Insights into optimal surgical fixation for posterior malleolar fractures

a network meta-analysis

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Aims
The optimal management of posterior malleolar ankle fractures, a prevalent type of ankle trauma, is essential for improved prognosis. However, there remains a debate over the most effective surgical approach, particularly between screw and plate fixation methods. This study aims to investigate the differences in outcomes associated with these fixation techniques.

Methods
We conducted a comprehensive review of clinical trials comparing anteroposterior (A-P) screws, posteroanterior (P-A) screws, and plate fixation. Two investigators validated the data sourced from multiple databases (MEDLINE, EMBASE, and Web of Science). Following PRISMA guidelines, we carried out a network meta-analysis (NMA) using visual analogue scale and American Orthopaedic Foot and Ankle Score (AOFAS) as primary outcomes. Secondary outcomes included range of motion limitations, radiological outcomes, and complication rates.

Results
The NMA encompassed 13 studies, consisting of four randomized trials and eight retrospective ones. According to the surface under the cumulative ranking curve-based ranking, the A-P screw was ranked highest for improvements in AOFAS and exhibited lowest in infection and peroneal nerve injury incidence. The P-A screws, on the other hand, excelled in terms of VAS score improvements. Conversely, posterior buttress plate fixation showed the least incidence of osteoarthritis grade progression, postoperative articular step-off ≥ 2 mm, nonunions, and loss of ankle dorsiflexion ≥ 5°, though it underperformed in most other clinical outcomes.

Conclusion
The NMA suggests that open plating is more likely to provide better radiological outcomes, while screw fixation may have a greater potential for superior functional and pain results. Nevertheless, clinicians should still consider the fragment size and fracture pattern, weighing the advantages of rigid biomechanical fixation against the possibility of soft-tissue damage, to optimize treatment results.

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Take home message

- The anteroposterior screw is most likely to yield superior results, improving American Orthopaedic Foot and Ankle scores and reducing infection and nerve injury rates, while the posteroanterior screw excels notably in enhancing visual analogue scale scores.
- Although open plating shows the greatest potential for improved radiological outcomes, it underperforms in several other clinical measures.
- It is important for clinicians to evaluate the fragment size and fracture pattern, balancing the benefits of strong biomechanical fixation with the risks of soft-tissue damage to achieve optimal therapeutic outcomes.

Introduction

Ankle fractures constitute a prevalent category of fractures, with an annual incidence rate of one to two cases per 1,000 individuals.[1] Notably, posterior malleolar fractures (PMFs) account for over one-third of all ankle fractures.[2] In the absence of appropriate treatment, these fractures may precipitate a reduction in the contact area, subsequently leading to suboptimal pressure distribution during dorsiflexion-plantar flexion movements.[3] Consequently, the presence of PMFs is deemed a detrimental prognostic factor among ankle fractures, potentially resulting in worsened clinical outcomes and the development of post-traumatic arthritis.[4,5] Surgical intervention, particularly via fixation techniques, has demonstrated improved functional outcomes and radiological results in PMFs, regardless of the fragment size.[3,4,6] Additionally, fixing the posterior malleolus can improve the stability of the syndesmosis and support the posterior inferior tibiofibular ligament, potentially reducing the need for direct syndesmosis fixation.[6,7] Despite the general necessity for surgical fixation in cases of displaced PMFs, the optimal implant for surgical intervention remains a subject of ambiguity in the current medical literature.

Presently, three principal methods are employed for the fixation of PMFs, encompassing anteroposterior (A-P) screws, posteroanterior (P-A) screws, and plate fixation.[8-12] A-P screws are deemed less invasive due to the reduced extent of soft-tissue dissection required. However, the indirect reduction manoeuvres may impede complete anatomical reduction because the fracture fragments are not directly observable during the reduction process.[2,11-14] In contrast, P-A screws facilitate direct anatomical reduction through a posterolateral incision and manipulation of minute fragments.[2,15] However, the technique necessitates additional soft-tissue release, and the extent to which it yields superior clinical outcomes compared to A-P screws remains inconclusive.[2,8-1215,,16] Plate fixation, another widely employed technique, enables direct fracture reduction, stable fixation, and the fixation of small fragments.[13,17] However, it is correlated with increased soft-tissue exposure, elevated risks of implant irritation, and a close proximity between the peroneal neurovascular structures and perforating branches during proximal exposure for plate placement.[2,8-1012-16] The selection of the optimal fixation method is critical for achieving the best clinical outcomes, and continues to be a subject of debate. This decision typically requires assessing the extent of soft-tissue damage, the stability of the fixation, and the resulting condition after reduction.

