

Efficacy of Minimally Invasive Surgery on Hallux Valgus – A Systematic Review and Meta-Analysis

Anthony B. Lisacek-Kiosoglous¹; Andrew C. Georgiou¹; Stavros A. Antoniou², MD PhD; Stavros Ristanis³, MD PhD

1 European University Cyprus, School of Medicine;

2 Department of Surgery, Mediterranean Hospital of Cyprus, Limassol, Cyprus;

3 Department of Orthopaedics, Metropolitan Hospital, Athens, Greece.

Conflict-of-interest statement: The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

Open-Access: This article is an open-access article which was selected by an in-house editor and fully peer-reviewed by external reviewers. It is distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>

Correspondence to: Anthony Lisacek-Kiosoglous, European University Cyprus 6 Diogenis Str., 2404 Engomi P.O. Box: 22006, 1516, Nicosia-Cyprus.

Email: anthony@lkiosoglous.com

Received: April 15, 2021

Revised: May 26, 2021

Accepted: May 28 2021

Published online: June 28, 2021

ABSTRACT

INTRODUCTION: The evolution of minimal incision surgery for hallux valgus has led to some of many procedures being performed minimally invasively, with no definitive consensus on which technique is more effective. The aim of this study is to systematically search the literature in order to evaluate the effect of minimally invasive surgery over conventional open surgery 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. We considered Randomised Controlled Trials and observational studies with a comparison arm. Primary outcomes focused on hallux valgus angle, intermetatarsal angle, distal metatarsal articular angle.

Secondary Outcomes included the American Foot & Ankle Society Score (AOFAS), as well as Pain on a Visual Analogue Scale (VAS), patient satisfaction, complications, SF-36 questionnaire and Manchester Oxford Foot Questionnaire (MOXFQ). The inclusion criteria included patients with primary diagnosis of hallux valgus and no other co-morbidities. Subgroup analysis allowed for more accurate meta-analysis based on surgical technique to remove potential confounding due to heterogeneity. Effect estimates were summarized using Mantel-Haenszel meta-analysis and odds ratios or mean differences with respective 95% confidence intervals (CI) were calculated.

RESULTS: 8 randomized trials and 7 cohort studies were identified. A total of 907 patients were included with a mean age of 48 years. Radiological outcomes between similar techniques (comparing MIS and Open) were found to have no significant difference pre and post operatively at final follow up (6 months to 5 years). Visual analogue scale scores were found to be significantly lower in the MIS groups compared to open techniques (MICA v Scarf) in the short term at Day 1 ($p < 0.00001$) MD = -1.96 95% CI: -2.28, -1.65; $P = 0\%$; Week 2 ($p = 0.001$) MD = -1.40; 95% CI: -2.26, -0.54; and Week 6 ($p = 0.005$) MD = -1.50; 95% CI: -2.55, -0.45. There was no statistical difference at 6 months (3 studies) ($p = 0.46$) MD = -0.16; 95% CI: -0.59, 0.27; $P = 0\%$; or final follow up (6 m to > 24m) ($p = 0.94$) MD = -0.02; 95% CI: -0.44, 0.41; $P = 0\%$). There were no statistically important differences between post-operative AOFAS scores across comparisons, whereas AOFAS mean difference was found to be significantly higher in Open Scarf vs MICA ($p = 0.003$); MD = -5.54; 95% CI: -9.19, -1.88. $P = 0\%$.

CONCLUSION: The present review found that Open Scarf resulted in a higher mean difference AOFAS score compared with MICA, while post-operative scores at final follow up were statistically insignificant. The data also showed that early post-operative VAS scores were significantly better in the MICA group compared to the Open Scarf. Randomised and observational evidence on long term follow up is awaited.

Key words: Hallux Valgus; Minimally Invasive Surgery; Hallux Valgus Surgery

© 2021 The Author(s). Published by ACT Publishing Group Ltd. All rights reserved.

Lisacek-Kiosoglous AB, Georgiou AC, Antoniou SA, Ristanis S. Efficacy of Minimally Invasive Surgery on Hallux Valgus – A Systematic Review and Meta-Analysis. *International Journal of Orthopaedics* 2021; **8(3)**: 1476-1492 Available from: URL: <http://www.ghrnet.org/index.php/ijo/article/view/3138>

INTRODUCTION

Hallux valgus (HV) is a deformity of the first ray and is one of the most common foot deformities that requires surgery^[1]. A recent systematic review and meta-analysis in 2010 pooling data from 76 studies and 496,790 participants showed a pooled prevalence estimate of 23% in adults aged 18-65 years and 35.7% in elderly people aged over 65 years^[2]. Often accompanied by significant functional disability and foot pain. Despite frequent mention in a diverse body of literature, a precise estimate of the prevalence of HV is difficult to ascertain. The purpose of this systematic review was to investigate prevalence of HV in the overall population and evaluate the influence of age and gender. In 2018/2019 alone the England NHS data digital service reported a total number of people admitted to hospital with a primary diagnosis of HV (acquired) to be 17,859^[3]. Additionally, when pooling the data from the years 2010-2019, we see a total number of HV finished consultant consultations to be 386,008^[3]. With regards to the number of actual procedures for HV correction, reported numbers in England between 2010-2019 were 378,856^[3]. This shows the importance of evidence based treatment as the number of people effected by the condition is significant.

More than 130 procedures have been described in the literature, all with varying degrees of success^[1,4]. Most of these procedures are performed by relatively large open incisions despite the growing body of evidence in favour of minimally invasive surgery^[1]. In part this is thought to be a result of the large learning curve with no substantial difference in patient outcomes^[1].

A recent Australian study looking at surgeon preference for HV showed a distinct correlation 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^[1,4]. The evolution of minimal incision surgery has led to some of these said procedures being performed minimally invasively, with no definitive consensus on which technique is more effective, or whether they are indeed more effective than the open counterpart^[1,5]. A systematic review conducted in 2018 on various minimally invasive surgical techniques indicated potential for three techniques namely Chevron, Akin^[5]. However, despite these promising results there remains a 13% reported complication rate, without appropriate long term follow up randomised controlled trials.⁵ In comparison, 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].

A Cochrane systematic review published in 1999 highlighted that there was no superiority between interventions with regard to open techniques^[6]. However, the authors noted the poor methodological quality of the 12 small included trials. In light of the large number of people effected with hallux valgus deformity and the lack of robust high quality evidence for the different surgical procedures, it is evident further research is required in order to make definitive recommendations for surgeons choice of technique and future training.

Aim / Hypothesis

The aim of this study is to systematically search the literature in order to evaluate the effect of minimally invasive surgery (MIS) over conventional open surgery for hallux valgus with respect to surgical outcomes and patient reported outcomes. We hypothesise that there is no difference between MIS and Open approaches with regard to long term outcomes, but a superior effect seen with MIS in the short term.

METHODS

The preferred reporting items for systematic reviews and meta-analyses 2009-2020 (PRISMA) statement was used as a reporting guideline for this study^[7].

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 for the correction of Hallux Valgus Surgery compared to Open Surgery?" – an update of the most current literature.

Eligibility Criteria for Studies

The inclusion and exclusion criteria were created by discussion among the authors and were based on the most recent techniques identified in our initial 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 first search was on June 1st 2020, and the last search was on January 27th 2021. We considered studies published in English in the last 10 years.

Search Strategy

The systematic review and meta-analysis was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines^[7]. A systematic review of data bases: Medline Complete, PubMed, Cochrane Library, Scopus, SAGE Journals and gray literature was performed. This was performed on the 6th of June 2020 with limits from 2010 until 2020 and an updated search was performed on the 27th of January 2021. Due to the larger learning curve and recent advances in surgical techniques we limited our search to 10 years. Search terms included: ("Hallux" OR "Hallux Valgus" OR "Metatarsus 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.

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.

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. If there was missing data or the data of effect was not homogenous with other papers, authors were contacted in order to request the missing information. This was done in eight of the 15 comparative studies, of which there were three replies in the period August 2020 until January 2021. The authors who provided extra data on request were Frigg *et al.* 2020 and Kaufmann *et al.* 2020.

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 they applied measures to eliminate confounding and 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 7 years. For the primary analysis on surgical outcomes we used final follow up times ranging from 1-7 years. For Primary analysis on patient reported outcomes we used both stratified and final follow up times ranging from 1 day-7 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^[23]. If absolutely necessary means or standard deviations were taken from figures in the included studies.

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 RevMan 5.4 software downloaded from the Cochrane library. Where possible mean difference and standard deviations were input as primary outcomes, as well as post operative means and standard deviations. If authors presented median and interquartile ranges, the authors were contacted to request means and standard deviations for the data set. Relative risk ratios with 95% confidence were calculated using RevMan 5.4 with the number of events of complications and satisfaction (see table 4-5 of results). Higgins’s I2 Heterogeneity statistic was used and generated by RevMan. The interpretation of the I2 test was based on the common opinion that >50% represents substantial heterogeneity^[23]. Subgroup analysis was based on procedure type and severity of HV. Pooled estimates were also considered if no particular paper skewed the data in any direction.

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 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

Table 2 Eligibility Criteria

Studies	Participants	Interventions	Comparisons	Outcomes
INCLUSION CRITERIA				
Randomised Controlled Trials(RCTs), Non-RCTs, observational studies; Peer reviewed; Journals; conference, proceedings; 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 and Secondary 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, 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.

