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Review Article

Scarf vs minimally invasive 5^{th} metatarsal osteotomy for the reduction of tailors bunions: A systematic review and meta-analysis

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ABSTRACT

Background: Scarf osteotomy is established for correcting bunionette deformities. Popularity of MIS has challenged whether percutaneous osteotomy has comparable outcomes with fewer complications although head-to-head trials are lacking.
Materials and Methods: All studies demonstrating bunionette reduction via scarf or percutaneous osteotomy between 2000-2023 were collated. Systematic review and meta-analysis of clinical and patient reported outcomes was performed. Methodological quality assessment and risk of bias was reviewed. Mean statistical analyses of outcomes and complications were calculated.
Results: 11 small cases series met inclusion: 115 scarf osteotomy vs 170 MIS surgical episodes. All studies demonstrated statistically significant and comparable outcomes. Complications varied between procedures. All studies demonstrated high risk of bias.
Conclusion: Both techniques adequately correct deformity delivering high patient satisfaction. Complication rates are similar although they manifest differently. The results of this study can be used to aid patient selection when considering open scarf or percutaneous 5^{th} metatarsal osteotomy.

1. Introduction

Growing interest in minimally invasive surgery (MIS) has resulted with an explosion of percutaneous reconstructive techniques over the last decade. Early advocates of MIS report comparable outcomes to open surgery with reduced complications, however this remains a subject of debate with traditionalists defensibly refuting these claims, touting high reporting and selection bias.[1–3] The surgical management of metatarsus quintus valgus is no exception with conflicting opinions regarding the most effective procedure and technical execution.

Historically bunionettes were considered an adaptation of the 5^{th} metatarsal head within the tailoring trade, however modern surgeons acknowledge the deformity as a complex pathology with multifactorial structural and mechanical drivers (Table 1).[4–6] Early writings explored the concept that mild 5^{th} metatarsal splaying and 5^{th} toe adduction were normal findings within the general population although rather ambiguously argued larger symptomatic deformities should be considered secondary pathology associated with global deformity such as pes plano valgus or hallux valgus.[5] Considered an oversimplification, these ideologies have been dispelled however paucity of research, small case series and confounding limits prospective data.

Lateralisation of the 5^{th} metatarsal contributes to a splay forefoot and presents with a typical symptomatologic triad of footwear irritation, plantar lateral callus and chronic adventitious bursal enlargement over the lateral aspect of the 5^{th} metatarsal head.[7] Adductovarus 5^{th} toe deformity is a common associated finding which may similarly present

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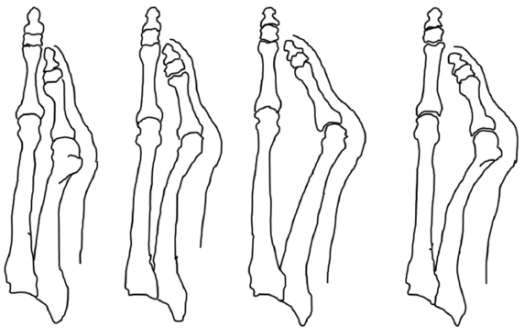
Table 1: Structural and biomechanical factors contributing to tailors' bunion deformity

Anatomical factors	Biomechanical factors
Congenital dorsiflexed / plantarflexed 5th ray	Tight footwear
Prominent 5th lateral metatarsal head	
Hypertrophy of soft tissue overlying lateral aspect of 5th metatarsal head	Lateral bending of the 5th metatarsal
Dumbbell shaped 5th metatarsal	Excessive pronation caused by hypermobility
Supernumeracy ossicles attached to the lateral 4th metatarsal head pushing the 5th metatarsal laterally	Subluxatory position of the 5th metatarsal
Increased 4th and 5th inter-metatarsal angle	Excessive lateral loading
Incomplete insertion or development of the transverse metatarsal ligament	Pes planus

with digital pain, rubbing and hyperkeratosis. Radiographic classification (Figure 1) continues to dominate deformity grading and determines the centre of rotation of angulation (CORA) aiding surgical planning.[8] Weight bearing (WB) dorso-plantar (DP) and medial oblique (MO) views are arguably the most valuable for classifying bunionette deformities however WB lateral views of the foot and ankle facilitates charting of sagittal plane deformity such as pes planus or cavus which may be of relevance, particularly in revision cases and managing patient expectations.[4,9,10]

Fallat's and Buckholtz Classification (1980)	
Type 1	Enlargement of the lateral surface of the fifth metatarsal
Type 2	Abnormal lateral bowing of the fifth metatarsal with a normal 4th inter-metatarsal angle.
Type 3	4th inter-metatarsal angle >8 degrees
Type 4	Combination of two or more of the above

a



b

Figure 1: a): Radiographic classification of tailors bunions; **b):** Classification by Fallat and Buckholtz

Surgical reduction is primarily undertaken via 5^{th} metatarsal osteotomy however there remains a lack of consensus regarding the most effective technique. The scarf osteotomy has been described as a versatile procedure with acceptable patient reported outcomes and deformity correction however some have challenged its efficacy reporting increased risk of complications. Increased application of MIS is challenging the status quo, specifically open techniques like the scarf osteotomy citing comparable outcomes with reduced complications owing to reduced dissection, preserved soft tissue envelope, and limited tourniquet use.[11] Head-to-head trials are lacking leaving surgeons ambiguous regarding the current evidence and arguably best practice. Systematic review and meta-analysis were performed to investigate two key objectives; Whether the scarf and MIS 5^{th} metatarsal osteotomies have comparable clinical and patient reported outcomes. Secondly, do MIS techniques reduce post-operative complications.