A multitude of systematic reviews have been carried out to explore the operative management outcomes for PMFs.[3,4,18,19] Nevertheless, none have undertaken a meta-analysis concerning the effect of implant choice on clinical outcomes. The existing meta-analyses primarily focused on assessing the influence of posterior malleolar fragment morphology on clinical outcomes,[6] or exclusively examined the juxtaposition between plate/screw fixation for substantially sized (> 25%) PMFs in posterior approaches,[20] omitting the fixation alternatives employing an anterior approach. Consequently, the objective of the present investigation is to undertake a comprehensive review and network meta-analysis (NMA), incorporating the most up-to-date exploration of obtainable evidence to compare various fixation techniques. We aim to contrast the disparities between screw and plate usage within anterior and posterior approaches.

Methods

Search methods for studies identification

Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Supplementary Table i), we conducted a systematic review (PROSPERO registration: CRD42023388516) to identify relevant studies by searching MEDLINE, EMBASE, and Web of Science databases from inception to 24 August 2023, without language restrictions. Additional studies were found through reference list examination. The search strategy is detailed in Supplementary Table ii.

Inclusion and exclusion criteria

This review encompasses studies employing prospective or retrospective designs (evidence levels 2 to 3) that investigate the comparative efficacy of distinct fixation approaches in adult patients with PMFs, including the use of A-P screws, P-A screws, and plates. Exclusion criteria were single-arm trials, paediatric trials, case reports, studies with unknown/incomplete outcomes, duplicate data, stress/open/pathological fractures, and unclear implant usage or outcome measurements. Excluded articles are listed in Supplementary Table iii.

Measurement of outcomes and treatment effects

The primary outcomes assessed in this review were pain scores, measured using the visual analogue scale (VAS; where 0 indicates "no pain" and 10 denotes "worst pain"), and functional improvement, measured using the American Orthopaedic Foot and Ankle Score (AOFAS).[21] Secondary outcomes included the limitation of range of motion (a loss of ankle dorsiflexion ≥ 5°), radiological outcomes (postoperative articular step-off ≥ 2 mm, the progression in osteoarthritis grade), and the incidence of complications (infection rate and peroneal nerve injury rate). Treatment effect measures included mean differences (MDs) with standard deviation (SD) for continuous variables and odds ratios (ORs) with 95% confidence intervals (CIs) for categorical variables.

Selection of studies

Two authors (YCS, YYW) independently reviewed titles/abstracts and conducted full-text evaluations. In instances where disagreements arose, a third author (CAS) was consulted to reach a consensus.

Data extraction and handling missing data

A single author (YCS) independently extracted the following information: first author's name, year of publication, study design, inclusion and exclusion criteria, patient characteristics, patient numbers, fracture type, implant choice, clinical and functional outcomes (pain score and functional score), and postoperative complications (osteoarthritis, loss of dorsiflexion, articular step-off). For the characteristic data, patient age, sex (male ratio), mean follow-up duration, publication year, study type (prospective or retrospective), and fracture size definition were collected. As no missing data were observed, no adjustments or calculation formulae were employed. The data extraction process was verified by a second author (CAS).

Assessment of risk of bias

Two evaluators (YCS, CWC) independently assessed methodological quality using the Risk of Bias in Non-randomized Studies of Interventions (ROBINS-I)[22] instrument for non-randomized trials and Version 2 of the Cochrane risk-of-bias tool (RoB 2)[23] for randomized trials. ROBINS-I evaluated potential biases, including confounding, participant selection, intervention classification, deviations from intended interventions, data incompleteness, outcome measurement, and reported results selection. RoB 2 addressed randomization, deviations from intended interventions, missing outcome data, outcome measurement, and reported result selection. In case of disagreement, a third author (CAS) was consulted. Risk of bias summary is provided in Supplementary Table iv.