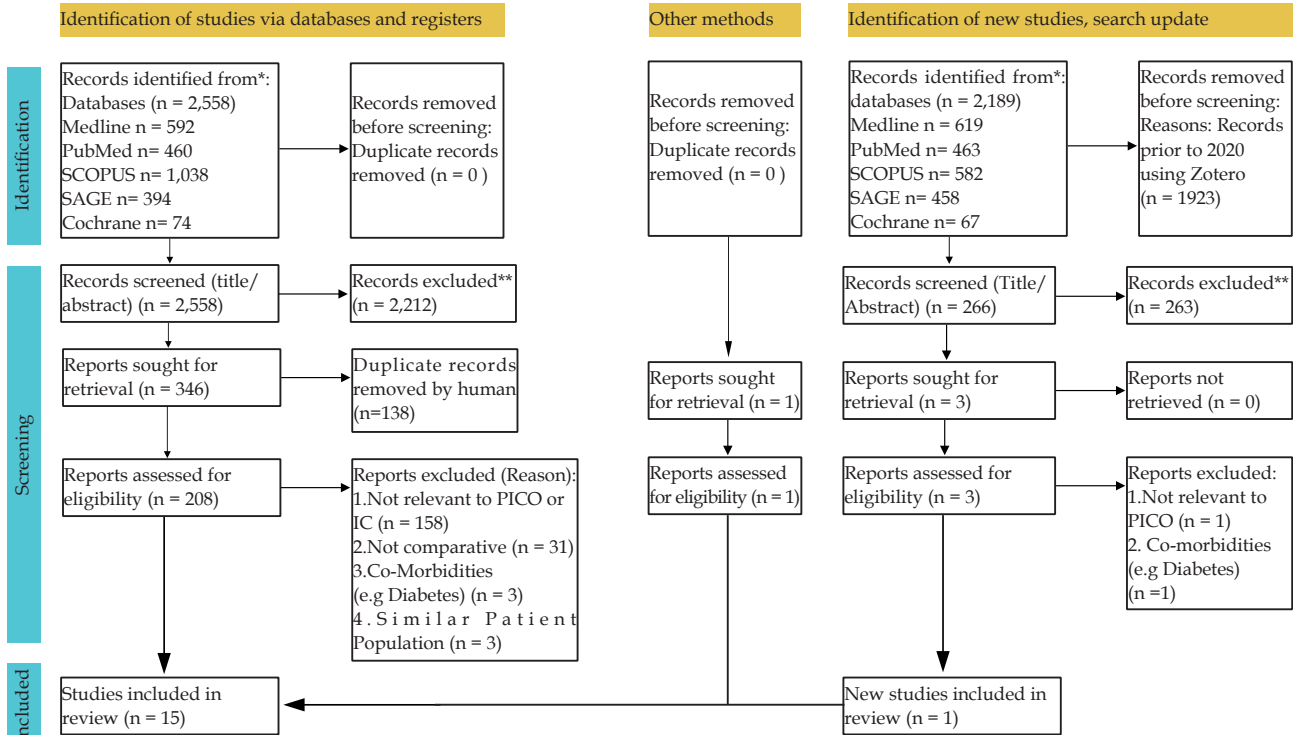


Figure 1 Flow-chart showing the flow of studies through the review^[8,9,18-22,10-17].

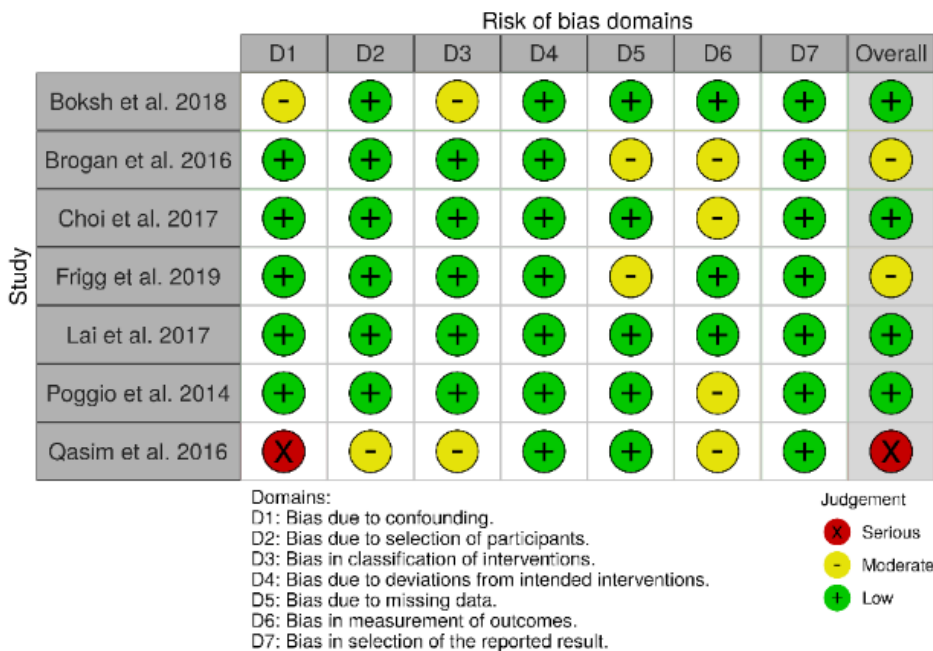


Figure 2 Risk of Bias In Non-randomised studies (ROBINS-I), traffic light plot.

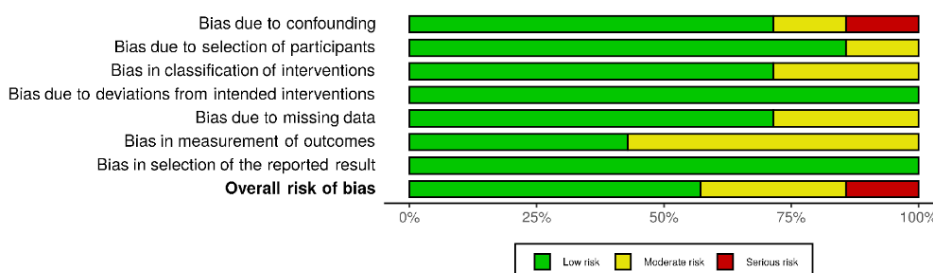


Figure 3 Risk of Bias In Non-Randomised Studies (ROBINS-I), summary plot.

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 arose advice of a third person was sought.

The following Critical Appraisal Tools were utilised to appraise each full text paper: (1) Cochrane RoB-2 for randomized clinical trials; (2) 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 supplement the paucity of available RCTs on the subject.

RESULTS

The literature search identified 2558 abstracts that we examined for the efficacy of minimally invasive surgery for primary diagnosis of Hallux Valgus and an additional 2 papers were identified when the

search was updated in January 2021 (Figure 1). Among those 2112 papers were removed due to not being related to the research question. Duplicates were removed from the remaining papers, leaving 209 eligible for full text screening. Predetermined inclusion and exclusion criteria were applied leaving 81 papers and 1 additional paper (Maffulli *et al.* 2009) removed from a systematic review by Singh *et al.* 2020. One of the additional papers by Schilde *et al.* 2020, was removed due to just falling short of the inclusion criteria, that being some patients were diabetic or were diagnosed with Rheumatoid Arthritis, as well as not focusing on one particular surgical technique. Overall the search revealed 15 eligible papers for analysis.

There were 5 randomised controlled trials (level II - NHMRC level of evidence), 3 pseudo-randomised controlled trials (level III-1), 6 cohort (III-2) and one non-randomised controlled trial (III-1)^[24]. All patients in these studies were diagnosed with Primary HV, ranging from mild, moderate or severe. Additionally, all patients were reported to be free from comorbidities. 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 15 studies identified was 907. Follow up times ranged from 1 day to 7 years, with the majority reporting 6 weeks, 12 weeks, 9 months, and

		Randomization process	Deviations from intended interventions	Missing outcome data	Measurement of the outcome	Selection of the reported result	Overall		
Kaufmann <i>et al.</i> 2018	1	+	+	+	+	?	!	+	Low risk
Radwan & Mansour 2012	1	+	+	?	-	?	!	?	Some concerns
Lim <i>et al.</i> 2020	1	?	+	+	+	+	+	-	High risk
Lee <i>et al.</i> 2017	1	+	+	+	+	+	+		
Kaufmann <i>et al.</i> 2020	1	+	+	+	+	+	+		
Giannini <i>et al.</i> 2013	1	?	?	+	+	+	!		
Maffulli <i>et al.</i> 2009	1	-	+	+	?	+	!		
Palmonovich <i>et al.</i> 2020	1	+	?	+	?	?	!		

Figure 4 Risk of Bias-2 (ROB-2) assessment summary in randomised studies.

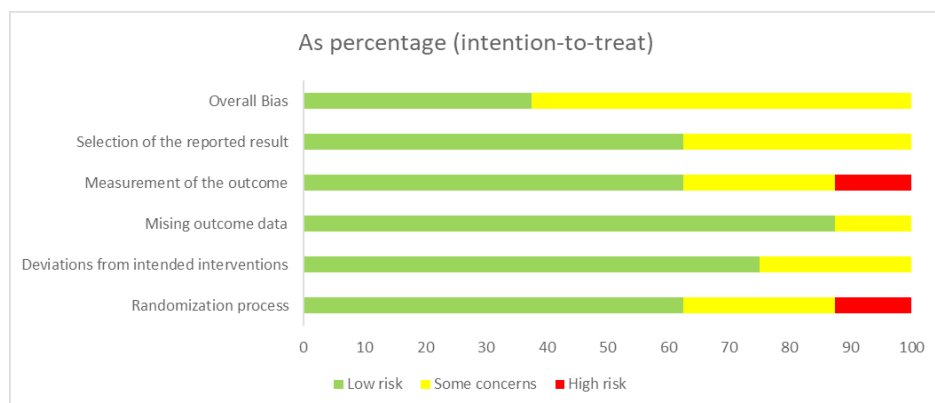


Figure 5 Risk of Bias-2 (ROB-2) graph in randomised studies.

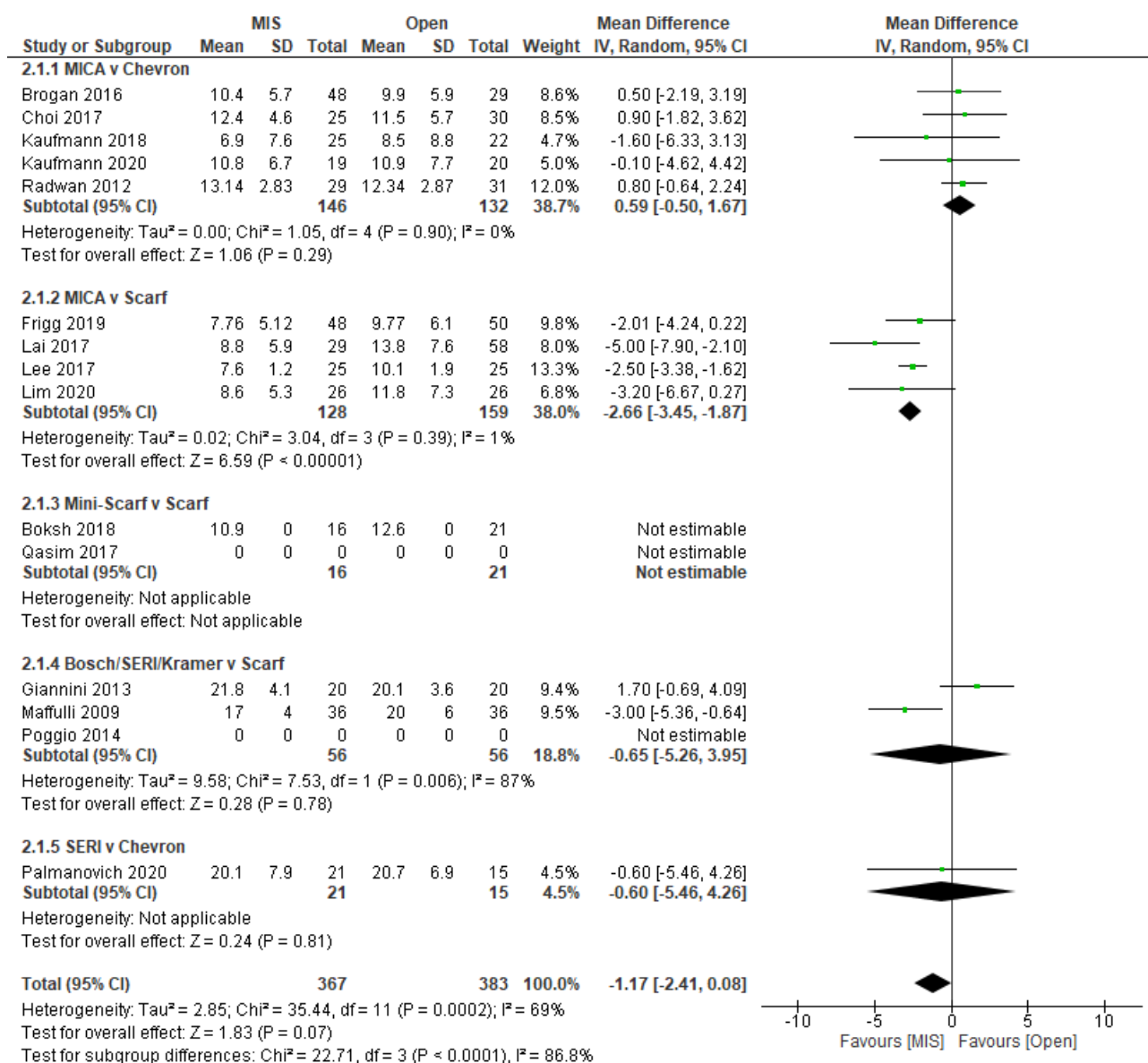


Figure 6 Forest plot of comparison: HVA Post op.