2. Materials and Methods

In compliance with the preferred reporting items for systematic re- views and meta-analyses (PRISMA), literature was sourced by 2 independent reviewers using electronic multidisciplinary bibliographic databases (Table 2). A PICO (Population, Intervention, Control, Outcome) tool (Table 3) was synthesised by the reviewers to aid research collection, standardize the search, and assist with data extraction. Negotiated medical subheadings (Mesh) and Boolean phrases "And" or "Or" provided a targeted search strategy, with all selected papers cross-referenced to avoid overlooking relevant literature.

Table 2: Bibliographic databases

	Bibliographic databases
1.	Allied and Complementary Medicine Database (AMED)
2.	BMJ Best Practice
3.	Cumulative Index to Nursing and Allied Health Literature (CINAHL)
4.	Clinical Key
5.	Cochrane Library
6.	Embase
7.	MEDLINE
8.	Ovid Journals
9.	PubMed
10.	SAGE Journals
11.	Science Direct
12.	Scopus
13.	Springer Journals
14.	Taylor and Francis Online Library

Included papers were required to meet the following criteria: studies utilising the scarf or percutaneous osteotomy for surgical reduction of tailors' bunions

Table 3:

PICO for Scarf Osteotomy			
Population	**Intervention**	**Outcome**	**Outcome**
Tailors Bunion	Scarf Osteotomy	Not applicable	Results
Bunionette	Scarfette		Outcomes
Metatarsus Quintus Valgus	Reverse Scarf Osteotomy		Post-operative
Fifth metatarsal	Z-cut osteotomy		Complications
Fifth ray	Mid-shaft Osteotomy		Follow up
Valgus fifth metatarsal	Diaphyseal Osteotomy		Patient reported outcomes
			Clinical outcomes
			Radiographic outcomes
			Correction
PICO for MIS			
Population	**Intervention**	**Outcome**	**Outcome**
Tailors Bunion	Percutaneous Osteotomy	Not applicable	Results
Bunionette	Percutaneous distal Osteotomy		Outcomes
Metatarsus Quintus Valgus	Minimally invasive Osteotomy		Post-operative
Fifth metatarsal			Complications
Fifth ray			Follow up
Valgus fifth metatarsal			Patient reported outcomes
			Clinical outcomes
			Radiographic outcomes
			Correction

in adults, studies reporting objective pre and post-operative clinical and radiological data, studies providing patient reported outcomes, studies reporting post-operative complications, studies published in English, studies produced between 2000 and 2023. A protracted search period was employed for several reasons although primarily due to paucity of research. Similarly, studies were not discriminated for including patients having concomitant foot surgery. Minimally invasive foot surgery inspired by Boesch' 1^{st} ray techniques was popularised in 2000, thus arguably birthing its modern concepts and formulated the baseline for this review.[12,13]

Excluded papers comprised those where procedures other than 5th metatarsal scarf or percutaneous osteotomies were performed to reduce the tailors' bunion, studies including paediatric populations, descriptive narratives, failure to disclose complications, studies failing to provide surgeon and patient reported outcomes.

51 texts were initially identified from electronic databases. Application of the PICO tool and inclusion criteria reduced the pool to 11 studies which were accepted for quality assessment: 5 scarf osteotomy and 6 MIS papers inclusive of 115 and 170 surgical episodes respectively.

Figure 2 illustrates a PRISMA flow diagram detailing the review process. Quality assessment of included articles was undertaken using the Joanna Briggs Checklist for Case Series checklist and Coleman Methodology Score due to its high reproducibility and correlation with evidence classification. A Modified Cochrane risk of bias (ROB) further scrutinised included studies.

Statistical analyses of pooled results and Coleman Methodology scoring was performed by each independent reviewer with discrepancies resolved following discussion and the final score decided as a team. Summary recommendations were unanimously agreed between reviewers according to their hierarchical level of evidence (Table 4). Score stratification was agreed between reviewers with 85–100 representing excellent quality, 70–84 good quality, 55–69 fair quality and < 55 demonstrating a poor-quality study.[14]

3. Results

3.1. Study characteristics

11 studies (Table 5) met the inclusion criteria, 10 of which identified as retrospective case series. 1 study identified as a prospective cohort, however this was considered author error, misrepresentative and for the purposes of this project labelled as case series[1]. European and South American dominance was observed across included studies, particularly MIS, with two papers including the same Brazilian faculty, illustrating industry leaders for this technique.[15,16] Two scarf osteotomy studies were conducted in the UK.[17,18] Follow up differed between procedures; 3/5 scarf osteotomy papers demonstrating mid-term review, two of which mid-long term follow up 7 years.[18,19] 3/6 MIS studies presented mid-term review, mean follow up 28 months.[12,20,21] The remaining five studies for both procedures included short term follow up, mean up 12.8 months. Patient demographics were poorly represented except for age and sex. Mean age of study participants was

