Foot and Ankle Surgery 25 (2019) 580–588

Contents lists available at ScienceDirect

Foot and Ankle Surgery

journal homepage: www.elsevier.com/locate/fas

Review

A systematic review and meta-analysis of the sinus tarsi and extended lateral approach in the operative treatment of displaced intra-articular calcaneal fractures

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ARTICLE INFO

Article history:
Received 20 October 2017
Received in revised form 26 June 2018
Accepted 15 August 2018

Keywords:
Displaced intra-articular calcaneal fractures
Extended lateral approach
Sinus tarsi approach
Postoperative wound healing complications

ABSTRACT

Background: The optimal surgical approach for displaced intra-articular calcaneal fractures (DIACF) is subject of debate. The primary aim of this systematic review and meta-analysis was to assess wound-healing complications following the sinus tarsi approach (STA) compared to the extended lateral approach (ELA). Secondary aims were to assess time to surgery, operative time, calcaneal anatomy restoration, functional outcome, implant removal and injury to the peroneal tendons and sural nerve.
Methods: MEDLINE, EMBASE and Cochrane databases were searched for clinical studies comparing the STA and the ELA (until September 2017).
Results: Nine studies were included (two randomized controlled trials; seven comparative studies). 326 patients (331 fractures) were treated by the STA and 383 patients (390 fractures) by ELA. Ninety-nine per cent were Sanders type II/III fractures. Wound healing complications in the STA and ELA occurred in 11/331 and 82/390 fractures, respectively. Weighted means were 4.9% and 24.9%, respectively. Meta-analysis showed significantly less wound healing complications in the STA compared to ELA (risk ratio 0.20; 95% CI 0.11–0.36; $P < 0.00001$; $I^2 = 0\%$). In general, time to surgery and operative time were shorter in the STA. Meta-analysis was not possible due to heterogeneity between studies. No differences were found in remaining secondary outcomes.
Conclusions: The STA is associated with significantly less wound healing complications. With similar functional outcome and calcaneal anatomy restoration, the STA may be the preferred approach in the operative treatment of Sanders type II/III DIACF.

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1. Introduction

Calcaneal fractures are complex injuries which predominantly occur in young, active patients [1]. As a result, these fractures may lead to significant long-term disability [2] and a high socio-economic

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https://doi.org/10.1016/j.fas.2018.08.006
1268-7731/

impact [3,4]. Calcaneal fractures are mostly comminuted, displaced intra-articular compression injuries, with a loss of hindfoot anatomy [1]. Treatment can be either conservative or operative [5,6]. Advantages of operative treatment include the restoration of calcaneal anatomy and, in particular, the possibility of a more accurate reduction of the posterior facet [7]. This is associated with better functional outcomes [6,8–10]. Operative treatment furthermore reduces the chance of developing posttraumatic osteoarthritis [11].

The most frequently used approach in the operative treatment of displaced intra-articular calcaneal fractures is the extended lateral approach (ELA) [5,12]. This approach may result in significant wound healing complications [5]. A meta-analysis comparing operative treatment using the ELA with conservative therapy showed that the benefits of surgery were negatively influenced by the high incidence of postoperative wound healing complications [6]. Nowadays, less invasive approaches such as the sinus tarsi approach (STA) have regained interest [7]. By using a smaller incision and less extensive tissue manipulation, this approach theoretically may result in fewer wound-healing complications.

The purpose of this study was to systematically review the existing literature on the operative treatment of displaced intra-articular calcaneal fractures through the less invasive STA compared with the conventional ELA. The primary aim was to assess the difference in postoperative wound healing complications between the two techniques. We hypothesized that the STA would result in significantly less postoperative wound healing complications. Secondary aims were to evaluate time to surgery, operative time, restoration of calcaneal anatomy, functional outcome, rate of implant removal and peroneal tendon or sural nerve injury.

2. Material and methods

This systematic review was performed according to the PRISMA guidelines [13]. A search was performed in MEDLINE, Embase and the Cochrane Library until September 2017. The following search strategy was used in MEDLINE: (Sinus tarsi[tiab]) OR ((“Calcaneus”[Mesh] OR calcan*[tiab] OR calcis[tiab] OR heel bone*[tiab]) AND (“Fracture Fixation”[Mesh] OR “Intra-Articular Fractures”[-Mesh] OR fractur*[tiab]) AND (“Minimally Invasive Surgical Procedures”[Mesh] OR modified Palmer[tiab] OR limited open reduction[tiab] OR percutaneous*[tiab] OR ((minimal*[tiab] OR limit*[tiab] OR obliq*[tiab] OR small[tiab] OR short[tiab]) AND (invasiv*[tiab] OR surg*[tiab])))) AND (open reduction and internal fixation[tiab] OR ((exten*[tiab] OR convention*[tiab] OR L-shape* [tiab] OR plate*[tiab] OR plati*[tiab]) AND (approach*[tiab]))). In this search, truncation (i.e. *) is used to replace characters at the end to accept multiple forms of a particular search term. Using [tiab] coding, only titles and abstracts are searched. Finally, Medical Subject Headings (i.e. Mesh) were used which index articles in MEDLINE. The search strategy was modified and accordingly used in Embase and the Cochrane Library.