12 months follow up. This study did not only focus on one procedure, rather the most commonly used including Chevron, Scarf, SERI, Kramer and Bosch.

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 VAS pain scores were also included in order to elucidate a more objective understanding of patient reported outcomes. Where possible meta-analysis was performed in order to accumulate similar papers with similar outcomes so that the association between the surgery technique and the outcome may better be elucidated. Due to the varied outcomes presented by authors not all outcomes are consistent across all papers.

Risk of Bias Assessment

The revised Cochrane risk-of-bias tool for randomized trials was

used to assess risk of bias in the eight included RCTs^[25]. Additionally, the ROBINS-I tool was used as it was developed to assess risk of bias in observational studies that compare health effects of two or more interventions^[26]. Risk of bias summaries/graphs for all included studies are present in figure 2-5. Only one study was considered at high risk of bias because it was a conference proceeding and the original paper was not able to be identified through additional searches.

Results of individual studies

This systematic review includes 15 papers, with 907 participants across all studies, 76 of which were male and the rest female. The mean age range on included patients was from 32.7 to 54, with outliers at 69 years of age. (See Table 3 below for included studies).

Follow up times varied across all studies, with the majority reporting 12 monthly data. One study by Frigg et al. reported data as long as 5 years post operatively, and Gianni et al. 7 years. Where possible, similar post-operative follow up scores were grouped and stated in order to potentiate a more meaningful meta-analysis, otherwise final follow up times were used.

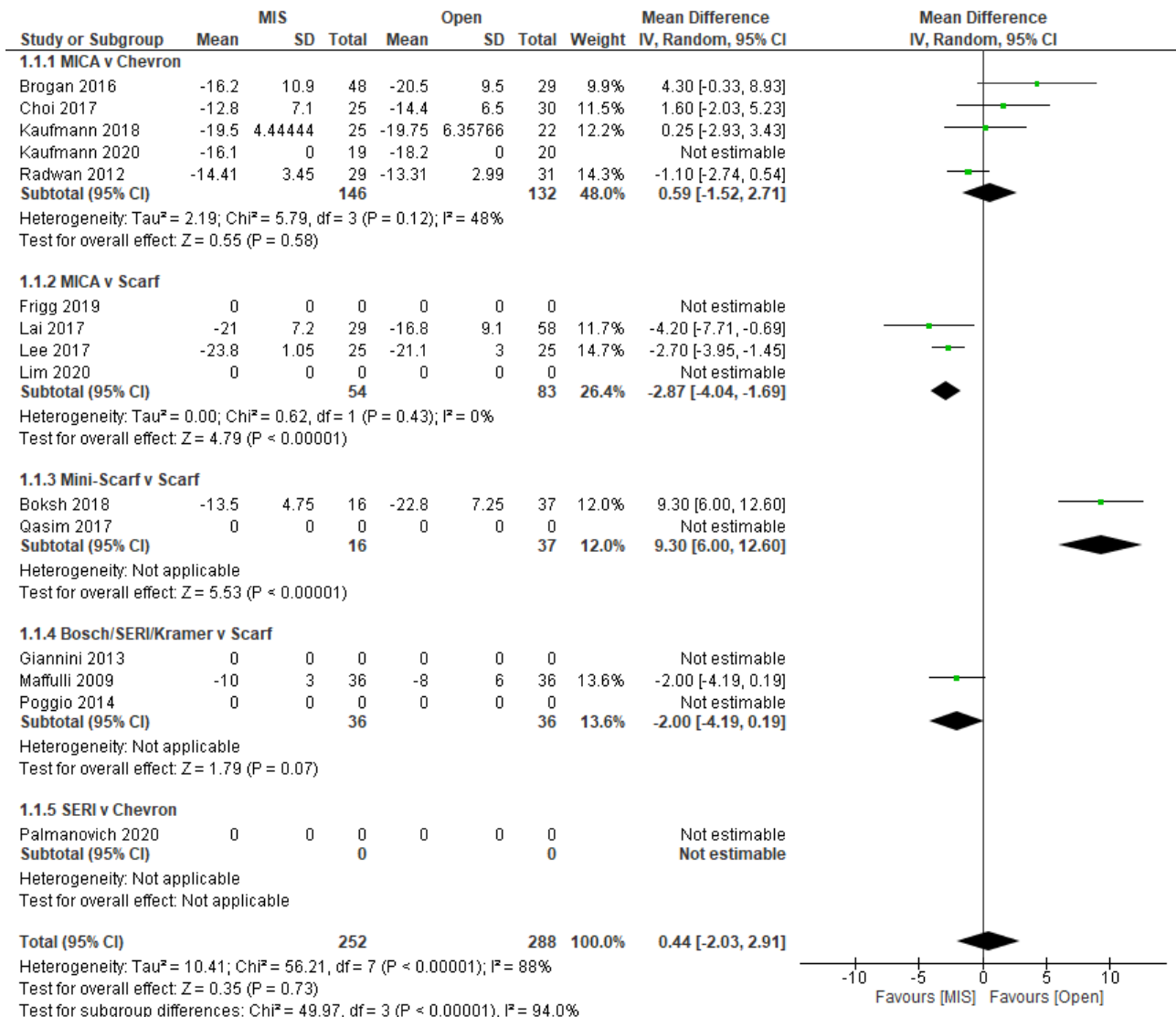


Figure 7 Forest plot of comparison: HVA Pre-Post Op Mean Difference.

Most studies provided data on preoperative and postoperative outcomes for hallux valgus angles, intermetatarsal angles, distal metatarsal articular angles, AOFAS scores, satisfaction, complications, subjective pain scores and post operative protocols. Whilst there is a myriad of techniques for treating hallux valgus only fifteen papers that met our inclusion criteria were present in the literature comparing minimally invasive techniques to more traditional open procedures. These techniques are generally understood to be of use for different severities of hallux valgus. 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 Figures 6-13 the analysis included subgroups of the following comparisons: MICA v Chevron, MICA v Scarf, Mini-Scarf v Scarf, as well as Bosch/Kramer/SERI v Scarf.

Surgical Outcomes (Radiological Analysis)

Forest plot comparisons can be seen in figure 6-13. Scores of ‘0’ indicate no data was available, therefore was not included in the comparison.

Hallux Valgus Angle (Figure 6-7)

The analysis of the post-operative HV angle (Figure 6) revealed

no significant difference overall (12 studies) comparing MIS and Open techniques. MD = -1.17; 95% CI: -2.41, 0.08; I² = 69%; (p = 0.07). No appreciable difference was observed when removing observational studies from the analysis (p > 0.05). Subgroup comparison (Post-op only) comparing MICA v Scarf (4 studies) revealed a statistical significant pooled effect in favour of MIS between groups (p < 0.00001), MD = -2.66; 95% CI: -3.45, -1.87; I² = 1%; Figure 6 Notably no appreciable difference was observed when removing two observational studies (p < 0.00001).

Comparison of mean difference (Pre-post operative) (Figure 7) was not significant overall MD: 0.44 [-2.03, 2.91] (9 studies) as previously reported in a systematic review^[27]. Post-hoc analysis (5 studies) with RCTs, revealed a significant difference (p = 0.002) MD: -1.78; 95% CI: -2.89, -0.68; favouring MIS, this was appreciable due to the study by Lee et al. 2017 (MICA v Scarf). Regarding subgroup analysis, Pre-Post Op mean difference also showed a significant difference in favour of MICA over Open Scarf p < 0.00001 (Figure7); MD = -2.87; 95% CI: -4.04, -1.69; I² = 0%.

One study by Boksh et al, comparing Mini-Scarf vs Open scarf reported a significant difference between groups p < 0.05 for min-scarf and p < 0.001 for open scarf^[17] (Figure 7).