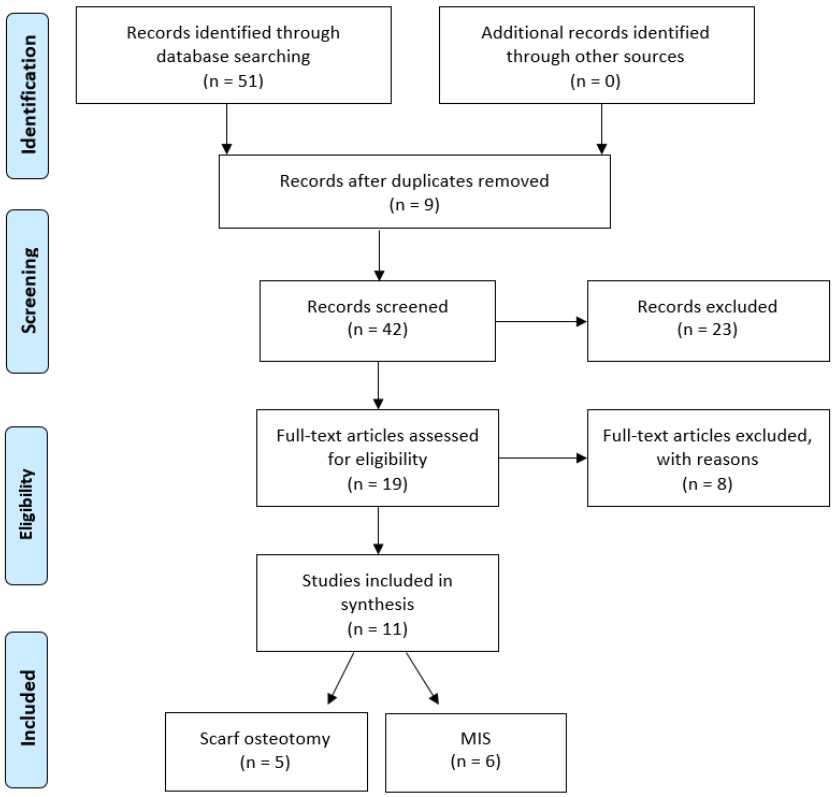


Figure 2: Prisma flow diagram demonstrating review process

Table 4: NICE Hierarchy or evidence and recommendations grading scheme

Level	Type of evidence	Grade	Evidence
I	Evidence obtained from a single randomised controlled trial or a meta-analysis of randomised controlled trials	A	At least one randomised controlled trial as part of a body of literature of overall good quality and consistency addressing the specific recommendation (evidence level I) without extrapolation
IIa	Evidence obtained from at least one well-designed controlled study without randomisation	B	Well-conducted clinical studies but no randomised clinical trials on the topic of recommendation (evidence levels II or III); or extrapolated from level I evidence
IIb	Evidence obtained from at least one other well-designed quasi-experimental study		
III	Evidence obtained from well-designed non-experimental descriptive studies, such as comparative studies, correlation studies and case studies		
IV	Evidence obtained from expert committee reports or opinions and/or clinical experiences of respected authorities	C	Expert committee reports or opinions and/or clinical experiences of respected authorities (evidence level IV) or extrapolated from level I or II evidence. This grading indicates that directly applicable clinical studies of good quality are absent or not readily available

similar in both groups, mean 47 years. One scarf osteotomy paper demonstrated a relatively young group, mean age 26 years, lowering the scarfs average however this was considered sampling bias.[22] There was a clear female: male dominance amongst both groups (Scarf 70%; MIS 88%), however 1 paper failed to report differences between sexes limiting pooled scarf numbers.[22]

3.2. Procedural variation

3.2.1. Tourniquet use

40% of included studies reported use of an ankle tourniquet however varied. 2 scarf papers referenced the use of ankle tourniquets as standard practice,[18,22] however MIS studies were more diverse, restricting application of a tourniquet to patients undergoing concomitant 1^{st} ray procedures or complex forefoot reconstruction.[12,20]

3.2.2. Osteotomy

Scarf osteotomy was similarly described across all 5 studies with a longitudinal dorso-lateral incision over the 5^{th} metatarsal, layered dissection, lateral tubercle exostectomy, diaphyseal 'Z' osteotomy and reduction of deformity owing to medialisation of the plantar fragment. Inter-surgeon variation existed between the angle of the transverse cuts; however, the scarfs geometric interlocking cuts were unanimously maintained. 2 studies performed shortening osteotomies for all patients removing 2-4mm bone blocks from the transverse cuts to decompress the 5^{th} MTPJ and aid mobilisation of the plantar fragment.[17,23] These studies had a similar academic panel and so this procedure modification was assumed to be institution preference. MIS demonstrated considerable variation, most notably osteotomy location and orientation of cuts. All MIS studies similarly reported use of fluoroscopy. 4/6 reported a stab incision to the lateral aspect of the 5^{th} metatarsal, sharp and blunt dissection to expose the lateral cortex of the 5^{th} metatarsal, and percutaneous osteotomy with a 2x12mm Shannon burr. Lui (2014) reported a medial wedge osteotomy using a Isham straight flute burr. Laffenetre et al. (2015) performed a medial closing wedge osteotomy with preservation of the lateral hinge using a long Shannon bur (12x2mm). All studies orientated the burr at 45 degrees in the sagittal plane from dorsal distal lateral to plantar proximal medial to encourage medial transposition, reduce dorsal displacement of the capital fragment and transfer metatarsalgia. One study described a traditional chevron osteotomy with 60–80-degree cuts at the level of the 5^{th} metatarsal head[20]. Sub-capital osteotomy was performed in all other studies with a degree of technical variation. 2 studies cited the importance of osteotomy performance at a pre-determined apex of deformity in keeping with Coughlin's radiographic classification.[12,16] Remaining studies documented a vague reference point within the distal 3^{rd} of the 5^{th} metatarsal.[1,15] Laffenetre et al. (2015) maintained a lateral hinge to aid osteotomy stability, whilst all others performed complete osteotomies. Relevance of hypertrophic lateral tubercles varied across studies with 3 papers performing additional intra-capsular exostectomy where surgeons had concerns regarding residual prominence post-operatively.[1,12,21]