Data synthesis

Statistical analyses were performed with Stata (v. 15, 2017; StataCorp, USA). Traditional pairwise meta-analysis enabled direct comparisons, while network meta-analysis (NMA) incorporated direct and indirect evidence. Most outcomes used random-effects models, except for loss of dorsiflexion, requiring a fixed-effects model due to insufficient studies. Heterogeneity was assessed using I^2 estimate and Cochrane Q test. To evaluate local inconsistency, we employed a loop-specific method for examining discrepancies between direct and indirect evidence, and the node-splitting approach for inconsistency testing.[24,25] Additionally, the design-by-treatment analysis was performed for assessing global inconsistency in the network.[24,25] Meta-regression sensitivity analyses were performed, incorporating variables such as age, sex, publication year, and study type. These analyses aimed to evaluate potential intransitivity due to these effect modifiers in the studies included in the NMA. The surface under the cumulative ranking curve (SUCRA) ranked treatment outcomes,[26] while publication bias was evaluated through funnel plots and Egger's regression plots.[26] Confidence in Network Meta-Analysis (CINeMA) web application assessed certainty of evidence, covering six domains: within-study bias, reporting bias, indirectness, imprecision, heterogeneity, and incoherence.[27,28]

Results

Study selection and description

Overall, 13 studies (four randomized controlled trials (RCTs)[8,9,15,29] and nine non-RCTs)[2,10–14,16,17,30] were included for analysis (Figure 1; Table I). The trials involved P-A screw fixation (11 trials),[2,8–12,15–17,29,30] A-P screw fixation (six trials),[2,11–14,29] and plate fixation (11 trials).[2,8–10,12–17,30] Four studies analyzed trimalleolar fractures,[2,11,13,29] while the remaining nine included a combination of various fracture patterns,[8–10,12,14–17,30] such as trimalleolar fractures, concurrent posterior and lateral malleolar fractures, and/or isolated posterior malleolar fractures. Concerning the fractured posterior malleolus size, six studies included cases with PM ≥ 25%,[8–10,16,29,30] one study addressed PM ≥ 20%,[15] and the criteria in the remaining seven studies were either unlimited or unclear.[2,11-14,17] For the length of follow-up, one study reported a mean follow-up that was short-term (less than one year),[16] 12 studies had mid-term follow-ups (one to five years),[2,8–11,13–15,17,29,30] and one study had a long-term follow-up (more than five years).[12]

Quality

In non-RCTs, potential biases included confounding factors, missing information, participant selection, outcome measurement, and deviations in planned interventions and reported findings (Supplementary Table iv). In RCTs, potential biases were related to randomization, allocation concealment, and blinding of participants and outcome evaluators (Supplementary Table iv).

Network meta-analysis

Figure 2 presents the network and forest plots comparing various fixation methods. The network plot illustrates connections between treatments (nodes), indicating that at least one clinical trial has provided direct evidence comparing these treatments. The width of each circle is proportional to the number of studies involving the respective treatment, and the thickness of the lines corresponds to the number of studies comparing those treatments. Supplementary Figure a and Supplementary Table v detail the outcomes of pooled estimates, illustrating the results of the network meta-analysis, which combines both direct and indirect comparisons, as well as the pairwise meta-analysis that focuses solely on direct comparisons. Moreover, Figure 3 demonstrates the likelihood of each treatment being the most effective, while Supplementary Figure b displays the cumulative probability of each treatment being ranked highest in terms of outcomes. Additionally, Table II provides a qualitative summary of these outcomes, emphasizing the SUCRA rankings.