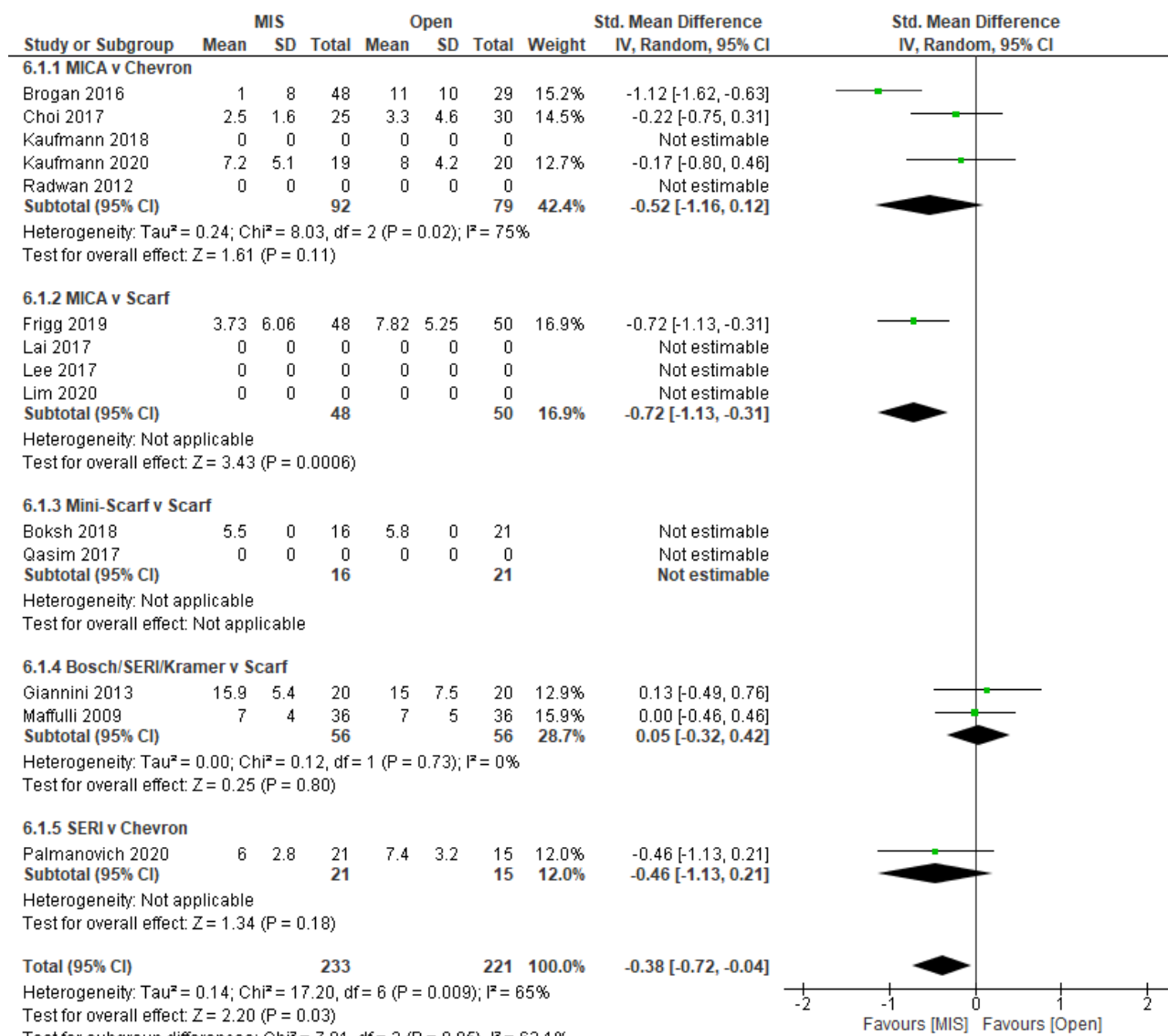


Figure 8 Forest plot of comparison: DMAA Post-op.

It is important to note, that no statistical significance was observed with any comparable techniques.

Intermetatarsal Angle

Fourteen studies reported post-operative intermetatarsal angles, overall pooled estimates did not reach statistical significance. ($p = 0.76$) MD=-0.04; 95% CI: -0.32, 0.24; I² = 70%. As previously reported in a systematic review, there was no statistical significance of overall mean difference pre-post op^[27]. No appreciable difference was observed when only considering RCTs.

There was no statistical difference observed across all subgroups, with post-op or pre-post op analysis.

Distal Metatarsal Articular Angle (Figure 8)

Eight studies reported post-operative DMAA's and were included in the analysis, see figure 8. The overall effect was found to be significant in favour of MIS, ($p = 0.03$); I² = 65%; MD=-0.38; 95% CI: -0.72, -0.04. However, this was not held when observational studies were removed from the analysis. In two individual studies by Brogan et al 2016 (MICA v Chevron) and Frigg et al 2019 (MICA v Scarf) a statistically significant effect was found in favour of MIS.

Patient reported outcomes

American Foot and Ankle Society Score (AOFAS) (Figure 9-10)

Eleven studies reported post-operative AOFAS scores (figure 9). However, only ten provided complete data for synthesis. Frigg et al. 2019 and Kaufmann et al. 2020 provided missing data through email correspondence. Palmanovich et al. 2020 reported a limitation of their paper was the missing pre-operative AOFAS scores, but a higher mean AOFAS score postoperatively at 1 year in favour of MIS. Overall, pooling all available studies (RCTs and Observational studies) no statistical significance was reached comparing MIS and open procedures at final follow up ($p > 0.05$) see figure 9. When removing observational studies from the analysis, no statistical significance was reached ($p > 0.05$) comparing MIS with open at final follow up (Ranges 6 months-5years). A high level of heterogeneity was observed when pooling all RCTs. Heterogeneity: I² = 80% MD=-0.35; 95% CI: -0.14, 0.83.

Subgroup analysis according to procedure type did not reach statistical significance, $p > 0.05$.

Ten studies reported pre-post-operative AOFAS mean differences and respective standard deviations (See figure 10). When pooling all available studies, no statistical significance was reached ($p = 0.07$). I² = 80% MD=-2.79; 95% CI: -5.84, 0.27. After removing

Lisacek-Kiosoglous AB *et al.* Minimally Invasive Surgery for Hallux Valgus

Table 3: Table of included comparative studies. Severity defined as Mild (HVA < 20 degrees), Moderate (HVA 20-40 degrees) & Severe (HVA >40 degrees). Values Mean (Standard deviation) unless otherwise specified. R=Range, IQR= Interquartile Range, RCT=Randomised Controlled Trial, NR-CT=Non-randomised Controlled Trial.

Authors	Study Design	NHMRC	Severity	Technique	Consent	Age-Range Mean(SD)	Male/ Female	Incision Length (mm)	No. of Participants	No. of Feet	Follow up (wk/ m/y)	Lost to follow up
Maffulli et al. 2009	Pseudo-randomised Trial	III-1	Mild to moderate	Bosch v Scarf	YES	52.6(3) Bosch, 51.5(3.1) Scarf	0/36	20mm Bosch, 60mm Scarf	36 Bosch, 36 Scarf	72	2.5y (range 2.1-3.2)	None
Radwan et al. 2012	RCT	II	Mild to moderate	Percutaneous v Open Chevron	-	32.7 (7.4) MIS, 35.7 (6.9) Open	4/25 MIS, 3/28 Open	10 to 20 mm / x2(2nd incision was only K-wire) MIS, 50mm Open	31 MIS, 33 Open	64	21.7m (range 13 - 36)	yes x2 each group
Giannini et al. 2013	Pseudo-randomised Trial	III-1	Mild to moderate	SERI v Scarf	YES	53(11)	-	10mm SERI, 30mm Scarf	20 SERI, 20 Scarf	20 SERI, 20 Scarf	2y and 7 years	None
Poggio et a 2014	Retrospective Cohort	III-2	Mild to moderate	SERI/ KRAMER v Scarf	YES	62.5 (8.9) SERI, 52.9 (10) Scarf	3/56 SERI, 9/93 Scarf	-	59 SERI, 102 Scarf	69 SERI, 133 Scarf	1 y	None
Brogan et al. 2016	Retrospective Cohort	III-2	Mild to severe	MIS v Open	-	53 (10.8) MIS, 57(10.9) Open	7/46 MIS, 0/32 Open;	Stab incisions MIS, traditional open technique	49 MIS, 32 Open	49 MIS, 32 Open	31 m (range 26-58) MIS, 37m (24-58) Open	None
Qasim & Mangwani 2016	Comparative cohort	III-2	Mild	Short Scarf v Open Scarf	-	49 (13)	-	-	16 Short, 21 Open	16 Short Scarf, 21 Open	3m (range 2-12)	None
Choi et al. 2017	Retrospective Cohort	III-2	Moderate	MIS v DCMO	Ethics	21.3(5.1) MIS, 22.4(3.8) DCMO	0/21 MIS, 0/24 Open	8-10mm proximal to bunion MIS, 20mm for adductor tenotomy + 45.4(2.8) medial incision Open	21 MIS, 24 Open	25 MIS, 30 Open	20 m MIS, 20.5m Open	None
Lee at al. 2017	RCT	II	Moderate to severe	PECA v Open	Yes	52.6 (R,20-76) PECA, 53.4 (R,25-75) Open	2/23 PECA, 3/22 Open	3-5 mm at tarsometatarsal joint PECA, Traditional Open	25 PECA, 25 Open	25 PECA, 25 Open	1 day, 2 weeks, 6 weeks, and 6 months	None
Lai et al. 2017	Retrospective Cohort	III-2	Mild to severe	PECA v Open Scarf	-	54.3(12.8) PECA, 54.3 (12.7) Open	4/25 PECA, 6/52 Open	3-5 mm PECA, Traditional Open	29 PECA, 58 Open	29 PECA, 58 Open	6m and 24m	None
Kaufmann et al. 2018	RCT	II	Mild to moderate	MIS Chevron v Open Chevron	-	52 (IQR 25) MIS, 44 (IQR 25) Open	4/21 MIS, 3/19 Open	3-5 mm / x2 (3-5mm) for STR MIS, 40mm OPEN	25 MIS, 22 Open	25 MIS, 22 OPEN	6, 12 weeks and 9 months	none
Boksh et al. 2018	Prospective Cohort	III-2	Mild to moderate	Mini-scarf v Scarf	-	52.2(14) Mini, 46(13.2) Open	-	Mini is halfway between open and percutaneous.	21 Mini, 16 Scarf	21 Mini, 16 Scarf	28 m	None
Frigg et al. 2019	NR-CT	III-1	Mild to moderate	MICA v Open Scarf/ Akin	YES	48.04 MIS, 48.23 Open	7/41 MIS, 6/44 Open	15mm MIS, Longitudinal incision Open	48 MIS, 50 Open	98	24m	None
Lim et al. 2020	Pseudo-randomised Trial	III-1	Mild to moderate	MICA v Open Scarf	Ethics	48.7 (13.4) MIS, 52.3 (15.7) Open	-	Stab incision MIS, medial longitudinal incision Open	26 MIS, 26 Open	52 MIS, 52 Open	12.9 m MIS, 16.8 m Open	None
Kaufmann et al. 2020	RCT	II	Mild to moderate	MIS Chevron v Open	YES	54(15.2) MIS, 47(14.3) Open	3/16 MIS, 3/17 Open	3-5mm MIS, Standard Open	19 MIS, 20 Open	19 MIS, 20 Open	6 wks, 12, wks, 9m, & >5 y.	8
Palmanovich et al. 2020	RCT	II	Mild to Moderate	SERI v Chevron	Ethics	38.7(23) SERI, 49.2(18.9) Chevron	6/14 SERI, 3/12 Open Chevron	Minimal incision	21 SERI, 15 Chevron	38	1 year	none

Table 4 Comparative studies complications table. * indicates no specific numbers were attributed to the complication. Sgx = surgery was required, with reason. CRPS=Chronic Regional Pain Syndrome.