3.2.3. Fixation

Inter-procedure osteosynthesis differed. All scarf osteotomies were fixated with lag screws generating rigid inter-fragmentary compression and absolute stability. Marginal variation in screw fixation was observed in 1 study, with 58% receiving 2 screws, and 42% 1 screw; the rationale for the variation was not defined however it was assumed that this was based on intra-operative findings of construct stability or institution preference.[17] No internal fixation was employed for MIS procedures. 1 study performed a medial closing wedge osteotomy, maintaining an intact lateral hinge which was argued to maintain a single point of fixation.[12] 1 study did not use internal or external fixation.[21] Fixation of all other MIS procedures involved external strapping of the 5^{th} digit and or forefoot for intervals ranging from 4-6 weeks.

3.3. Post-operative management

Weight bearing protocols varied between authors for both procedures, particularly following scarf osteotomy. 2 scarf studies kept patients non-weight bearing for 3 weeks before allowing protected weight bearing in a post-op shoe for a further 3-6 weeks.[19,23] Immediate partial weight bearing was observed in 3 papers although this ranged from 2-6 weeks.[17,18,22] 2 scarf studies also detailed an initial 4-day inpatient stay, although no rationale for this was provided; otherwise, day case surgery was undertaken.[22,23] MIS weight bearing regimes were more uniform with all cases immediately fully weight bearing in a post-operative sandal, however this ranged from 3-6 weeks based on surgeon preference.

Table 5:

Scarf Osteotomy		
Study	**Clinical outcomes**	**PROMs**
Necas et al.[19] (2020)	Mean reduction in 4th IM angle – 7.90 Mean reduction in 5th MTP angle – 13.60 4th IMA reduction P = 0.001 5th MPJ angle reduction P = 0.001	Mean AOFAS increase from 59.4 – 93 AOFAS increase P = 0.001 Coughlin satisfaction score: 79% excellent 18% Good 3% Fair
Hrubina et al[23] . (2015)	Mean reduction in 4th IM angle – 7.80 Mean reduction in 5th MTP angle – 13.70 4th IMA reduction P = 0.001 5th MPJ angle reduction P = 0.001	Mean AOFAS increase from 59.8 – 92.3 AOFAS increase P = 0.001 Coughlin satisfaction score: 74% excellent 22% Good 4% Fair
Guha et al.[17] (2012)	Mean reduction in 4th IM angle – 5.80 Mean reduction in 5th MTP angle – 13.50 4th IMA reduction P = 0.0008 5th MPJ angle reduction P = 0.0009	Mean AOFAS increase from 54.25 – 89.58 AOFAS increase P = 0.001 100% would refer a friend
Maher & Kilmartin[18] (2010)	Mean reduction in 4th IM angle – 4.20 Mean post-op ROM 5th MTPJ – 540 4th IMA reduction P = 0.001	Mean AOFAS increase from 44.1 – 88.1 AOFAS increase P = 0.001 Modified satisfaction Score: Completely: 86% Reservations: 11% Dissatisfied: 3% Would undergo same procedure: Yes: 91% No:9%
Seide & Petersen[22] (2001)	Mean reduction in 4th IM angle – 3.50 100% pain free ROM 5th MTPJ 4th IMA reduction P < 0.05	Mean FFSS increase from 29.5-73 FFSS = P < 0.05 Cosmetic score: Excellent: 80% Good: 20%

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Table 5 continued

	MIS	
Study	**Clinical outcomes**	**PROMs**
Nunes et al.[16] (2022)	Mean reduction in 4th IM angle – 5.80 Mean reduction in 5th MTP angle – 12.30 4th IMA reduction P = 0.001 5th MPJ angle reduction P = 0.001	Mean AOFAS increase from 49.6 – 92.4 AOFAS increase P = 0.001 Mean VAS decrease: 6.5 points VAS decrease P = 0.001 Coughlin satisfaction score: 83% excellent 11% Good 11% Fair
Valdivia & Thull[20] (2022)	Mean reduction in 4th IM angle – 5.50 Mean reduction in 5th MTP angle – 160 4th IMA reduction P = 0.001 5th MPJ angle reduction P = 0.001	Mean AOFAS increase from 65.8 – 95 AOFAS increase P = 0.001 Mean VAS decrease: 6 points VAS decrease P = 0.001
De Vete Lima et al.[15] (2020)	Mean reduction in 4th IM angle – 6.20 Mean reduction in 5th MTP angle – 9.20 4th IMA reduction P = 0.001 5th MPJ angle reduction P = 0.001	Mean AOFAS increase from 51.3 – 94 AOFAS increase P = 0.001 Mean VAS decrease: 6.4points VAS decrease P = 0.001
Ferreira et al.[1] (2020)	Mean reduction in 4th IM angle – 7.70 Mean reduction in 5th MTP angle – 11.70 4th IMA reduction P = 0.001 5th MPJ angle reduction P = 0.001	Mean AOFAS increase from 58.8 – 93.7 AOFAS increase P = 0.001 Mean VAS decrease: 6.6 points VAS decrease P = 0.001 Coughlin satisfaction score: 89% excellent 7.5% Good 3.5% Fair
Laffenetre et al.[12] (2015)	Mean reduction in 4th IM angle – 4.40 Mean reduction in 5th MTP angle – 11.980 4th IMA reduction P < 0.05 5th MPJ angle reduction P < 0.05 100% resolution of callus	Mean AOFAS increase from 58 – 97 AOFAS increase P < 0.05 Mean VAS decrease: 7.4 points Coughlin satisfaction score: 97% satisfied 3% dissatisfied
Lui,[21] 2014	Mean reduction in 4th IM angle – 80 Mean reduction in 5th MTP angle – 170 4th IMA reduction P < 0.0001 5th MPJ angle reduction P < 0.0001	Mean AOFAS increase from 61.8 – 100 AOFAS increase P < 0.0001 Coughlin satisfaction score: 100% excellent