Primary outcomes

Control groups using the P-A screw were established for comparative analysis. A positive MD value indicates a favourable outcome for the intervention over the control (P-A screw). Regarding AOFAS changes (n = 9),[2,8-1012,15-17] A-P screw and plate showed combined MDs of 3.02 points (95% CI -2.79 to 8.84) and 1.07 points (95% CI -1.48 to 3.63), respectively. For VAS changes (n = 3),[2,9,11] A-P screw and plate had combined MDs of -0.07 points (95% CI -0.46 to 0.33) and -0.03 points (95% CI -0.47 to 0.41), respectively. A-P screw ranked best for greater AOFAS improvement (SUCRA = 78.8%), while P-A screw (SUCRA = 59.4%) ranked best for greater VAS improvement.

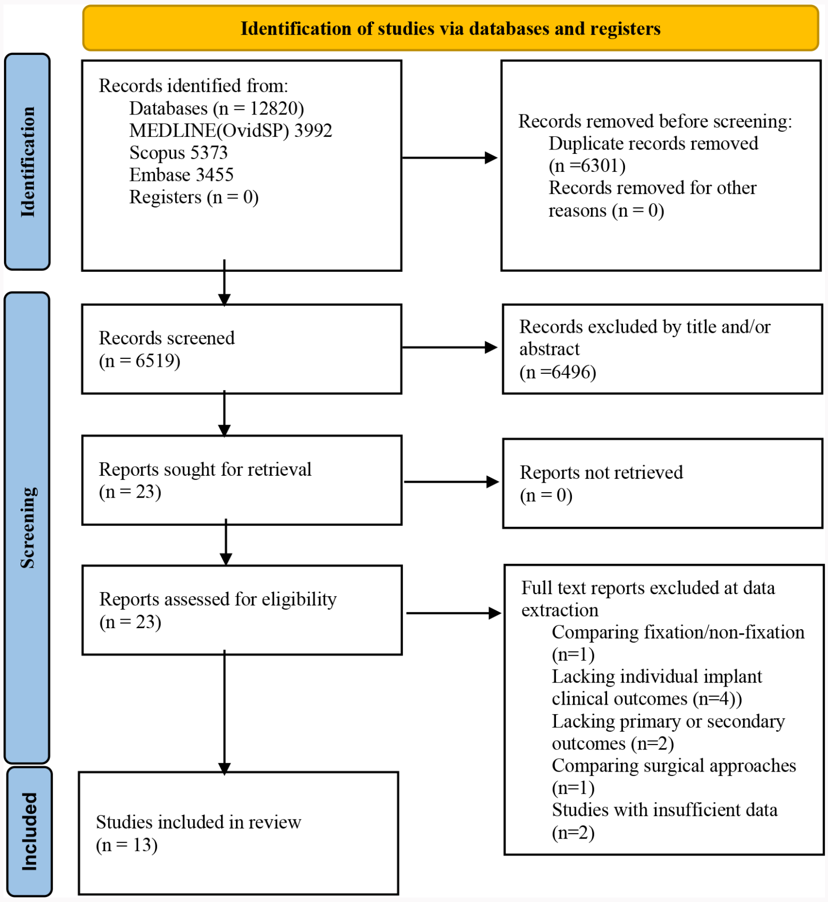

Fig. 1
PRISMA flow diagram.

Secondary outcomes

Control groups were established for the P-A screw. An OR value less than 1 indicates a reduced risk of incidence and a favourable outcome for the intervention compared to the control (P-A screw). In studies assessing the incidence of OA grade progression (n = 7),[2,9–11,14,15,30] the combined ORs were 2.24 (95% CI 0.89 to 5.67) for the A-P screw and 0.83 (95% CI 0.36 to 1.89) for the plate. Similarly, for the incidence of step-off ≥ 2 mm (n = 7),[9,11,13–15,29,30] the combined ORs were 3.05 (95% CI 1.23 to 7.59) for the A-P screw and 0.79 (95% CI 0.25 to 2.48) for the plate. Regarding the incidence of nonunions (n = 12),[2,8–11,13–17,29,30] the combined ORs were 1.02 (95% CI 0.16 to 6.40) for the A-P screw and 0.89 (95% CI 0.24 to 3.31) for the plate. In the incidence of loss of ankle dorsiflexion ≥ 5° (n = 2),[2,15] the combined ORs were 1.56 (95% CI 0.44 to 5.49) for the A-P screw and 0.64 (95% CI 0.25 to 1.63) for the plate. For the incidence of infections (n = 9),[2,8–10,14–16,29,30] the combined ORs were 0.73 (95% CI 0.16 to 3.27) for the A-P screw and 1.24 (95% CI 0.50 to 3.12) for the plate. Lastly, regarding the incidence of peroneal nerve injuries (n = 5),[2,9,10,14,15] the combined ORs were 0.70 (95% CI 0.05 to 9.38) for the A-P screw and 1.32 (95% CI 0.32 to 5.46) for the plate.