Inclusion criteria were: (1) studies published in peer-reviewed journals; (2) randomized controlled trials, quasi-randomized controlled trials and comparative studies comparing the STA with the ELA in the operative treatment of closed and displaced intra-articular calcaneal fractures (i.e. Sanders type II, III, IV) [14]; (3) studies with a primary or secondary outcome which includes one of the following: postoperative wound complications, time to surgery, operative time, restoration of calcaneal anatomy, functional outcome including patient related outcome measures, rate of implant removal and peroneal tendon or sural nerve injury.

Exclusion criteria were: (1) open fractures; (2) approaches other than the STA or ELA, such as fully percutaneous techniques; (3) patients younger than 17 years of age; (4) case reports or surgical technique reports; (5) patients treated by a primary arthrodesis; (6) studies in language other than English, German, Dutch or French.

All titles and abstracts were independently screened by two authors using an online tool (www.covidence.org). If relevant or inconclusive, articles were retrieved and included when eligible after full text review. Fig. 1 shows the flow chart of the literature search. Finally, references of all included studies were manually searched for potentially relevant studies.

The STA was defined as an incision over the sinus tarsi (on the line between the tip of the lateral malleolus and the base of the fourth metatarsal) for direct visualization and reduction of the posterior facet, combined with percutaneous indirect reduction of the extra-articular portion of the fracture by means of ligamentotaxis, followed by plate and/or screw fixation [7]. Length of incision in general is 3–5 cm [7], but may be extended if the fracture involves the calcaneocuboid joint [15]. If needed, an additional mini-incision for plate application was allowed. The ELA was defined by an L-shaped incision over the lateral foot, full-thickness fasciocutaneous flap preparation, exposure of the entire lateral calcaneus and posterior facet for direct reduction, followed by plate and screw fixation [16].

The primary outcome measure was the occurrence of postoperative wound healing complications. Infectious complications were classified according to the criteria of the Centers for Disease Control and Prevention [17]. Specifically, minor wound healing complications were defined as minor wound edge necrosis, superficial wound dehiscence and superficial wound infections, all amendable for conservative treatment with oral antibiotics, local wound irrigation, frequent dressing changings or hematoma evacuation. Major wound healing complications were defined as deep wound dehiscence and deep wound infections, including osteomyelitis and infected implant(s), plate fistula or extensive wound edge necrosis, all in need for implant removal or intravenous antibiotic treatment and/or operative wound debridement (with or without local antibiotic treatment, vacuum assisted closure or fasciocutaneous/skin graft covering).

Secondary outcome measures were time to surgery, operative time, restoration of calcaneal extra- and intra-articular anatomy as assessed by conventional radiology or computed tomography (CT), functional outcome including patient related outcome measures, rate of implant removal and peroneal tendon or sural nerve injury. Restoration of calcaneal anatomy was assessed according to improvement of Böhler’s angle and reduction of the posterior facet as determined on CT, as these parameters are both correlated to functional outcome [8,10,18].

For both approaches, in addition to the primary and secondary outcomes, the following data was independently extracted from each study by two authors: (1) type of study; (2) number of patients and number of fractures; (3) patient age; (4) type of fracture according to the Sanders classification [14]; (5) follow-up time and percentage lost to follow-up. Finally, known risk factors for developing postoperative wound healing complications were assessed (i.e. smoking, diabetes, comorbidity, use of bone graft, wound drain usage) [19–21].

Two authors independently assessed risk of bias. Risk of bias for non-randomized studies was assessed by using the validated MINORS score (Methodological Index for Non-Randomized Studies) [22]. The MINORS score grades comparative studies according to twelve items. Items are scored 0 (not reported), 1 (reported but inadequate) or 2 (reported and adequate). The maximum score for comparative studies is 24. For randomized controlled trials, the Cochrane Collaboration’s tool for assessing risk of bias was used [23]. Any disputes were resolved by discussion.

Statistical analyses were performed using the Cochrane Collaboration Review Manager (Cochrane Collaboration, version