3.4. Clinical and patient reported outcomes

All included studies assessed changes in pre and post-operative 4^{th} IM and 5^{th} MTPJ angles. 2 papers reviewed post-op 5^{th} MTPJ range of motion (ROM) although failed to include any pre-operative data.[18,22] 1 study vaguely reviewed pedometric changes in plantar pressures and subjectively analysed callus patterns.[12] 1 study utilised the "Forefoot scoring system" (FFSS) to record PROMs, all other studies uniformly employed the AOFAS.[22] Change in visual analogue scale (VAS) was measured in all MIS papers and 9/11 papers recorded patient satisfaction.[15,20]

All studies demonstrated statistically significant changes in pre and post-operative outcomes measures (Table 5). Pooled mean changes (Figure 3) in 4^{th} IM angle for scarf and MIS were 5.8^0 and 6.2^0 respectively. 3/5 scarf and 6/6 MIS papers reviewed 5^{th} MTPJ angular change demonstrating 13.6^0 and 13.03^0 respectively. AOFAS scores increased from mean 54.4 – 91 following scarf osteotomy vs mean increase 57.55 – 95.35 following MIS. Mean change in AOFAS between groups was 36.6 and 37.8 (Scarf & MIS). The study utilising FFSS demonstrated mean increase 29.5 -73. 5/6 MIS papers recorded change in VAS; mean decrease in 6.6 points. Post-operative satisfaction following each procedure was 97.5% and 92.25% (Scarf & MIS).

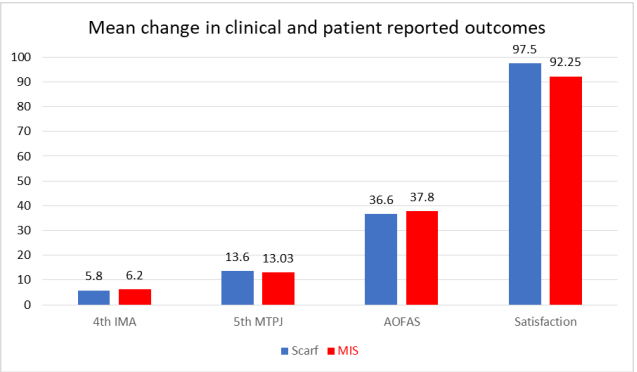

Figure 3: Pooled changes in outcomes

3.5. Complications

Complication incidence was 11% and 15.5% for scarf and MIS respectively. Revision surgery was required in 5.2% following scarf osteotomy; the most common reasons were excision of recurrent plantar corns, fixation removal. 1 patient required 2-4 weils osteotomy due to transfer metatarsalgia. 1 individual developed a deep infection requiring wound debridement. 1 wound dehiscence was noted following MIS requiring revision debridement and closure. Infection was low for both procedures; Scarf 1.7% and MIS 0.6%. The most frequently occurring complication following scarf osteotomy were recurrent intractable hyperkeratotic lesions (2%). Conversely following MIS, hypertrophic fracture callus was more common (8%) however poorly reported as a complication. Delayed union rates where similar; Scarf 1.7% vs MIS 1.9%. However, time to union was considerably different; Scarf 14 weeks vs MIS 24 weeks. Two asymptomatic non-unions were reported following MIS.

3.6. Quality assessment

Mean modified Coleman methodology scores (Table 6) for the scarf osteotomy and MIS were similar, scoring 61.8/100 and 63.6/100 respectively, indicating fair quality studies 10/11 papers. 1 MIS study scored low quality.[21] MIS papers were marginally better at reporting outcomes and had larger subject numbers in 2 studies resulting in a higher mean score.[1,12] Risk of bias (Table 7) was high for both procedures. 2/5 scarf and 3/6 MIS studies demonstrated satisfactory outcome reporting however the remaining studies reported mean outcomes limiting subgroup or individual scrutiny.[15–17,21,22] Scarf had marginally reduced attrition as 1 paper highlighted those lost to follow up and confirmed that their findings are only representative of completed outcome measures.[18] 60% of studies for each procedure included participants undergoing concomitant foot surgery introducing significant confounding.[12,16–18,20,23] Reporting bias was considerably high in MIS studies with discrepancies between authors as to whether hypertrophic fracture callus was a complication or expectation.