The plate was found to be the most effective treatment for reducing the progression of osteoarthritis (SUCRA = 81.9%), step-off (SUCRA = 83.3%), nonunion (SUCRA = 57.0%), and loss of ankle dorsiflexion ≥ 5° (SUCRA = 88.2%). In contrast, screws, specifically A-P screws, showed the highest effectiveness for lowering the incidences of infection (SUCRA = 72.2%) and peroneal nerve injury (SUCRA = 63.9%).

Level of evidence

Using CINeMA, most confidence ratings ranged from low to moderate, with some as very low (Supplementary Table vi).

Reporting bias

All outcomes showed no publication bias based on funnel plots and Egger's plots, except for AOFAS, which exhibited significant asymmetry (Supplementary Figure c).

Sensitivity analysis

Meta-regression with age, sex, publication year, and study type showed that none of them moderated the outcomes (Supplementary Table vii).

Assessment of inconsistencies

No global design inconsistency or local loop inconsistencies were noted for any of the outcomes, except for AOFAS change (Supplementary Table viii), which showed local inconsistency with the side-splitting method (Supplementary Table vix).

Discussion

This study is the first to conduct a NMA on fixation methods for PMFs. The NMA highlighted varied outcomes between anterior and posterior approaches using different implants. The anterior method with A-P screws notably improved

Table I. Characteristics of the included trials.

Author	Level of evidence	Patients, n (F/M)	Fracture type/size	Intervention	Mean AOFAS change, points (SD)	Mean VAS change, points (SD)	Osteoarthritis grade progression, n	Step-off ≥ 2 mm, n	Nonunions, n	Loss of dorsiflexion ≥ 5°, n	Infections, n	Peroneal nerve injuries, n	Mean follow-up, mths
Erdem (2014)[15]	II	20 (9/11)	TM or PM + LM/	Plate	93.55 (4.58)		1	1	0	7	0	0	39.2
		20 (11/9)	≥ 20%	P-A screws	94.55 (4.19)	N/A	2	1	0	8	1	0	37.2
Kalem (2018)[2]	III	20 (8/12)		A-P screws	86.4 (7.97)	0.55 (0.82)	2		0	9	0	0	14.4
		13 (8/5)	TM/	P-A screws	93.8 (4.05)	0.76 (1.3)	0		0	5	0	0	16.3
		34 (24/10)	Unlimited	Plate	94.7 (5.29)	0.94 (1.84)	1	N/A	0	8	1	0	17.1
Ma (2021)[10]	III	44 (25/19)	TM or PM + LM/	Plate	84.3 (8.5)		2		0		1	2	
		51 (27/24)	≥ 25%	P-A screws	85.5 (7.7)	N/A	2	N/A	0	N/A	2	3	18.2
Zhang (2020)[9]	II	24 (11/13)	Any PM	P-A screws	92.5 (5.3)	2.4 (1)	16	2	0		0	0	29.5
		24 (10/14)	≥ 25%	Plate	94.7 (5.6)	2.2 (3)	15	1	0	N/A	0	0	30.4
O'Connor (2015)[13]	III	11 (7/4)	TM/	A-P screws				2	0				32
		16 (9/7)	Unclear	Plate	N/A	N/A	N/A	2	0	N/A	N/A	N/A	54.9
Neumann (2022)[12]	III	14 (N/A)	TM or PM + LM/	A-P screws	89.71 (15.18)								
		13 (N/A)		P-A screws	87.96 (20.41)								
		36 (N/A)	Unclear	Plate	86.56 (22.25)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	83.6
Yu (2021)[11]	III	40 (15/25)		A-P screws		0.78 (0.7)	33	15	0				
		36 (12/24)	TM/ unclear	P-A screws	N/A	0.75 (0.69)	25	5	0	N/A	N/A	N/A	30
Vidovic (2017)[29]	II	24 (N/A)	TM/	P-A screws A-P screws				1	0		1		
		22 (N/A)	≥ 25%		N/A	N/A	N/A	5	0	N/A	0	N/A	20.5
Wang (2020)[17]	III	89 (43/46)	Any PM/ unlimited	P-A screws	91.74 (5.99)				0				
		81 (44/37)		Plate	87.74 (5.40)	N/A	N/A	N/A	0	N/A	N/A	N/A	17.9
Liu (2020)[8]	II	38 (19/19)	Any PM/	P-A screws	81.71 (12.39)				0		2		
		47 (18/29)	≥ 25%	Plate	86.62 (10.12)	N/A	N/A	N/A	0	N/A	4	N/A	13.1
Wang (2017)[30]	III	84 (37/47)	TM or PM + LM/	P-A screws	92.6 (3.3)		0	5	0		1		16.9
		83 (45/38)	≥ 25%	Plate	91.7 (4.1)	N/A	0	0	0	N/A	3	N/A	17.1
Huber (1996)[14]	III	30 (16/14)	TM or PM + LM/unclear	A-P screws			1	5	0		2	0	≥ 12
		30 (19/11)		Plate	N/A	N/A	0	2	0	N/A	3	1	≥ 12
Wang (2016)[16]	III	50 (18/32)	Any PM/	P-A screws	85.1 (8.6)				0		3		9.8
		50 (15/35)	≥ 25%	Plate	89.4 (7.9)	N/A	N/A	N/A	0	N/A	2	N/A	9.2

