	
R-I+A+B+W	Fernandez R. 2017	50			1	1	1	7							1		6					4					3			24	48	
R-I+B	Cervi et al. 2014	213												21																21	10	22.5
Mod-Severe																																Overall = 22%
	Total	2324	6	1	3	5	1	18	7	13	6	3	1	27	1	11	40	3	13		25	55	27	4	35	29	36	3		373	16	Total = 16%

Akin (A), Bunionectomy (B), Chevron (C), Distal Minimally Invasive Metatarsal Osteotomy (DMMO), Distal Soft Tissue Release (DSTR), Lapidus (L), Lateral Soft Tissue Release (LSTR), Ludloff (LU), Medial Capsule Plication (MCP), Minimally Invasive Chevron + Akin (MICA), Minimally Invasive Distal Metatarsal Osteotomy (MIDMO), Mitchel-Kramer (M-K), Oblique Osteotomy (OO), Percutaneous Extra-articular Reverse-L Chevron (PERC), Proximal Basal Closing Wedge Osteotomy (PBCWO), Reverdin-Isham (R-I), Weil Osteootomy (W). *Reason for Re-operation.

Table 7 Satisfaction Single Arm Studies categorised based on operative technique; Mean (SD) M=Median R=Range IQR = Interquartile range;

			Excellent	Good	Not satisfied	Dissatisfied	Total	Total %
Intervention	Authors	Feet n=						
A + DSTR + B	Martinez-Nova et al. 2011	79	Not reported				0	0
A + DSTR + B	Liuni et al. 2018	58	55	3			58	100
PBCWO	Chan & Yeung 2018	23	Not reported					
PBCWO	Kurashig and Seiichi 2016	17	Not reported					
C+A+B	Altenberger et al. 2018	43	Not reported					
C+DSTR+MCP	Karry et al. 2015	23	Not reported					
C+DSTR+L+W	Michels et al. 20111	5	7.5/10 (R 6.5-8.5) VAS Scale					
C+A+B	Lavigne et al. 2011	6	Not reported					
DSTR+MCP	Ling et al. 2017	85	Not reported					
LU	Marijuschkin 2017	15	High degree of patient satisfaction					
MICA +DSTR	Brogan et al. 2014	45	Not reported					
MICA +DSTR	Chan et al. 2017	13	Not reported					
MICA	Carlucci et al. 2019	38	Not reported					
MICAa	Jowett & Bedi 2017 (a)	53		46		7*	46	87
MICAb	Jowett & Bedi 2017 (b)	53		46		7*	46	87
MICA	Vernois et al. 2013	408		388			388	95
MICA	Holme et al 2019	40	32	8				100
MIDMO	El-Tantawy et al. 2015	20		20			100	100
M-K	Gaadek and Liszka 2013	59		59			59	100
OO+B	Wei-dng et al. 2010	150	56	88			144	96
A+LSTR+PERC	Hernandez et al. 2016	45		37			37	82
R-I+A+B	Carvalho et al. 2016	93		84			84	90
R-I+A+B+DMMO	Romero et al. 2017	89		71			71	80
R-I+B	Bauer et al. 2010	104		93			93	89
R-I+B	Lucattelli et al. 2019	195		185			185	95
R-I	Severyns et al. 2018	57		51			51	89
R-I+A+LSTR	Biz et al. 2016	80	Not reported					
R-I +B	Gicquel et al. 2013	33	6	18	0	9*	24	73
R-I+A+B+DMMO	Romero et al. 2017	132		100		9*	100	76
R-I+A+B+W	Fernandez R. 2017	50	Not reported					
R-I+B	Cervi et al. 2014	213	113	83	17*		196	92

Akin (A), Bunionectomy (B), Chevron (C), Distal Minimally Invasive Metatarsal Osteotomy (DMMO), Distal Soft Tissue Release (DSTR), Lapidus (L), Lateral Soft Tissue Release (LSTR), Ludloff (LU), Medial Capsule Plication (MCP), Minimally Invasive Chevron + Akin (MICA), Minimally Invasive Distal Metatarsal Osteotomy (MIDMO), Mitchel-Kramer (M-K), Oblique Osteotomy (OO), Percutaneous Extra-articular Reverse-L Chevron (PERC), Proximal Basal Closing Wedge Osteotomy (PBCWO), Reverdin-Isham (R-I), Weil Osteootomy (W), *Patients reported to be not satisfied or dissatisfied respectively.

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Conflict of Interest

Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article.

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