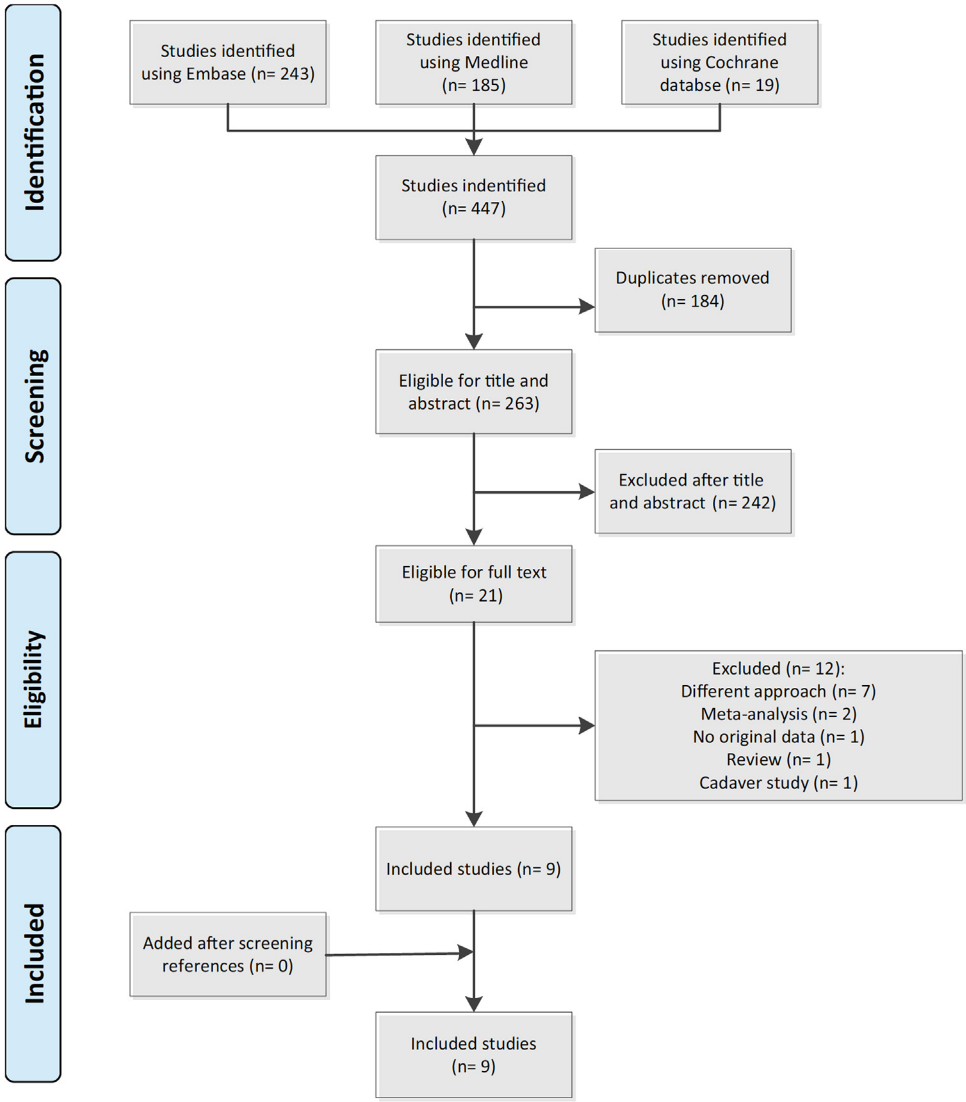

Fig. 1. Flowchart literature search according to the PRISMA 2009 Guidelines [13].

5.3, London, UK). Data were pooled if an outcome was reported in at least three studies and if heterogeneity between studies was absent or low. Heterogeneity was assessed using the I^2-index. Cut-off values for low, moderate and high heterogeneity between studies were set at I^2 values of 25%, 50% and 75%, respectively [24]. Risk ratios including 95% confidence intervals (CI) were calculated in the case of dichotomous outcome measures and mean difference including 95% confidence intervals (CI) was used for continuous outcome measures. In the latter, if necessary, data was transformed from median or mean (range) to mean (standard deviation) [25]. For each meta-analysis, the random-effects model was used. A P value less than 0.05 was considered statistically significant (two-sided test). A minimum of ten included studies was set as a condition to perform plot analysis for publication bias. For the primary outcome, a weighted mean percentage of wound healing complications per approach was calculated. Inverse variance was used to determine the weight factor per study.

3. Results

The search retrieved 447 articles of which 184 were duplicates. A total of 263 articles were reviewed by title and abstract, after which 242 articles could be excluded. Of the remaining 21 articles, twelve studies were excluded after full text review [21,26–35,43].

Nine studies were included in the final analysis Fig. 1. In total, 326 patients with 331 fractures were treated by the STA and 383 patients with 390 fractures by the ELA. The nine included studies comprised of two randomized controlled trials [36,37], one prospective comparative cohort study [15], one prospective comparative cohort study with retrospective analysis of data [38] and five retrospective comparative cohort studies [39–42,44].

Of the twelve excluded studies, one article compared the ELA, percutaneous procedures and the STA. Data from the latter two approaches were combined and analysed together [21]. The author was contacted but was unable to provide original data for the STA. Seven studies were excluded because a different approach than the STA was used [26–29,32,34,43]. One narrative review [30] and one cadaver study [35] were excluded. Two systematic reviews and meta-analyses [31,33] were found which compared the outcomes of the STA and the ELA. In the first, by Zhang et al. [31], the investigators included eight comparative studies until November 2015. Four of the studies [36,39–41] were also included in the present review. Four other studies included in the meta-analysis by Zhang et al. [31] were not found by our search but would be excluded based on language. The present study additionally includes five more studies [15,37,38,42,44] than the meta-analysis by Zhang et al. [31]. In the second systematic review and meta-analysis by Yao et al. [33], the authors included seven studies until 2016. Six of the studies were also included in the present review [15,36,39–42]. One study [43] was excluded in the present review due to different approach than the sinus tarsi. The study by Yao et al. did not include two studies [38,44] which were included in the present review.

Finally, manual cross-check of the references of the included studies yielded one potentially relevant paper, which was excluded because of language [45].