	Kaufmann 2018		Radwan 2012		Choi 2017		Lim 2020		Boksh 2018		Brogan 2016		Lee 2017		Lai 2017		Frigg 2019		Qasim 2017		Kaufmann 2020		Poggio 2013		Giannii 2014		Maffulli 2009		Palmanovich 2020			
Total patients n=	25	22	29	31	25	30	52	52	16	21	48	32	25	25	29	58	15	19	16	21	19	20	69	133	20	20	36	36	35	15		
Complications	MIS	OPEN	MIS	OPEN	MIS	OPEN	MIS	OPEN	MIS	OPEN	MIS	OPEN	MIS	OPEN	MIS	OPEN	MIS	OPEN	MIS	OPEN	MIS	OPEN	MIS	OPEN	MIS	OPEN	MIS	OPEN	MIS	OPEN	MIS	OPEN
K-wire removal	12																				16									1		
Screw removal		2					1				4	1	6					13	1			4				2						
Delayed healing																	0	5					*	*								
Osteotomy displaced																							*	*								
fracture of 1st MT																		1					*	*								
Revision surgery					2	1	1											4					2						2	4		
Radio Recurrence		3						1			1	1					3	2			2	3										
Troughing																		1					*	*								
Superficial infection			2	1			2	2								3	2	0					*	*						1		
Deep infection								1															2	sgx								
Decreased ROM			2	3		1											0	0								3	4			0	1	
wound dehiscence				1																												
Paresthesia				4							4	1					4	4														
Ongoing pain												1					2													1		
CRPS																	5	5					*	*								
Metatarsalgia														2												1						
Hallux Varus																						1										
Degenerative (arthritis)																	1	2								1						
TOTAL:	12	5	4	9	2	2	4	4	-	-	9	4	6	2	0	3	30	25	-	-	18	8	19	9	3	8	11	6	5	5		

observational studies from the analysis no statistical significance was achieved. ($p = 0.57$) $I^2 = 72\%$ MD=-1.24; 95% CI: -5.84, 2.99.

Subgroup analysis (Figure 10) of pre-post op mean difference based on procedure revealed a statistical significant difference in favour of Open-Scarf when comparing MICA v SCARF, ($p = 0.003$) $I^2 = 0\%$; MD=-5.54; 95% CI: -9.19, -1.88; However, this did not hold when removing the observational studies leaving only the study by Lee et al. 2017. When comparing similar techniques Bosch/Kramer/SERI v Scarf(3 studies), a statistical significant difference was observed in favour of Open-Scarf ($p < 0.00001$); $I^2 = 2\%$; MD=-6.04;95% CI: -7.38, -4.71. After removing Poggio et al. 2014 and leaving only 2 pseudo-randomized trials for analysis, a statistical significance was still observed in favour of Open-Scarf $p < 0.05$.

SF-36 – Short Form-36

Two studies by Lim et al. 2020 & Lai et al. 2017 used standardized patient reported outcome measures including AOFAS, VAS and SF-36, measured both pre and post operatively. Lim et al reported a statistically significant difference in favor of MIS for SF-Role Physical (RP) and SF-Social Function (SF). SF-Physical Function just missed statistical significance with a P value of $p = 0.07$. Note the preoperative SF-36 sub groups were all non-statistically different between groups.

Lim et al. reported on SF-36, physical function and mental health subscale, neither reached statistical significance between groups at 6 or 24 months post operative.

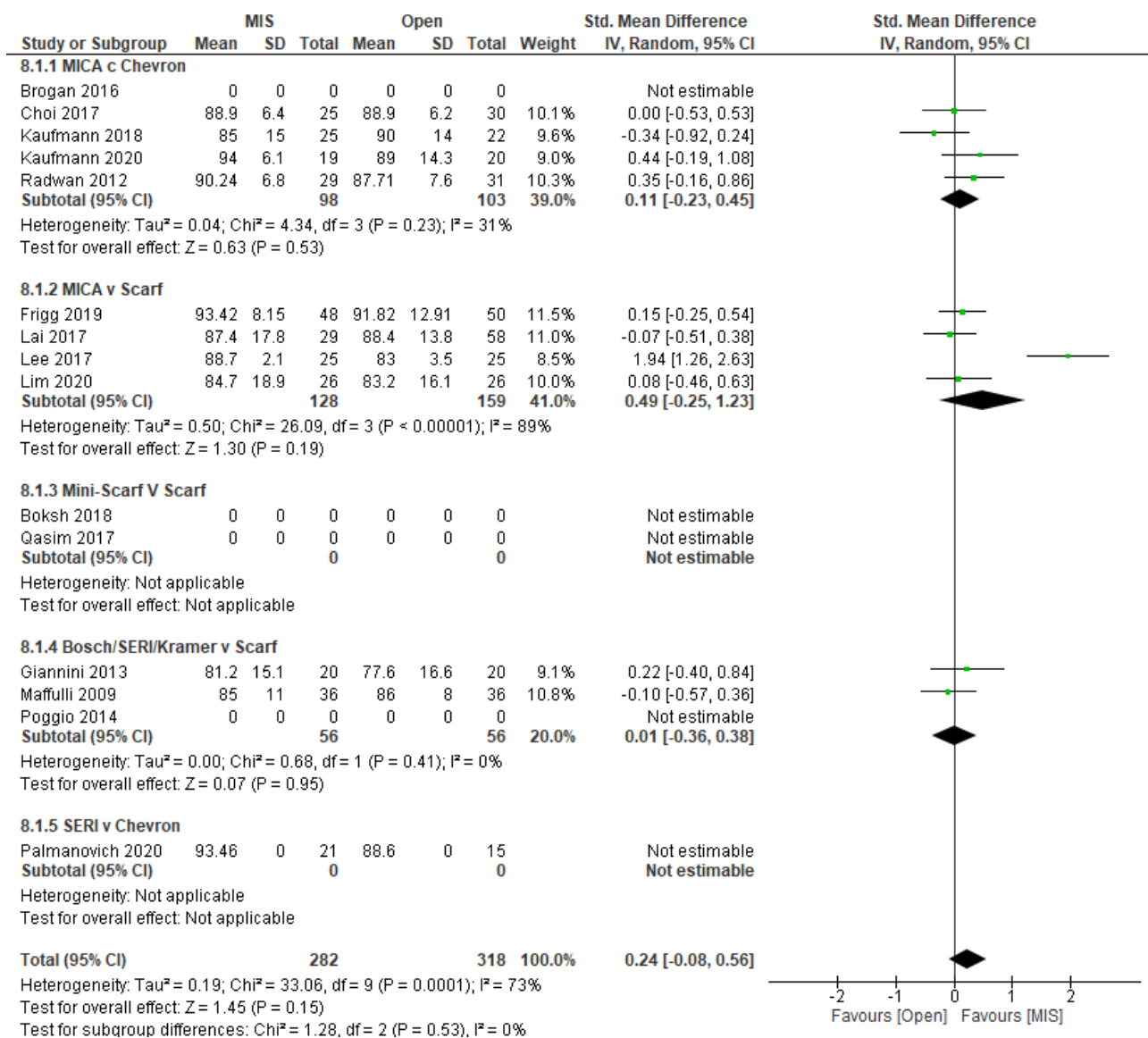


Figure 9 Forest plot of comparison: AOFAS Post Op Mean Differences.

Manchester Oxford Foot questionnaire score (MOxFAQ)

The MOxFAQ score was reported in two studies. Boksh *et al.* 2018 reported a significant difference favouring the procedures within groups pre and post operatively, both achieving significance $p < 0.01$. Data comparing groups was not provided. The standard scarf achieved a score of 15.5 +/- 17.1 post operatively and the Mini-Scarf achieved a score of 19.9 +/- 25.3 post operatively at 28 months follow up.

Brogan *et al.* 2016 (MICA v Open) reported no statistical significance in any domain (Walking, Pain, Social interaction) between groups at the mean post-operative period 31-37months.

Pain VAS (Figure 11)

Five studies (MICA v Scarf or, MICA v Open Chevron) reported Pain on a visual analogue scale (VAS), with follow up including: Day 1, 2 weeks, 6 weeks, 12 weeks, 6 months and final follow up differing from 9 months, 2 years and >5 years. No statistical significance was found overall (Figure 11) when pooling papers final follow up times (6months to > 5 years). ($p = 0.81$) MD=-0.06; 95% CI: -0.59, 0.46^[9-11,15,21].

Met-Analysis was not possible at all levels of subgroup analysis

Table 5 Comparative studies complications table.

Complications	MIS Total (n = 424)	OPEN total (n = 520)
K-wire removal	29	-
Screw removal	24	10
Delayed healing	-	5
fracture of 1st MT	-	1
Revision surgery	7	9
Radio Recurrence	6	10
Troughing	-	1
Superficial infection	7	6
Deep infection	2	1
Decreased ROM	5	9
wound dehiscence	-	1
Paresthesia	8	9
Ongoing pain	3	1
CRPS	5	5
Metatarsalgia	-	3
Hallux Varus	-	1
Degenerative (arthritis)	1	3
TOTAL	97	75
%	21.1	14.0
% w/o Kwire	14.8	14.0

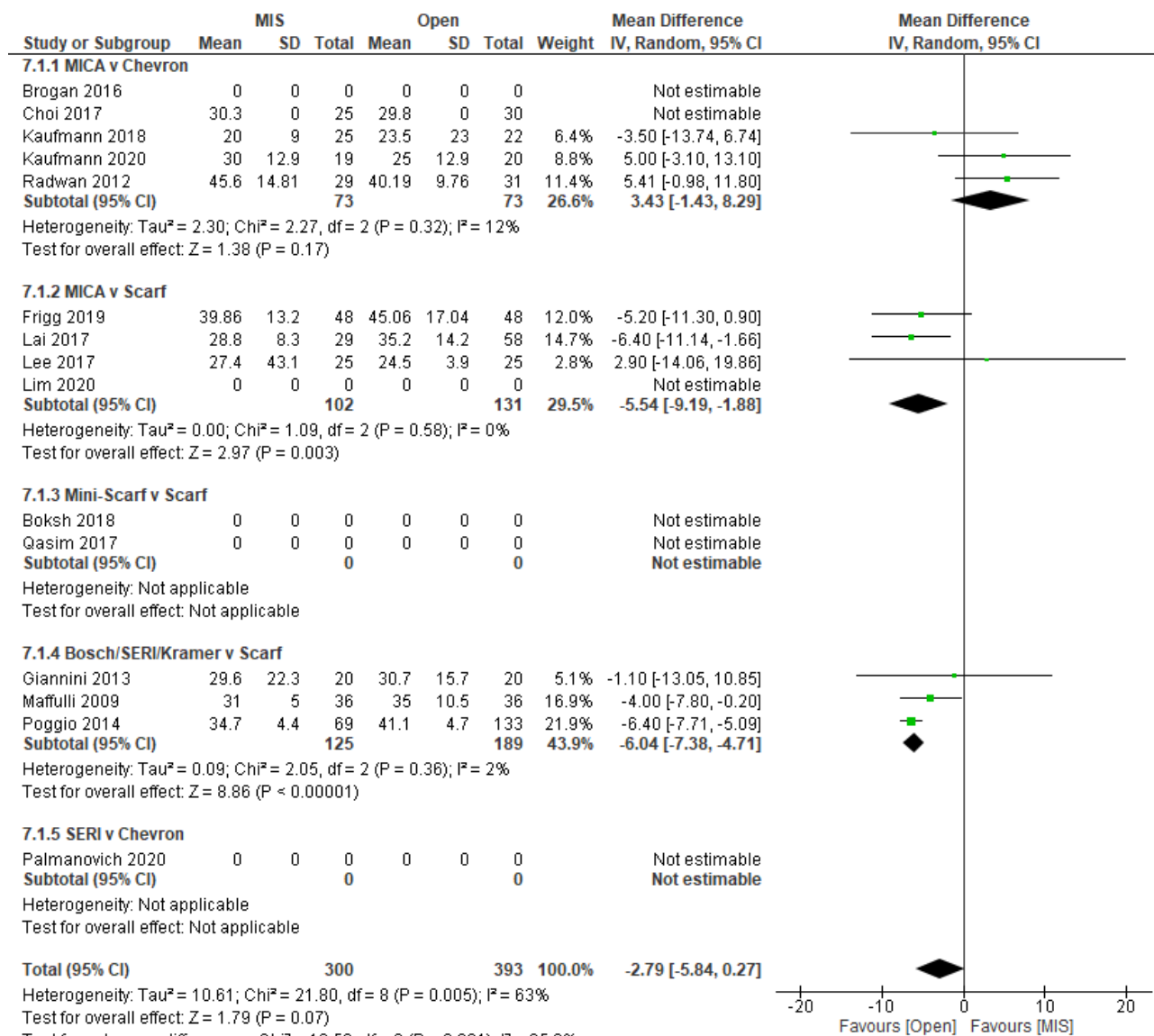


Figure 10 Forest plot of comparison: AOFAS Pre-Post Op Mean Differences.