4. Discussion

74 years following Davies (1949) conceptualisation of tailors bunions, foot and ankle surgeons lack substantive guidance for deformity correction and have pragmatically adopted 1^{st} ray principles to overcome this conundrum. Scarf osteotomy has remained a staple for hallux valgus reduction due to versatile and powerful correction; its rotatory capabilities making it particularly attractive for the 5^{th} metatarsal.[18,24–27] MIS has challenged the norm and continues to be a point of contention amongst foot and ankle surgeons. Recent systematic review identified that distal 5^{th} metatarsal osteotomies present the lowest complication rate compared to diaphyseal or basal procedures (5%, 7% and 19% respectively) albeit with the least deformity correction.[6] These data are reflective of traditional open procedures and therefore cannot be easily extrapolated to MIS, leaving a substantial void within the evidence.

MIS enthusiasts claim that they can deliver comparable outcomes to open techniques with less complications, regardless of deformity classification.[28] The unstable nature of 'through and through' percutaneous osteotomies enable powerful triplanar correction with minimal insult to the soft tissue envelope arguably maintaining vascular integrity and a degree of natural constraint with the metatarsal head

Table 6: Modified coleman methodology score

Study	Study size	Mean follow up	Surgical approach	Study type	Diagnostic certainty	Description of surgical technique	Description of post op rehab	Outcome criteria	Procedure of assessing outcome	Description of selection process	Total
Necas et al.[19] (2020)	4	10	0	0	5	5	5	2,0,3,0	5,0,3,3	5,5,5	60/100
Guha et al.[17] (2012)	0	4	0	0	5	5	5	2,0,3,3	5,0,3,3	5,5,5	53/100
Hrubina et al.[23] (2015)	0	7	10	0	5	5	5	2,2,3,3	5,0,3,3	5,5,5	68/100
Maher & Kilmartin (2010)[18]	0	10	10	0	5	5	5	2,0,3,3	5,0,3,3	5,5,5	69/100
Seide & Petersen (2001)[22]	0	4	10	0	5	5	5	2,2,0,0	5,0,3,3	5,5,5	59/100
Nunes et al.[16] (2022)	0	4	10	0	5	5	5	2,0,3,3	5,0,3,3	5,5,5	63/100
Valdivia & Thull[20] (2022)	0	4	10	0	5	5	5	2,3,3,3	5,0,3,3	5,5,5	66/100
De Vete Lima et al.[15] (2020)	0	4	10	0	5	5	5	2,0,3,3	5,0,3,3	5,5,5	63/100
Ferreira et al.[1] (2020)	4	4	10	0	5	5	5	2,3,3,3	5,0,3,3	5,5,5	70/100
Laffenetre et al.[12] (2015)	4	4	10	0	5	5	5	2,0,3,3	5,0,3,3	5,5,5	67/100
Lui[21] (2014)	0	4	0	0	5	5	5	2,0,3,3	5,0,3,3	5,5,5	53/100

migrating 'to its ideal position'. Traditional distal osteotomy is limited by a short lever arm, with research demonstrating modest reduction in IM angle despite capital fragment rotation.[29] Proximal osteotomy offers the greatest corrective power through its long lever however research is limited, with recent systematic review demonstrating a conservative 2 papers.[6] Perhaps unsurprisingly the scarf osteotomy has been popularised by offsetting the limitations of capital and basal procedures.

Pooled results from the 11 included studies (Figure 3) demonstrated comparable radiological reduction of deformity and patient reported outcome measures. All papers recorded statistically significant changes in 4^{th} IM, 5^{th} MTP angles and return of 4th IM angles to a normal range $<8^0$. Alignment, pain, and function significantly improved for both procedures according to AOFAS with MIS demonstrating a modest mean increase compared to scarf osteotomy. Patient satisfaction was high following both procedures with scarf osteotomy marginally succeeding MIS with 97.5% vs 92.25%. The researchers would caveat these results with disparity in follow up. Scarf osteotomy demonstrated 3/5 papers with mid-term review, two of which presented results following mean review 81 months compared to mean follow up 27 months following MIS.[12,18–20] Revision surgery was limited to scarf osteotomy, however studies describing revision procedures were mid-term reviews provoking uncertainty as to whether MIS patients would require revision later.

Procedure specific complications (Figure 4) differed which could have implications for clinical practice. Wound healing and infection rates were satisfactory for both however MIS demonstrated 2 (1.3%) cases of chronic regional pain syndrome (CRPS). Limiting surgical trauma is an important advantage of MIS and therefore one would consider CRPS rates to be lower than open surgery, however these assumptions are clearly flawed. Single centre study identified risk of CRPS following foot and ankle surgery 4.36%, of which 53% occurred following forefoot procedures, although it is unknown if surgery was open or percutaneous.[30] Middle aged females with a history of smoking, anxiety and depression were considered the greatest risk, however a direct comparison with this study's findings cannot be made due to methodological bias. Females of mean age 47 years represented a majority in this study however reporting bias is limiting. Recent literature reviewing the learning curve following 3^{rd} generation percutaneous chevron / akin osteotomy for hallux valgus identified that surgeons required on average 38 cases before reaching technical proficiency; perhaps explaining the reported incidence of CRPS.[31] Regulating burr temperature with intra-operative irrigation has been attributed to minimizing soft tissue necrosis however subtle variation in stab incisions was observed across MIS studies which arguably may have been responsible for nerve injury. Tourniquet use was poorly defined for both procedures. 1 study reinforced the benefit of performing surgery wet for cooling effect on the Shannon burr.[1] Increased tourniquet use was observed for scarf osteotomies however this did not present any additional sequalae, and so a relationship between omitting tourniquets and reduced complication rates cannot be drawn.