Both randomized controlled trials [36,37] were at substantial risk of bias (Table 1). Comparative studies [15,38–42,44] were hampered by a retrospective design, lack of prospective sample size calculation, biased assessment of end-points and high patient loss at follow-up (Table 2).

In total, per approach, patients with similar numbers of Sanders fractures subtypes [14] were included (Table 3). Notably, one study showed 20% more Sanders type II fractures in the STA [44]. The use of bone graft was generally not described or not used (Table 4). If described, the number of patients with diabetes, smoking status and comorbidities was equal between groups. Wound drains (placed before wound closure) were either used or their usage was not described.

Table 1
Assessment of risk of bias for the included randomized controlled studies according to the Cochrane Collaboration's tool.

Item	Risk of bias	
	Xia et al. [36]	Li et al. [37]
Random sequence generation (selection bias)	Unclear	Low
Allocation concealment (selection bias)	Unclear	Low
Blinding participants and personnel (performance bias)	High	High
Blinding of outcome assessment (detection bias)	Unclear	High
Incomplete outcome data (attrition bias)	Low	Low
Selective reporting (reporting bias)	Unclear	Low
Other bias	High	Unclear

3.1. Primary outcome

All nine included studies [15,36–39,40,41,42,44] reported on wound healing complications. Postoperative wound healing complications (major and minor) occurred in 11 out of 331

Table 2
Quality of study assessment according to the MINORS Score (Methodological Index for Non-Randomized Studies) for comparative, non-randomized studies that were included. The MINORS score grades comparative studies according to twelve items. Items are scored 0 (not reported), 1 (reported but inadequate) or 2 (reported and adequate). The maximum score for comparative studies is 24.

Item	Zhou et al. [44]	Schepers et al. [38]	Takasaka et al. [42]	Basile et al. [15]	Yeo et al. [40]	Kline et al. [39]	Weber et al. [41]
Clearly stated aim	2	2	2	1	2	2	2
Inclusion of consecutive patients	1	2	2	2	2	2	1
Prospective collection of data	0	1	0	2	0	0	0
Endpoints appropriate to aim of study	2	2	2	2	2	2	2
Unbiased assessment of study endpoint	1	0	0	1	1	1	0
Follow-up period appropriate to aim of study	2	2	2	2	2	2	2
Loss to follow-up less than 5%	1	2	2	1	0	0	1
Prospective calculation of sample size	0	0	0	0	0	0	0
Adequate control group	2	2	2	2	2	2	2
Contemporary groups	1	1	2	2	2	2	1
Baseline equivalence of groups	1	2	0	2	2	1	1
Adequate statistical analysis	2	2	1	2	2	1	2
Total (maximum 24)	15	18	15	19	17	15	14

Table 3
Summary of included studies.

Study	Nr. pts. (nr. fractures)		Sanders fracture type number (percentage)					
	STA	ELA	Type II		Type III		Type IV	
			STA	ELA	STA	ELA	STA	ELA
[a]Zhou et al. [44]	28 (28)	37 (37)	17 (61%)	15 (41%)	11 (39%)	22 (59%)	0	0
[b]Schepers et al. [38]	65 (65)	60 (60)	50 (77%)	48 (80%)	15 (23%)	12 (20%)	0	0
[c]Li et al. [37]	32 (32)	32 (32)	16 (50%)	17 (53%)	11 (34%)	11 (34%)	5 (16%)	4 (13%)
[a]Takasaka et al. [42]	27 (27)	20 (23)	NP[d]	NP[d]	NP[d]	NP[d]	0	0
[b]Basile et al. [15]	18 (18)	20 (20)	7 (39%)	7 (35%)	11 (61%)	13 (65%)	0	0
[a]Yeo et al. [40]	40 (40)	60 (60)	25 (63%)	37 (62%)	15 (38%)	23 (38%)	0	0
[c]Xia et al. [36]	59 (64)	49 (53)	39 (61%)	31 (58%)	25 (39%)	22 (42%)	0	0
[a]Kline et al. [39]	33 (33)	79 (79)	20 (61%)	42 (53%)	13 (39%)	37 (47%)	0	0
[a]Weber et al. [41]	24 (24)	26 (26)	20 (83%)	20 (77%)	4 (17%)	6 (23%)	0	0
Total	326 (331)	383 (390)	194 (64%)[e]	217 (59%)[e]	105 (35%)[e]	146 (40%)[e]	5 (2%)[e]	4 (1%)[e]

STA = sinus tarsi approach. ELA = extended lateral approach. NP = not provided.
[a] Retrospective comparative series.
[b] Prospective comparative series.
[c] Randomized controlled trial.
[d] Included were type II and III fractures, but subtype amount per approach was not provided.
[e] To calculate total percentages of Sanders fracture subtypes for both the STA and ELA, total amount of patients excludes the patients from Takasaka et al., as no Sanders subtypes were given in this study.

Table 4
Patient age, the use of bone graft, closed suction drainage and risk factors for postoperative wound healing complications.