due to the low number of similar studies. Figure 11 allows for comparison of postoperative Pain VAS scores at different follow up times and should be interpreted with caution. Comparing MICA v Scarf, (Studies by Lai, Lee & Lim) a statistical significant difference in favour of MIS is observed at Day 1 ($p < 0.00001$) MD = -1.96 95% CI: -2.28, -1.65; I² = 0%; Week 2 ($p = 0.001$) MD = -1.40; 95% CI: -2.26, -0.54; and Week 6 ($p = 0.005$) MD = -1.50; 95% CI: -2.55, -0.45. There was no statistical difference at 6 months (3 studies) ($p = 0.46$) MD = -0.16; 95% CI: -0.59, 0.27; I² = 0%; or final follow up (6 m to > 24m) ($p = 0.94$) MD = -0.02; 95% CI: -0.44, 0.41; I² = 0%. This held true when the observational study by Lai et al. was removed.

In a sub group analysis comparing MICA v Open Chevron (Kaufmann et al's two included studies) there is no statistical significant difference at any of the follow up times when pooling the data ($p > 0.05$). However, Kaufman et al 2020 reports a significant difference in favour of MICA over open Chevron at 5 years follow up. MD= -1.00 95% CI: -1.99, -0.01. (Note: this data was retrieved via email correspondence due to missing Standard deviations and mean values in the original paper as only IQR and Medians were provided).

Satisfaction (Figure 12)

Figure 12 depicts the pooled analysis of satisfaction, where the event is defined as satisfied or very satisfied. Ten studies reported subjective patient satisfaction on a scale of very-dissatisfied, dissatisfied, satisfied or very satisfied. An overall estimate of effect was not found to be statistically significant ($p = 0.22$) I² = 51%; RR = 1.06; 95% CI: 0.97,1.16. Accordingly, subgroup analysis involving removing observational studies from the analysis showed no statistically significant effect.

Complications (Figure 13)

Table 4 & 5 depicts the reported complications across all included studies. As can be seen in table 5 there is comparable complication rates between MIS approaches and Open, 14.8% to 14% respectively. An overall pooled effect was not found to be statistically significant ($p = 0.28$) I² = 61%; RR= 1.31; 95% CI: 0.80, 2.15 (Figure 13). There was no statistical significance when stratifying for procedure type or upon removing observational studies. Frigg et al 2019 (MICA v Scarf) reported on multiple complications in both groups, most notably that the rate of recurrence and other complications were comparable, except for reoperations which was higher in the MICA

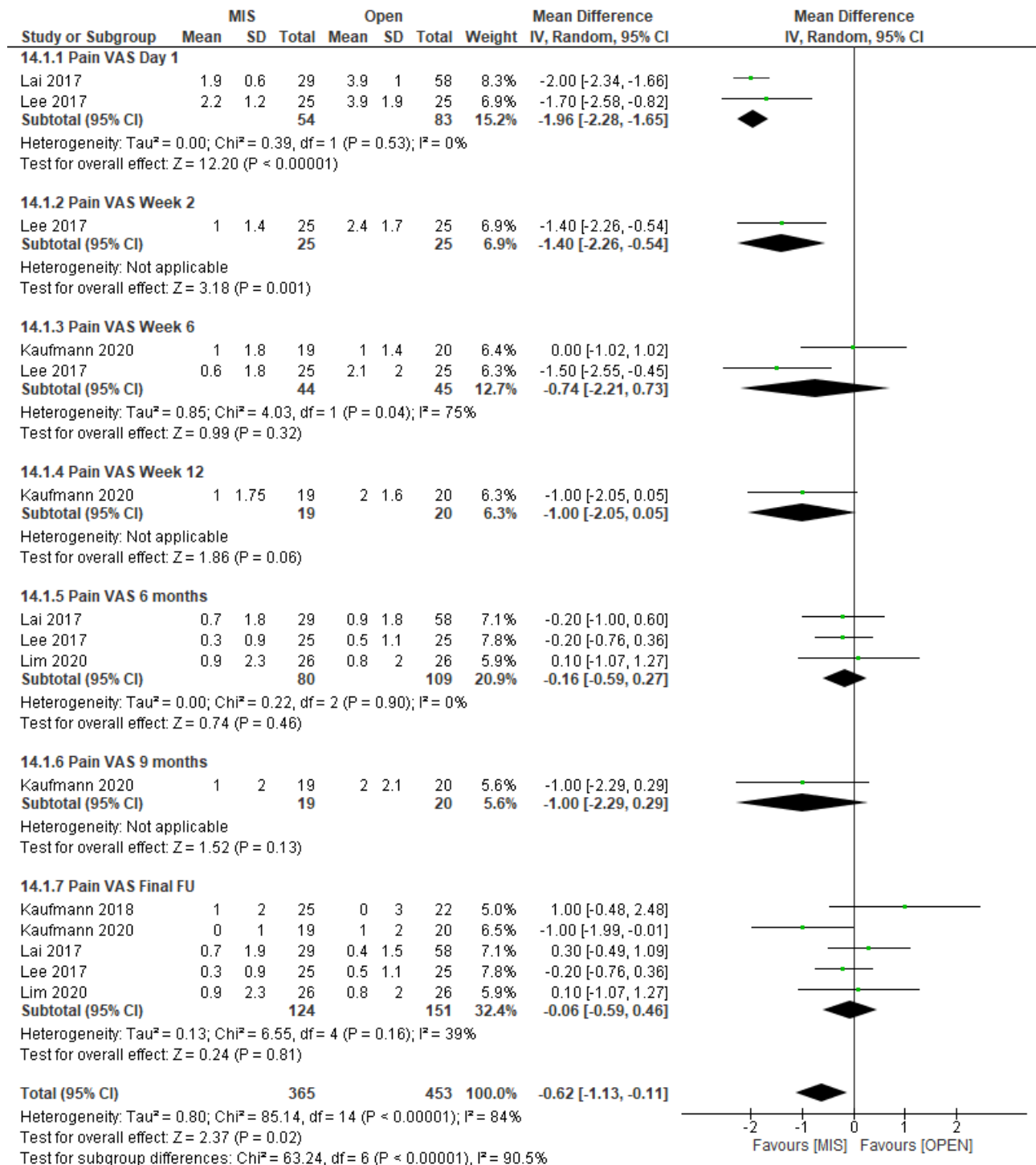


Figure 11 Forest plot of comparison: Post-op, Pain VAS.

group mainly for screw removal (27%) compared with scarf (8% for stiffness). It was also noted 14% in the MICA group were converted to open surgery.

Secondary outcomes

Incision size

In subgroup analysis comparing MICA v Chevron (5 studies) the average incision size as seen in table 3 was a stab incision, up to 20mm. For open chevron technique the largest was 50 mm. In MICA v Scarf, most of the MICA procedures were via a stab incision, whilst the Scarf procedures were mostly medial longitudinal incisions. The mini incision Bosh technique was reported to be 20 mm, whilst

the Scarf was 60mm. SERI was performed with minimal 10 mm incisions, whilst the comparative Scarf was 30 mm.

Post op protocols & rehabilitation

Ten of the fifteen included papers provided their post operative protocols. Of the studies that implorded the MICA v Open Chevron technique, only one study by Radwan et al 2012 began with NWB for 2 weeks with an appropriate back slab and bandage to maintain toe alignment, followed by AROM/PROM at 4 weeks. The other four studies encouraged immediate weight bearing as tolerated from the day of surgery with an orthopedic shoe for 6 weeks as well as bandages that aimed to hold position of the hallux. Of the studies