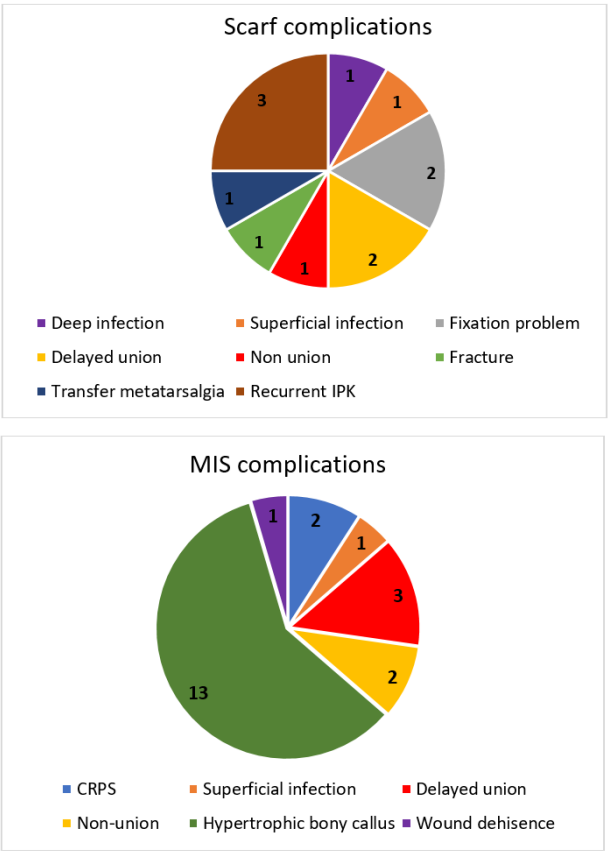

Figure 4: Procedure specific complications

Maher and Kilmartin (2010) cautioned readers regarding the recurrence of intractable plantar hyperkeratosis (IPK), particularly in the cavoid foot, citing a higher revision rate of plantar condylectomy +/- lesion excision. Absence of prospective study or additional case series identifying this relationship limits external validity as this may represent sampling bias and error in patient selection. Lesion misdiagnosis within this study also cannot be excluded. Recent histopathological analysis of IPK identified 51.2% of these lesions to include human papillomavirus (HPV) which may explain the failure to resolve following deformity correction.[32]

Notable variations regarding osteotomy healing were identified which should be considered on a case-by-case basis. Most percutaneous osteotomies were stabilised post-operatively with external strapping, of which there was inter-surgeon variation in technique and duration. 61%

Table 7: Risk of bias

Studies	Procedure	Selection	Performance	Attrition	Reporting
Necas et al. (2020)	Scarf	•	•	★	★
Guha et al. (2012)	Scarf	•	•	★	★
Hrubina et al. (2015)	Scarf	•	•	•	•
Maher & Kilmartin (2010)	Scarf	•	•	★	★
Seide & Petersen (2001)	Scarf	•	•	★	•
Nunes et al. (2022)	MIS	•	•	★	•
Valdivia & Thull (2022)	MIS	•	•	•	★
De Vete Lima et al. (2020)	MIS	•	•	★	★
Ferreira et al. (2020)	MIS	•	•	•	•
Laffenetre et al. (2015)	MIS	•	•	•	•
Lui (2014)	MIS	•	•	•	★

★ Low risk
• High risk

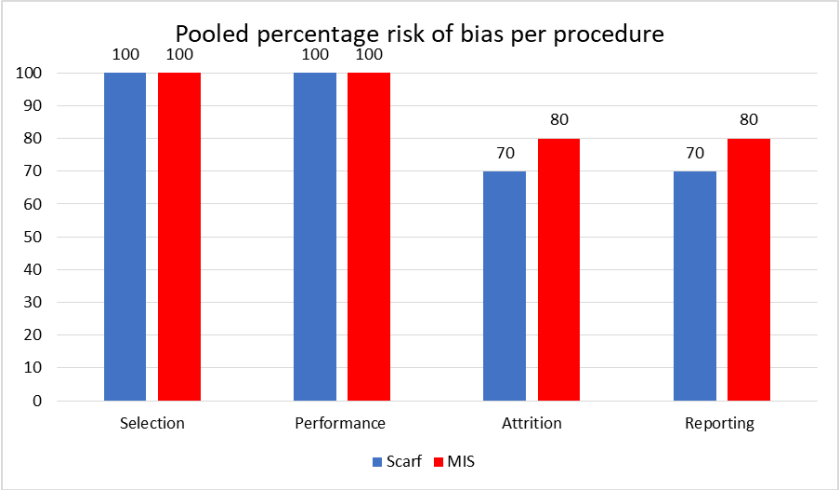

Figure 5:

of MIS complications involved symptomatic hypertrophic osteotomy callus persisting between 3-6 months; symptoms including pain, footwear irritation and delayed return to activity.[12,15,16] This was poorly reported with divided opinion between the MIS authors as to whether this should be considered a complication or demoted to procedure expectation. This may conflict with patient expectations revolving MIS regarding minimal convalescence and rapid return to activity. Delayed union following MIS followed a similar pattern. Although little difference was observed regarding the incidence of delayed union (1.7% vs 1.9%), mean time to union significantly differed. It should be highlighted that 1 participant with protracted time to union (10 months) significantly affected results and perhaps could be considered an outlier, however other cases of delayed union required 4-6 months to consolidate and therefore all results have been documented for reader consideration.[12,16] It is acknowledged that discrepancies in healing are secondary to reduced stability and lack of internal fixation, however attitudes regarding their severity are arguably somewhat cavalier. Growing interest in MIS for surgical offloading diabetic foot ulceration has surfaced with advocates reinforcing the benefits of minimal soft tissue injury, immediate weight bearing and absence of retained hardware.[33] Early outcomes are undeniably impressive with rapid ulcer healing and minimal convalescence however risk of propagating charcot neuroarthropathy is theoretically increased with delayed / non-union in neuropathic patients: One should caveat that to the authors knowledge there have been no documented incidences of MIS triggering charcot.[34] Fracture is an established risk of scarf osteotomy, with early ambulation and vulnerability to stress risers through the osteotomy or fixation considered detrimental.[35] Only 1 individual sustained an early post-operative fracture, perhaps unsurprisingly this series permitted immediate weight bearing. Despite healing with continued partial weight bearing, this is overshadowed by subsequent transfer metatarsalgia.[18] 2 studies kept patients non-weight bearing for 3 weeks however on balance, no significant benefit was gained with delayed union and fixation migration still

occurring.[19,22] Fundamentally ideological post-operative guidelines are lacking.

High risk of bias and considerable methodological diversity was observed across all papers with retrospective observational bias impairing validity. 60% of each group included concomitant surgeries introducing considerable confounding, however readers should interpret this with a degree of pragmatism and appreciate these results as a reflection of real practice. Technical execution of percutaneous osteotomy varied, further confounding results and limiting validity. Reported scarf re-operative rates also deserve some scrutiny. Necas et al. (2020) identifies a reoperation rate of 8.8% following decompressive scarf, which the authors indicate as an acceptable range. This exceeds the UK average reoperation rate following orthopaedic trauma 8.6%.[36] Acceptable revision rates remain ill-defined however one would caution accepting a higher incidence of revision surgery following clean elective cases. An interesting observation was the failure to prioritise post-operative stiffness as an outcome. MIS proponents frequently attribute reduced joint stiffness with percutaneous techniques however no single study demonstrated this. This may reflect attitudes that ROM at the 5^{th} MTPJ is less important than 1^{st} ray, however these shortcomings marry opinions that reduced arthrofibrosis following MIS is purely theoretical and limited by selection bias.[2]

4.1. Strengths

Debate regarding open and percutaneous foot surgery remains both topical and contentious. These results add to the greater body of research providing the most recent evidence to guide foot and ankle surgeons when considering between an open scarf or percutaneous osteotomy for reducing tailors bunion deformity. Clear rationale and study aims were identified, exploring topical themes, and providing meaningful data to support clinicians. PICO and PRISMA facilitated a transparent and exhaustive screening process to identify existing research. Structuring a well-defined inclusion/exclusion criterion enabled repeatable data extraction of key studies. All included papers were subjected to rigorous quality assessment and review of bias using established academic tools. Mean statistical analysis of shared clinical and patient reported outcomes provided measurable data to meet the primary objective of the project. Combined quantitative analysis and detailed narrative regarding individual procedure complications enabled remaining secondary objectives to be met.

5. Limitations

Low study numbers limited external validity, however fortunately, surgical episodes were similar for both procedures. Quality assessment identified heterogeneity and methodological shortcomings for all studies, with poorly reported patient demographics, and confounding. PROMs (AOFAS & FFSS) in all studies were unvalidated, generally favouring surgeon outcomes, poorly correlating with perceived patient importance factors, and grossly impairing internal validity.[37] Appraisal of case series was not exempt from scrutiny and remains ambiguous. Modified Coleman Methodology Scores are convenient and repeatable quality assessment tools however can be ambiguous and interpretation can be subjective.[14]

6. Conclusion

Summary recommendations:

There is insufficient evidence to determine the most effective surgical procedure to reduce buniontte deformities.

1. Grade of recommendation: B
   (a) Both Scarf and percutaneous 5^{th} metatarsal osteotomies can adequately reduce tailors bunion deformities producing comparable clinical and radiological outcomes.
2. Grade of recommendation: B
   (a) Patient satisfaction is high for both scarf osteotomy and percutaneous techniques.
3. Grade of recommendation: B
   (a) Complication rates are similar however they manifest differently between procedures and patient selection should be made on a case-by-case basis.
4. Grade of recommendation: B
   (a) Delayed union rates are comparable however time to union following percutaneous osteotomy is considerably higher. Individuals with increased risk factors for non-union should be consented accordingly.
5. Grade of recommendation: B
   (a) The ideal fixation construct and weight bearing protocol following 5^{th} metatarsal osteotomy remains ill-defined.
6. Grade of recommendation: B
   (a) Current data suggests revision surgery is higher following scarf osteotomy.
7. Grade of recommendation: B
   (a) There is no definitive evidence that percutaneous 5^{th} metatarsal osteotomy reduces post-operative stiffness compared to the scarf osteotomy.
8. Grade of recommendation: B
   (a) Modified Coleman methodology score.

7. Source of Funding

None.

8. Conflict of Interest

None.

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