Study	Age (years)		Bone graft		Drainage		Amount of patients and percentage per risk factor					
	STA	ELA	STA	ELA	STA	ELA	Diabetes		Smoking		Comorbidities	
							STA	ELA	STA	ELA	STA	ELA
[a]Zhou et al. [44]	43.6 (21–65)	43.8 (26–64)	NP	NP	No	Yes	Excluded	Excluded	Exclusion long term or perioperative smokers		NP	NP
[b]Schepers et al. [38][f]	46 (37–59)	48 (39–56)	NP	NP	NP	NP	0/65 (0%)[f]	2/60 (3%)[f]	18/65 (28%)[f]	20/60 (33%)[f]	No statistically significant difference between ASA Classification[g]	
[c]Li et al. [37][f]	40 ± 9	41 ± 9	NP	NP	NP	NP	6/32 (19%)[f]	5/32 (16%)[f]	8/32 (25%)[f]	6/32 (19%)[f]	NP[e]	NP[e]
[a]Takasaka et al. [42]	Mean of 40		NP	No	NP	NP	NP	NP	NP	NP	NP	NP
[b]Basile et al. [15]	42 ± 12	40 ± 13	No	No	Yes	Yes	Excluded	Excluded	Non-smoking (in general or 12 weeks following operation		No major underlying medial comorbidities	
[a]Yeo et al. [40]	46 (20–65)	42 (17–64)	NP	NP	NP	NP	1/40 (3%)	2/60 (3%)	8/40 (20%)	13/60 (22%)	NP	NP
[c]Xia et al. [36]	38 (20–67)	37 (19–67)	Yes	NP	Yes	Yes	All patients were no long-term smokers nor did have severe diabetes				NP[e]	NP[e]
[a]Kline et al. [39]	46 (21–66)	42 (18–65)	NP	NP	NP	Yes[d]	2/33 (6%)	1/79 (1%)	11/33 (33%)	31/79 (39%)	NP	NP
[a]Weber et al. [41]	43 (16–65)	40 (15–64)	NP	NP	Yes[d]	Yes	NP	NP	NP	NP	NP	NP

ELA = extended lateral approach. STA = sinus tarsi approach. NP = not provided.
ASA = American Society of Anaesthesiologists.
[a] Retrospective comparative series.
[b] Prospective comparative series.
[c] Randomized controlled trial.
[d] Used at surgeon's discretion.
[e] Because of randomization, comorbidities should be equal. However, no specific description was given per group.
[f] No statistically significant differences were seen with regard to smoking or diabetes per group.
[g] Exact data for ASA classification provided in original paper.

fractures in the STA and in 82 out of 390 fractures in the ELA. Weighted mean percentage of wound healing complications were 4.9% in the STA and 24.9% in the ELA. Meta-analysis showed significantly less wound healing complications (Fig. 2) in the STA than in the ELA (risk ratio 0.20; 95% CI 0.11 to 0.36; $P < 0.00001$; $I^2 = 0\%$). In the STA, all 11 wound healing complications were classified as minor. In the ELA, 58 out of 82 (71%) were classified minor and 24 out 82 (29%) were classified as major.

3.2. Secondary outcomes

Time to surgery in seven studies [15,37–41,44] and operative time in six studies [15,36,38,40,41,44] showed high heterogeneity (I^2 of 91% and 98% respectively). Results were not pooled. In general, time to surgery and operative time were shorter for the STA when compared to the ELA (Table 5).

Implant removal in four studies [15,39,41,44] showed moderate heterogeneity (I^2 of 50%). Results were not pooled. In total, implants were removed in 11 out 103 patients following the STA, and in 11 out of 162 patients following the ELA.

Fracture reduction according to Böhler's angle in seven studies [15,36–38,40,42,44] showed moderate heterogeneity (I^2 of 55%). Results were not pooled. No significant differences were found between both approaches (Table 6).

CT evaluation of posterior facet reduction was evaluated in two studies. In the first study [15], anatomic reduction of the STA (defined as no joint surface step-off) was achieved in 15 out of 18 fractures (83%), while nearly anatomic reduction (defined as joint surface step-off less than 2 mm) was achieved in the remaining three fractures (17%). For the ELA, the rates were 16 out of 20 (80%) and four out of 20 (20%), respectively. This was non-significant. In the second study [38], two out of 60 patients in the ELA group had a minimal step-off (defined as less than 2 mm). No step-off was seen in the STA group.

In total, five functional outcome measures were used (Table 7). Follow-up time and percentage of loss to follow-up varied widely. Results of the American Orthopaedic Foot and Ankle Society Hindfoot scale (AOFAS) in six studies [15,37,40–42,44] showed moderate heterogeneity (I^2 of 72%). Results were not pooled. One study [36] showed a significantly better outcome for the STA when compared to the ELA according to the Maryland Foot Score. The scores were given in percentages according to predefined cut-off values (excellent/good outcome in 94% versus 87% in the STA and ELA, respectively) and this difference was statistically significant