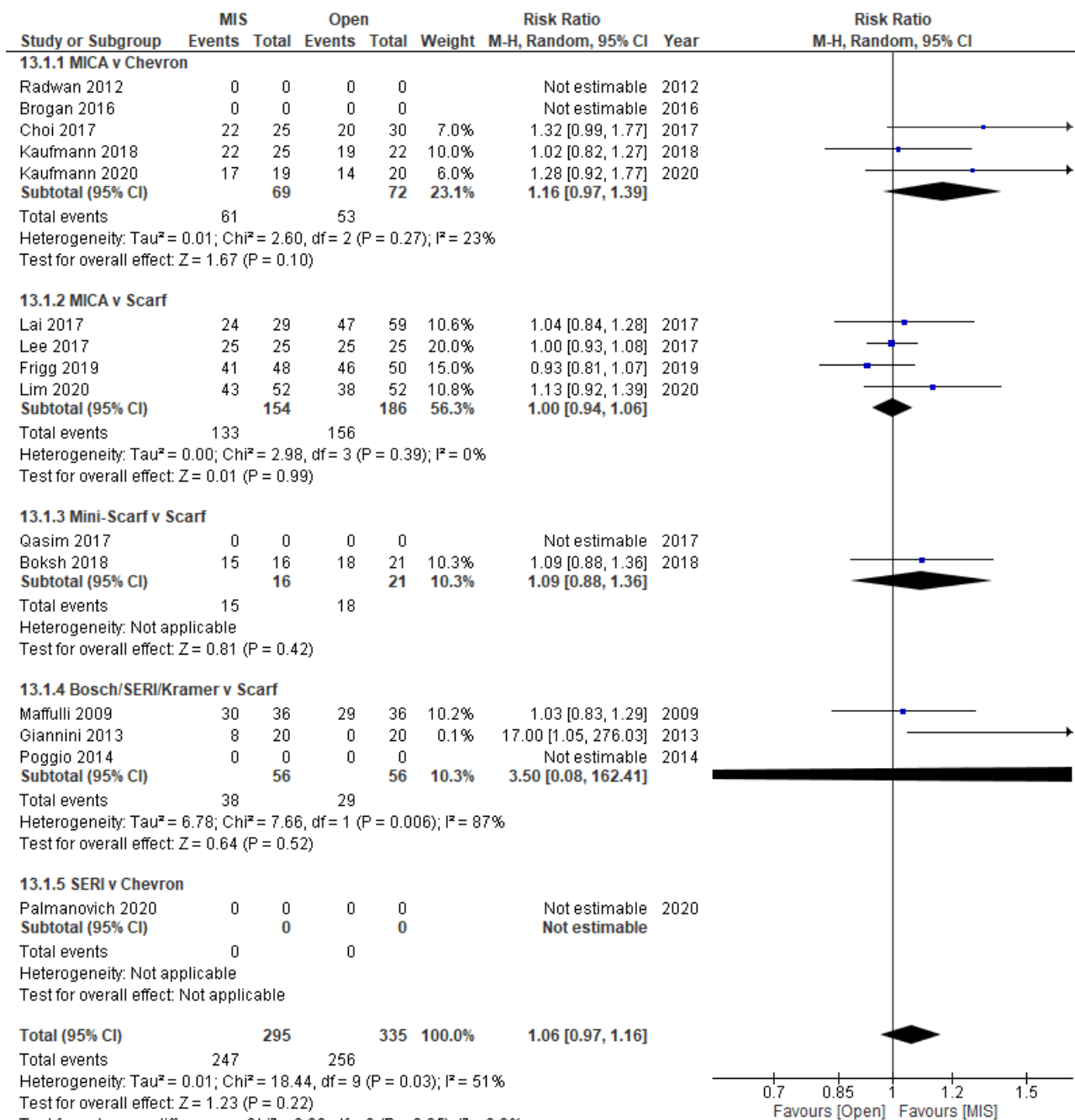


Figure 12 Forest plot of comparison: Patient Satisfaction.

using the MICA v Scarf techniques, they too used an orthopedic shoe and allowed FWB from day 0. Bandages were applied in all studies to ensure operative alignment was maintained. Lee at al. 2017 encouraged gentle AROM/PROM of the plantar flexors from 2 weeks along side gentle scar massage and Frigg et al. 2019 referred for physiotherapy at 6 weeks if ROM was < 20-30degrees. All studies included advice for post operative management for pain relief and advice for elevating the leg in the first two weeks and avoiding too much walking to encourage healing. Maffulli et al 2009, Palmanovich et al 2020 and Gianni et al. 2014 similarly had compression bandages, FWAT post operatively and K wire removal at the 4-6 week mark.

Cost effectiveness

Poggio et al. 2014 reported on the cost effectiveness when comparing Kramer and Scarf techniques. The AOFAS scores for Kramer and

scarf were 34.7 and 41.1 respectively $p < 0.05$, where patients in the Kramer group required more post-operative visits. The mean cost of follow up was significantly higher in the Kramer group (218.97 Euros vs 171.41 Euros, $p < 0.05$). Notably the Kramer technique also had significantly higher complication rates.

Qasim et al. 2016 reported cost effectiveness of the Mini Scarf procedure over the standard procedure, due to the length of the surgery and cost of the implant. Lim et al. 2020 reports on the cost effectiveness of simultaneous hallux valgus surgery for patients presenting with bilateral hallux valgus.

Meta-Analysis Figures 6-13; Produced using Rev Man v 5

DISCUSSION

The purpose of this review was to determine the efficacy of minimal

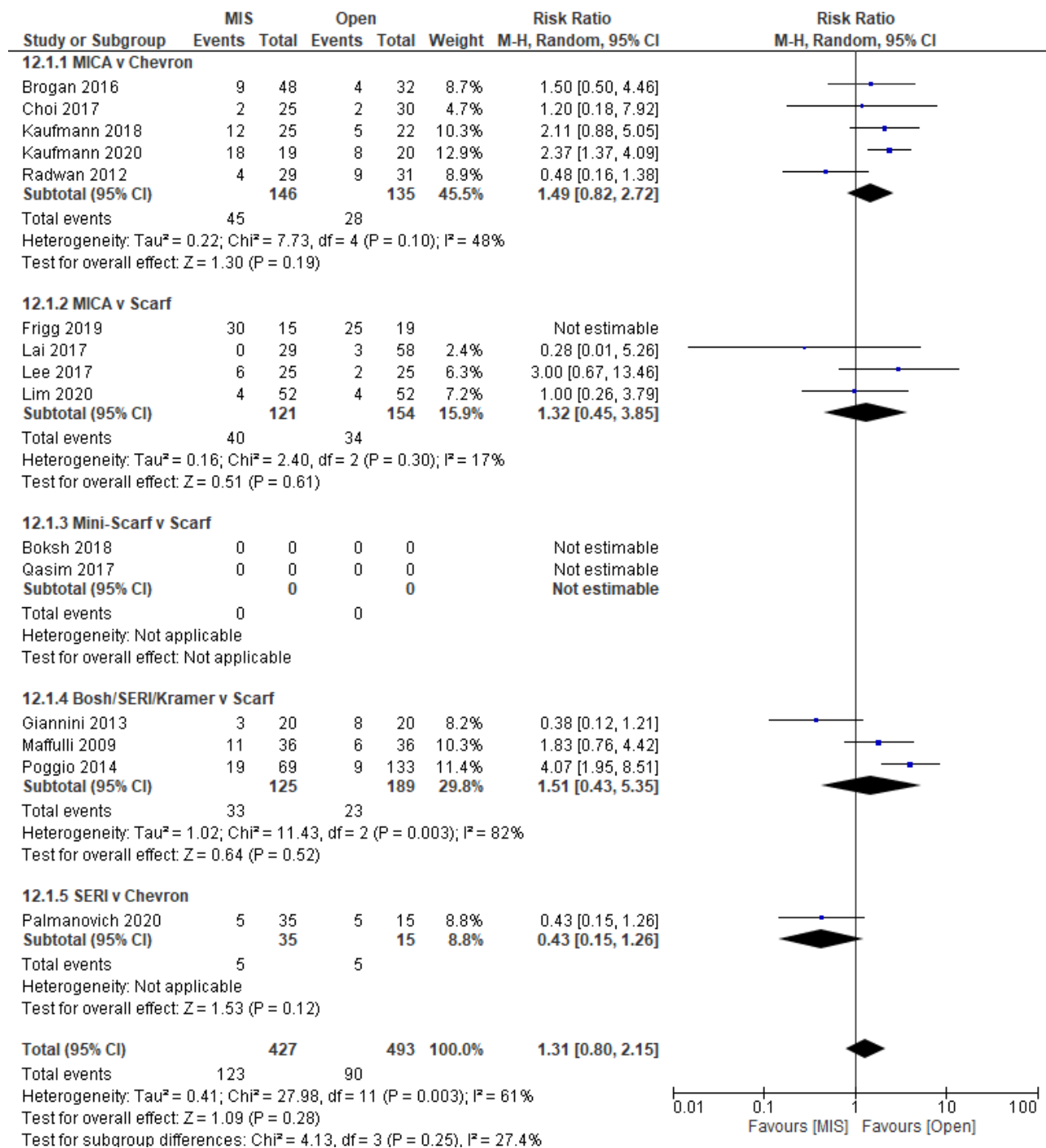


Figure 13 Forest plot of comparison: Complications

invasive surgery over traditional open approaches. We hypothesised that there was superiority of MIS in the short term but no difference with regard to long term outcomes. This is the first study to our knowledge that has provided an overview of minimally invasive surgery vs traditional open approaches based on the varying techniques used by orthopaedic surgeons.

With regard to surgical (radiological) outcomes our findings provide some evidence to show minimally invasive surgery is superior to its comparable open approach when considering only RCTs. However, only 5 studies were included in this analysis. There may be a statistically significant benefit of MIS, in particular in favour of MICA over Open Scarf, at final follow up with regard to the HV angle, this was not effected by removing observational

studies (4 studies in total). Our data showed no statistical significance across all subgroup analysis or overall with regard to IMA. DMAA was found to be statistically better in the MIS group, but this was not held when observational studies were removed from the analysis.

With regard to Pain on a VAS scale at final follow up, we found 5 papers with overlapping comparable follow up times. There appears to be a benefit of MICA over Open Scarf approaches with regard to Pain, at day 1, week 2 and week 6 follow up. However, meta-analysis including an observational study did not hold this true for week 6 to final follow up, indicating at final follow up there was no difference between procedures. In the study by Gianni et al & Frigg et al. 2020, some longer term data has shown the benefits of MIS, that being no difference to open approaches in terms of VAS, AOFAS,

and satisfaction, as well as surgical/radiological outcomes. This is promising as patients may enjoy both shorter term benefits with comparable longer term outcomes. More RCTs looking into short term outcomes e.g. pain are required to better understand comparable minimally invasive techniques over comparable open.

Interestingly, from our review there is no evidence to support any difference between minimally invasive surgery and comparable open techniques in terms of patient reported outcome measures (AOFAS scores) at final follow up. However, there may be a statistically significant benefit in terms of change in AOFAS scores in favour of Open Scarf over MICA at final follow up. Further controlled trials are required as only 6 studies have been reported. Bosch/Kramer/SERI v Scarf (3 studies) also showed a significant difference in favour of the open scarf, at final follow up. However, in terms of the same patients final follow up AOFAS score, no statistical significance was reached, further providing evidence there is no difference between Minimally invasive surgery and open techniques in terms of patient reported outcomes at final follow up.

Only a few studies provided additional patient reported outcomes, those being the MOxFQ and Short Form -36. Further research would benefit from the use of more validated patient reported outcome measures.

Interestingly we found an overall increased risk of complications in the MIS group 14.8% vs 14% in the Open groups. When attempting to analyse patient satisfaction based on event at final follow up, there too was no statistically significant difference between groups. We note the steep learning curve for MIS, and that surgeons should be cognisant of this fact when training to improve their practice. A recent comparative prospective cohort study assessing the learning curve reported a significant decrease in the number of complications after 50 procedures, 26% vs 15% in the second group^[28].

The somewhat confusing results in this study are due to the lack of large randomised trials and heterogeneity, as this study has not focused on one particular comparison, but has attempted to provide an overview of the evidence in the literature about the most currently used techniques. Therefore, careful attention is advised for the interpretation of the results. We believe this study provides a new overview of comparison between comparable techniques whilst considering their pooled estimates at the same time. This allows surgeons to appreciate the evidence when planning surgical techniques to achieve optimum patient outcomes.

We studied the association between MIS and open techniques and included both RCTs and Observational studies. We believe the results are complementary and have provided the estimates of pooling the data and when only considering RCTs alone. In the majority of cases no difference was found, therefore the conclusions of our review are stronger than if we would have included RCTs alone or observational studies alone. Similar conclusions have been found in other systematic reviews and meta-analyses further showing the direction of the data. Due to the fact the observational studies included as part of the analysis also caused changes to the results revealing statistical significance, there is proof that more RCTs are required in order to understand the true benefit of MIS.