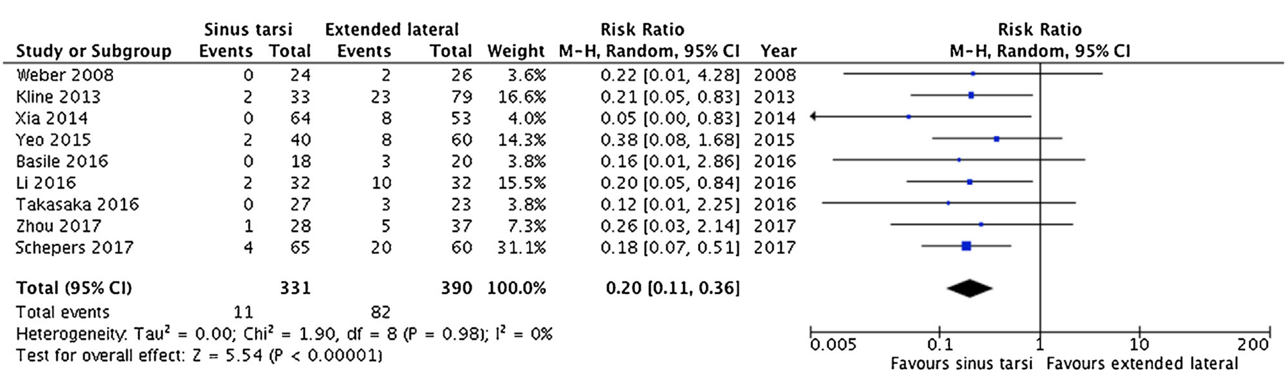

Fig. 2. Forest plot showing the risk ratio for postoperative wound healing complications following the sinus tarsi approach, as compared with the extended lateral approach.

Table 5
Time to surgery and operative time.

	Time to surgery (days)		Operative time (minutes)	
	STA	ELA	STA	ELA
[a]Zhou et al. [44]	4.9 ± 1[e]	7.2 ± 1.5[e]	77 ± 7[e]	83 ± 8[e]
[b]Schepers et al. [38]	14 ± 1.8[d]	18 ± 2.3[d]	105 ± 9[d]	134 ± 8[d]
[c]Li et al. [37]	4.6 ± 1.2[d]	6.9 ± 1.7[d]	NP	NP
[b]Basile et al. [15]	7 ± 3.6[d]	19.4 ±7.5[d]	122 ± 8[d]	187 ± 17[d]
[a]Yeo et al. [40]	7 ± 3.5[f]	7.5 ± 4[f]	62 ± 9[f]	76 ± 8[f]
[c]Xia et al. [36]	NP	NP	62 ± 9[d]	93 ± 11[d]
[a]Kline et al. [39]	9.9 ± 3.3[f]	14.7 ± 3.8[f]	NP	NP
[a]Weber et al. [41]	8.2[e]	8.0[e]	108 ± 26[d]	160 ± 26[d]

Data is provided as mean ± SD (when provided). STA = sinus tarsi approach. ELA = extended lateral approach. NP = not provided.
[a] Retrospective comparative series.
[b] Prospective comparative series.
[c] Randomized controlled trial.
[d] Significant difference in original study (P < 0.05).
[e] No significant difference in original study (P > 0.05).
[f] Significance not provided in original study.

(P < 0.01). The remaining studies [15,39–42,44] did not show significant differences between both approaches in terms of functional outcome.

Outcomes of pain according to the Visual Analogue Scale (VAS) was not pooled as studies measured VAS inconsistently during activities or did not specify when VAS was measured (Table 7). Four studies described sural nerve injury [39–42]. Meta-analysis (Fig. 3) showed no significant differences between both approaches (risk ratio 0.56; 95% CI 0.18–1.74); P = 0.32; $I^2 = 0\%$). While peroneal tendon injury was reported in three studies [15,40,42], no meta-analysis was performed as injury occurred once in both approaches.

4. Discussion

In the operative treatment of displaced intra-articular calcaneal fractures, the optimal approach with regard to postoperative wound healing complications and outcome is subject of debate. The main outcome of this systematic review and meta-analysis is that the STA is associated with significantly less postoperative wound healing complications than the ELA. The risk ratio equalled 0.20, which means that the risk of developing a wound infection (relative risk reduction) decreases with 80% when the STA is used. Of the operatively treated fractures by the ELA, 24.9% developed postoperative wound healing complications. This is consistent with previous reports on the ELA [5,6,8,11,19,46–48], while percentages up to 32% have also been described [21]. Furthermore, nearly a third (24/82 or 29%) of the complications following the ELA were classified as major. The incidence of postoperative wound healing complications following the STA in this review was much lower (4.9%) and no major complications were noted.

Case series on the STA report varying wound complication rates; 0%–19% [7,10,49–56]. The reasons for the low incidence of wound complications in the STA in this review compared to previous reports may be attributed to selection or publication bias.

The high incidence of wound healing complications in the ELA may be explained by the larger incision size and more extensive soft tissue dissection while raising full thickness flaps to expose the lateral calcaneus. Despite overlapping angiosomes, i.e. between the lateral calcaneal artery, the lateral malleolar artery and the lateral tarsal artery, the lateral calcaneal artery is responsible for the majority of blood supply to the corner of the flap in the ELA [57]. This artery furthermore supplies nearly half of the blood supply to the calcaneus [58]. As the lateral calcaneal artery is consistently found in the proximity of the vertical incision in the ELA [59], this approach may compromise the blood supply to the full thickness flap and the calcaneus. In contrast, the incision in the STA does not violate the course of the lateral calcaneal artery [7,59].

Meta-analyses show that the ELA, compared to non-operative treatment of calcaneal fractures, results in better shoe wear, walking ability and quicker return to work [6,60]. However, results are hampered by frequent wound healing complications [6,60]. This review suggests that by using the STA, similar functional outcome may be expected, with lower wound complications. This in turn may lower medical costs [61,62]. The STA furthermore may be of interest in patients at high-risk for wound healing complications, such as diabetics, smokers or patients with comorbidities. In clinical practice, operative treatment by the ELA in such patients may be omitted due to concern for complications [12]. As risk factors for complications in this review, if described, did not differ between both approaches, the STA may lower complications in high-risk patients [19–21].

Despite heterogeneity between studies, time to surgery in general was shorter in the STA. This indicates that soft tissue conditions, especially swelling, are less of an issue when using the STA, which relies on a small incision. Earlier operative treatment results in faster rehabilitation and shorter hospital stay. Whether delay of surgery in the ELA results in more postoperative wound healing complications is unclear. Previous studies have shown increased infection rates among patients with delayed operative fixation [46,47], while more recent studies do not [21,63]. Similarly, operative time in general was longer in the ELA compared to the

Table 6
Pre-operative, postoperative and follow-up measurements of Böhler's angle for the sinus tarsi (STA) and extended lateral (ELA) approach. Data is provided in mean ± standard deviation or median (range). No significant differences were found between both approaches.

Study	Böhler's angle pre-operative		Böhler's angle post-operative		Böhler's angle follow-up	
	STA	ELA	STA	ELA	STA	ELA
[a]Zhou et al. [44]	17 ± 4	16 ± 4	27 ± 3	27 ± 3	NP	NP
[b]Schepers et al. [38]	−2 (−14 to 9)	−5 (−15 to 7)	27 (24–32)	26 (20–30)	NP	NP
[c]Li et al. [37]	1 ± 2	2 ± 2	28 ± 3	28 ± 4	23 ± 4	25 ± 4
[a]Takasaka et al. [42]	NP	NP	18 (6–40)	22 (12–32)	NP	NP
[b]Basile et al. [15]	7 ± 8	7 ± 8	37 ± 7	39 ± 5	NP	NP
[a]Yeo et al. [40]	17 (0–35)	17 (0–46)	NP	NP	27 (5–45)	25 (4–45)
[c]Xia et al. [36]	2 ± 4	2 ± 4	28 ± 4	29 ± 4	NP	NP
[a]Kline et al. [39]	NP	NP	NP	NP	26	28
[a]Weber et al. [41]	No data given on Böhler's angle; authors only state that no loss of reduction was noticed according to Böhler's angle (no change >5° at any follow-up)					

NP = not provided.
[a] Retrospective comparative series.
[b] Prospective comparative series.
[c] Randomized controlled trial. .

Table 7
Length of follow-up and functional outcome for the included studies.

Study	Follow-up (months)		Loss to follow-up		Functional outcome			P-value
	STA	ELA	STA	ELA	Type	STA	ELA	
[a]Zhou et al. [44]	14.3	14.9	18/83 (22%)		AOFAS	88.4 ± 6.6	83.2 ± 5.6	0.296
					VAS	1.9 ± 0.7	2.3 ± 1.0	0.212
[b]Schepers et al. [38]	Minimum 6 Median 22		0/65 (0%)	0/60 (0%)	Functional outcome not assessed			
[c]Li et al. [37]	12	12	1/32 (3%)	3/32 (9%)	AOFAS	79.8 ± 7.9	79.3 ± 8.2	0.82
					VAS (during walking)	1.5 ± 0.7	1.8 ± 0.9	0.16
[a]Takasaka et al. [42]	Minimum 24		0/27 (0%)	0/20 (0%)	AOFAS	71 (60–90)	76 (69–94)	0.44
[b]Basile et al. [15]	Minimum 24		7/45 (16%)		AOFAS	82.2 ± 11.5	82.0 ± 10.9	>0.05
					VAS	2.1 ± 1.6	2.3 ± 1.4	>0.05
					FFI	18.4 ± 12.7	17.9 ± 11.0	>0.05
[a]Yeo et al. [40]	46 (26–100)	57 (36–96)	0/40 0%	0/60 0%	AOFAS	90 (79–94)	86 (76–94)	>0.05
					VAS	2 (1–5)	2 (1–5)	>0.05
					FFI	9.6 (8–14)	9.6 (8–15)	>0.05
[c]Xia et al. [36]	19 (8–28)		11/70 (16%)	8/57 (14%)	MFS	94% excellent/ good (60/64)	87% excellent/ good (46/53)	<0.01
[a]Kline et al. [39]	31 (12–50)	28 (12–49)	17/33 (52%)	48/79 (61%)	VAS (during activity)	3.1	3.6	0.48
					FFI	22.2	30.8	0.21
					SF-36	70.7	63.5	0.33
[a]Weber et al. [41]	31 (12–65)	25 (11–76)	11/61 (18%)		AOFAS	87.2 (65–100)	82.7 (44–98)	0.17

STA = sinus tarsi approach. ELA = extended lateral approach. AOFAS = American Orthopaedic Foot and Ankle Society Hindfoot scale. VAS = Visual Analogue Scale (Pain Score). FFI = Foot Function Index. SF-36 = Short Form 36 Health Survey. MFS = Maryland Foot Score.
[a] Retrospective comparative series.
[b] Prospective comparative series.
[c] Randomized controlled trial.