Limitations

One of the main concerns about the data is that there appears to be a significant learning curve for MIS as reported in a number of studies^[29,30]. This is one potential cause for the heterogeneity observed. Whilst there is some consensus on the gross similarity between the different techniques^[27], a strength of this study is that it attempts to elucidate the potential for those effects and makes obvious

the paucity of available evidence to compare individual techniques with comparable open approaches. Another cause of heterogeneity was obvious when stratifying for technique type and we believe this is also the case for severity. Another limitation inherent in this study is the small sample size of the subgroup analysis (as pooling all studies showed high heterogeneity). The varied follow up times amongst studies and cases of missing data were unfortunately inherent. An attempt to contact authors was made however due to time constraints only one email was sent to authors.

A suggestion for future RCTs would be to include standardised follow up times, with data at day 1, week 2, week 6, and a final follow up being a minimum of 12 months to 2 years, and if possible again at 5 years in order to further validate the latest trial by Frigg *et al.* 2020. In particular focusing on patient reported outcomes at all stages of follow up. We believe our data should be encouraging for surgeons to gain knowledge and skills in Minimally invasive surgery as it appears to provide similar outcomes to open techniques, in trained hands.

CONCLUSION

Whilst minimally invasive surgery has been described as offering better patient outcomes, there is still a paucity of evidence with regard to the true benefits. This review provides some evidence that there is no significant difference between comparable minimally invasive approaches over traditional approaches with regard to both radiological and patient reported outcomes. However, there is some evidence that there is a superior effect of MICA surgery over Open Scarf with regard to HVA and short term post op Pain scores. The evidence provided in this systematic review allows us to partly accept our hypothesis that minimally invasive surgery is superior to open techniques in the short term, when comparing MICA and Scarf. However, we reject our hypothesis when comparing similar techniques, MICA v Open Chevron or Mini-scarf v Open Scarf. Additionally, the current evidence allows us to partly accept our hypothesis that long term outcomes of minimally invasive surgery are comparable to open techniques in comparable procedures. But not when considering radiological outcomes for MICA v Open Scarf. In essence, comparable procedures show no difference.

ACKNOWLEDGEMENTS

Many thanks to Professor Constantinos Tsioutis, European University Cyprus, School of Medicine for his personal guidance with the methodology. Thanks also goes to Sofokleia Christodoulou as an independent data assessor and data extractor.

REFERENCES

1. Lam P, Lee M, Xing J, Di Nallo M. Percutaneous Surgery for Mild to Moderate Hallux Valgus. *Foot Ankle Clin.* 2016; **21**(3): 459-477. [PMID: 27524701]; [DOI: 10.1016/j.fcl.2016.04.001]
2. Nix S, Smith M, Vicenzino B. Prevalence of hallux valgus in the general population: A systematic review and meta-analysis. *J Foot Ankle Res.* 2010; **3**(1): 21. [PMID: 20868524]; [DOI: 10.1186/1757-1146-3-21]
3. NHS Trust. *Hospital Admitted Patient Care Activity, 2017-18 - NHS Digital.*; 2018.
4. Iselin LD, Munt J, Symeonidis PD, Klammer G, Chehade M, Stavrou P. Operative management of common forefoot deformities: a representative survey of Australian orthopaedic surgeons. *Foot Ankle Spec.* 2012; **5**(3): 188-194. [PMID: 22547532]; [DOI: 10.1177/1938640012443284]

5. Malagelada F, Sahirad C, Dalmau-Pastor M, Vega J, Bhumbra R, Manzanares-Céspedes MC, Laffenêtre O. Minimally invasive surgery for hallux valgus: a systematic review of current surgical techniques. *Int Orthop*. 2019; **43**(3): 625-637. [PMID: 30218181]; [DOI: 10.1007/s00264-018-4138-x]
6. Ferrari J, Higgins J, Williams R. Interventions for treating hallux valgus (abductovalgus) and bunions. In: *Cochrane Database of Systematic Reviews*. John Wiley & Sons, Ltd; 1999. [PMID: 10796404]; [DOI: 10.1002/14651858.cd000964]
7. Page MJ, McKenzie J, Bossuyt P, Boutron I, Hoffmann T, Mulrow C, Shamseer L, Tetzlaff J, Akl E, Brennan SE, Chou R, Glanville J, Grimshaw J, Hróbjartsson A, Lalu M, Li T, Loder E, Mayo-Wilson E, McDonald S. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. [DOI: 10.31222/OSF.IO/V7GM2]
8. Radwan YA, Mansour AMR. Percutaneous distal metatarsal osteotomy versus distal chevron osteotomy for correction of mild-to-moderate hallux valgus deformity. *Arch Orthop Trauma Surg*. 2012; **132**(11): 1539-1546. [PMID: 22821414]; [DOI: 10.1007/s00402-012-1585-5]
9. Lee M, Walsh J, Smith MM, Ling J, Wines A, Lam P. Hallux Valgus Correction Comparing Percutaneous Chevron/Akin (PECA) and Open Scarf/Akin Osteotomies. *Foot Ankle Int*. 2017; **38**(8): 838-846. [PMID: 22821414]; [DOI: 10.1177/1071100717704941]
10. Kaufmann G, Dammerer D, Heyenbrock F, Braito M, Moertlbauer L, Liebensteiner M. Minimally invasive versus open chevron osteotomy for hallux valgus correction: a randomized controlled trial. *Int Orthop*. 2019; **43**(2): 343-350. [PMID: 29869014]; [DOI: 10.1007/s00264-018-4006-8]
11. Kaufmann G, Mörtlbauer L, Hofer-Picout P, Dammerer D, Ban M, Liebensteiner M. 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*. 2020; **102**(10): 873-879. [PMID: 32149929]; [DOI: 10.2106/JBJS.19.00981]
12. Frigg A, Zaugg S, Maquieira G, Pellegrino A. Stiffness and Range of Motion After Minimally Invasive Chevron-Akin and Open Scarf-Akin Procedures. *Foot Ankle Int*. 2019; **40**(5): 515-525. [PMID: 30688526]; [DOI: 10.1177/1071100718818577]
13. Maffulli N, Longo UG, Oliva F, Denaro V, Coppola C. Bosch Osteotomy and Scarf Osteotomy for Hallux Valgus Correction. *Orthop Clin North Am*. 2009; **40**(4): 515-524. [PMID: 19773057]; [DOI: 10.1016/j.ocl.2009.06.003]
14. Giannini S, Cavallo M, Faldini C, Luciani D, Vannini F. The SERI distal metatarsal osteotomy and scarf osteotomy provide similar correction of hallux valgus foot and ankle. *Clin Orthop Relat Res*. 2013; **471**(7): 2305-2311. [PMID: 23494184]; [DOI: 10.1007/s11999-013-2912-z]
15. Lim WSR, Rikhray IS, Koo KOT. Simultaneous bilateral hallux valgus surgery: Percutaneous or conventional? Early results of a matched study from a tertiary institution. *Foot Ankle Surg*. 2020; (2019). [PMID: 32491945]; [DOI: 10.1016/j.fas.2020.04.014]
16. Qasim SN, Mangwani J. Short versus 'Standard' Scarf Osteotomy for Hallux Valgus Correction. *Foot Ankle Orthop*. 2016; **1**(1): 2473011416S00275. [DOI: 10.1177/2473011416S00275]
17. Boksh K, Qasim S, Khan K, Tomlinson C, Mangwani J. A Comparative Study of Mini-Scarf Versus Standard Scarf Osteotomy for Hallux Valgus Correction. *J Foot Ankle Surg*. 2018; **57**(5): 948-951. [PMID: 30001939]; [DOI: 10.1053/j.jfas.2018.03.039]
18. Poggio D, Melo R, Botello J, Polo C, de Retana PF, Asunción J. Comparison of postoperative costs of two surgical techniques for hallux valgus (Kramer vs. scarf). *Foot Ankle Surg*. 2015; **21**(1): 37-41. [PMID: 25682405]; [DOI: 10.1016/j.fas.2014.09.004]
19. Brogan K, Lindisfarne E, Akehurst H, Farook U, Shrier W, Palmer S. Minimally Invasive and Open Distal Chevron Osteotomy for Mild to Moderate Hallux Valgus. *Foot Ankle Int*. 2016; **37**(11): 1197-1204. [PMID: 27381179]; [DOI: 10.1177/1071100716656440]
20. Choi JY, Ahn HC, Kim SH, Lee SY, Suh JS. Minimally invasive surgery for young female patients with mild-to-moderate juvenile hallux valgus deformity. *Foot Ankle Surg*. 2019; **25**(3): 316-322. [PMID: 29409176]; [DOI: 10.1016/j.fas.2017.12.006]
21. Lai MC, Rikhray IS, Woo YL, Yeo W, Ng YCS, Koo K. Clinical and Radiological Outcomes Comparing Percutaneous Chevron-Akin Osteotomies vs Open Scarf-Akin Osteotomies for Hallux Valgus. *Foot Ankle Int*. 2018; **39**(3): 311-317. [PMID: 29241361]; [DOI: 10.1177/1071100717745282]
22. Palmanovich E, Ohana N, David S, Small I, Hetsroni I, Amar E, Sharfman ZT, Segal D, Atzmon R. Distal Chevron Osteotomy vs The Simple, Effective, Rapid, Inexpensive Technique (SERI) for Mild to Moderate Isolated Hallux Valgus: A Randomized Controlled Study. *Indian J Orthop*. Published online 2020. [DOI: 10.1007/s43465-020-00209-0]
23. Cochrane Handbook for Systematic Reviews of Interventions Cochrane Training.
24. *NHMRC Levels of Evidence and Grades for Recommendations for Developers of Guidelines*; 2009.
25. RoB 2: A revised Cochrane risk-of-bias tool for randomized trials Cochrane Bias.
26. ROBINS-I Cochrane Bias.
27. Singh MS, Khurana A, Kapoor D, Katekar S, Kumar A, Vishwakarma G. Minimally invasive vs open distal metatarsal osteotomy for hallux valgus - A systematic review and meta-analysis. *J Clin Orthop Trauma*. 2020; **11**(3): 348-356. [PMID: 32405192]; [DOI: 10.1016/j.jcot.2020.04.016]
28. Jowett CRJ, Bedi HS. Preliminary Results and Learning Curve of the Minimally Invasive Chevron Akin Operation for Hallux Valgus. *J Foot Ankle Surg*. 2017; **56**(3): 445-452. [PMID: 28237566]; [DOI: 10.1053/j.jfas.2017.01.002]
29. Palmanovich E, Ohana N, Atzmon R, Slevin O, Brin Y, Feldman V, Segal D. MICA: A Learning Curve. *J Foot Ankle Surg*. 2020; **59**(4): 781-783. [PMID: 32340840]; [DOI: 10.1053/j.jfas.2019.07.027]
30. Cervi S, Fioruzzi A, Bisogno L, Fioruzzi C. Percutaneous surgery of allux valgus: risks and limitation in our experience. *Acta Biomed*. 2014; **85**(June): 107-112. [PMID: 25409727]