STA. Longer operative time may be associated with increased wound infection [46]. Shorter operative time in the STA may be due to the less extensive tissue dissection and shorter wound closure time.

In general, no differences were found in functional outcome when comparing the ELA with the STA [15,37,40–42]. The higher incidence of postoperative wound healing complications may result in worse functional outcome [64]. A case series showed that at six years, patients with a postoperative wound infections following the ELA had a non-significant trend toward worse outcome according to the Foot Function Index and AOFAS (respectively 17 and 9 points lower), and a significantly worse outcome for pain according to the Visual Analogue Scale (VAS; 1.3 points lower) [64].

Despite the smaller incision in the STA, fracture reduction according to Böhler's angle [15,36–38,40–42] and restoration of the posterior facet [15,38] were comparable to the ELA. This may be explained by less extensive tissue dissection, allowing for reduction through ligamentotaxis [65], combined with direct visualisation of the posterior facet via the sinus tarsi, respectively. A cadaver study showed similar posterior facet exposure with the STA but significantly less dissection of the lateral wall when compared to the ELA [35]. CT-based case series confirm the favourable posterior facet restoration through the STA [7,10,66] and the stability of the osteosynthesis without loss of restoration at follow-up [7]. Restoration within 2 mm may be achieved in 91% [66] to 100% [38] in the STA, compared to 57%–82% in the ELA [8,11,48]. Both the restoration of Böhler's angle and the posterior facet are associated with improved outcome [8].

Rates of implant removal were similar in both approaches. Plates used in the STA are generally smaller [7] compared to those in the ELA [16] and thus may cause less implant related symptoms. The similar implant removal rates in the STA may be explained by symptomatic heel screws which may need removal [7,41]. Finally, despite more tissue dissection in the ELA, rates of peroneal tendon and sural nerve injury were equal for both approaches. However, a tendency towards more sural nerve injury was seen in the ELA.

This study is an up-to-date systematic review and meta-analysis, according to the PRISMA guidelines [13], on the outcome of the two commonly used approaches in operative calcaneal fracture treatment. Our results concur with two recent meta-analyses in terms of wound healing complications, restoration of Böhler's angle and functional outcome [31,33]. The present meta-analysis however included five additional studies [15,37,38,42,44] when compared to Zhang et al. [31] and two additional studies [38,44] when compared to Yao et al. [33]. Also, Zhang et al. [31] did not specify whether their study was performed according to the PRISMA Guidelines [13]. Furthermore, Yao et al. [33] included one study which did not use a sinus tarsi approach but a longitudinal approach between the Achilles tendon and the fibula [43].

There are limitations to our study. First, all included studies were of risk of bias. Only two randomized controlled trials were

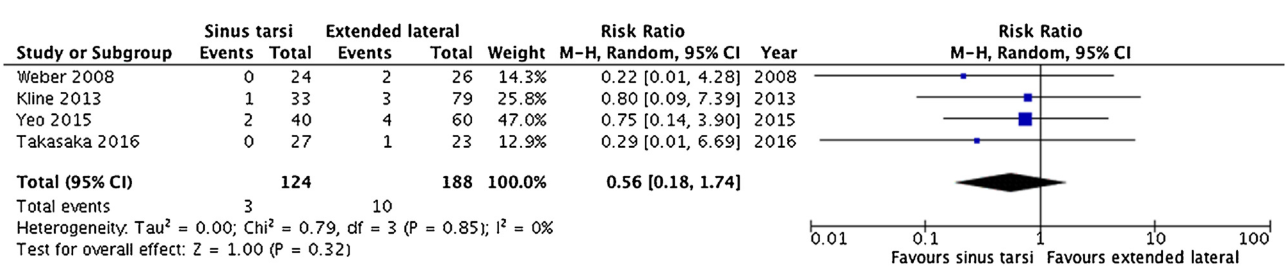

Fig. 3. Forest plot showing the risk ratio for sural nerve injury following the sinus tarsi approach, as compared with the extended lateral approach.

included. Second, assessment of publication bias through funnel plot analysis could not be performed. Third, many different outcome measures were used. CT assessment of posterior facet restoration, which is associated with clinical outcome [8], was assessed only in two studies. Fourth, meta-analysis of many secondary outcome measures could not be performed because of high heterogeneity. Finally, results may not apply to Sander's type IV [14] fractures.

5. Conclusion

The STA is associated with significantly less wound healing complications and, in general, with shorter time to surgery and shorter operative time when compared to the ELA. As functional outcome and restoration of calcaneal anatomy according to Böhler's angle and posterior facet reduction are similar, the STA may be the preferred approach in the operative treatment of patients with displaced Sanders type II and III intra-articular calcaneal fractures.

Conflict of interest

The authors declare that they have no conflict of interest.

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