AOFAS, American Orthopedic Foot and Ankle Score; A-P, anteroposterior ; LM, lateral malleolar; N/A, not applicable; P-A, posteroanterior ; PM, posterior malleolar; SD, standard deviation; TM, trimalleolar; VAS, visual analogue scale.

functionality (AOFAS changes) and minimized soft-tissue complications. In contrast, the posterior method with P-A screws excelled in pain relief (VAS changes). Plates, meanwhile, produced optimal radiological results (with the fewest instances of osteoarthritis grade progression, step-offs, and nonunions) but had the highest rate of dorsiflexion loss.

Biomechanically, the posterior malleolus is key to tibiotalar load bearing, counteracting posterior talar dislocation, and supporting the posterior inferior tibiofibular ligament.[7] Anatomical realignment and robust fixation improve the stability of the syndesmosis, while weak fixation may lead to misalignment and increased pressure, potentially causing degenerative arthritis.[7] Simulations of 25% to 50% PMFs have shown a 4% to 22% reduction in contact area.[31] Clinical studies have linked a postoperative step-off of 1 to 2 mm to mediocre outcomes and ankle osteoarthritis, independent of PM fragment size.[12,13] Pursuit of optimal realignment, often via a posterior approach, necessitates soft-tissue dissection, presenting potential risks and possibly affecting outcomes. This continues to fuel debates on the best approach to repair posterior malleolar fractures.

The posterior approach with plate fixation is common for treating fractured PMs, due to its direct visualization, open reduction, and stable fixation.[2,9,13,15] Our study showed superior outcomes of posterior buttress plates, particularly in postoperative radiological results (such as osteoarthritic changes and step-offs) and dorsiflexion loss reduction. These findings are in line with previous studies favoring the buttress plate for both radiological and functional outcomes over A-P and P-A screw fixations,[2,8,13,14] respectively. However, some research found no significant difference in clinical functionality between posterior plates and P-A/A-P screws.[9,10,15] Recent findings suggested a decrease in functionality (AOFAS and range of motion) for the plate group with smaller fragment sizes (<

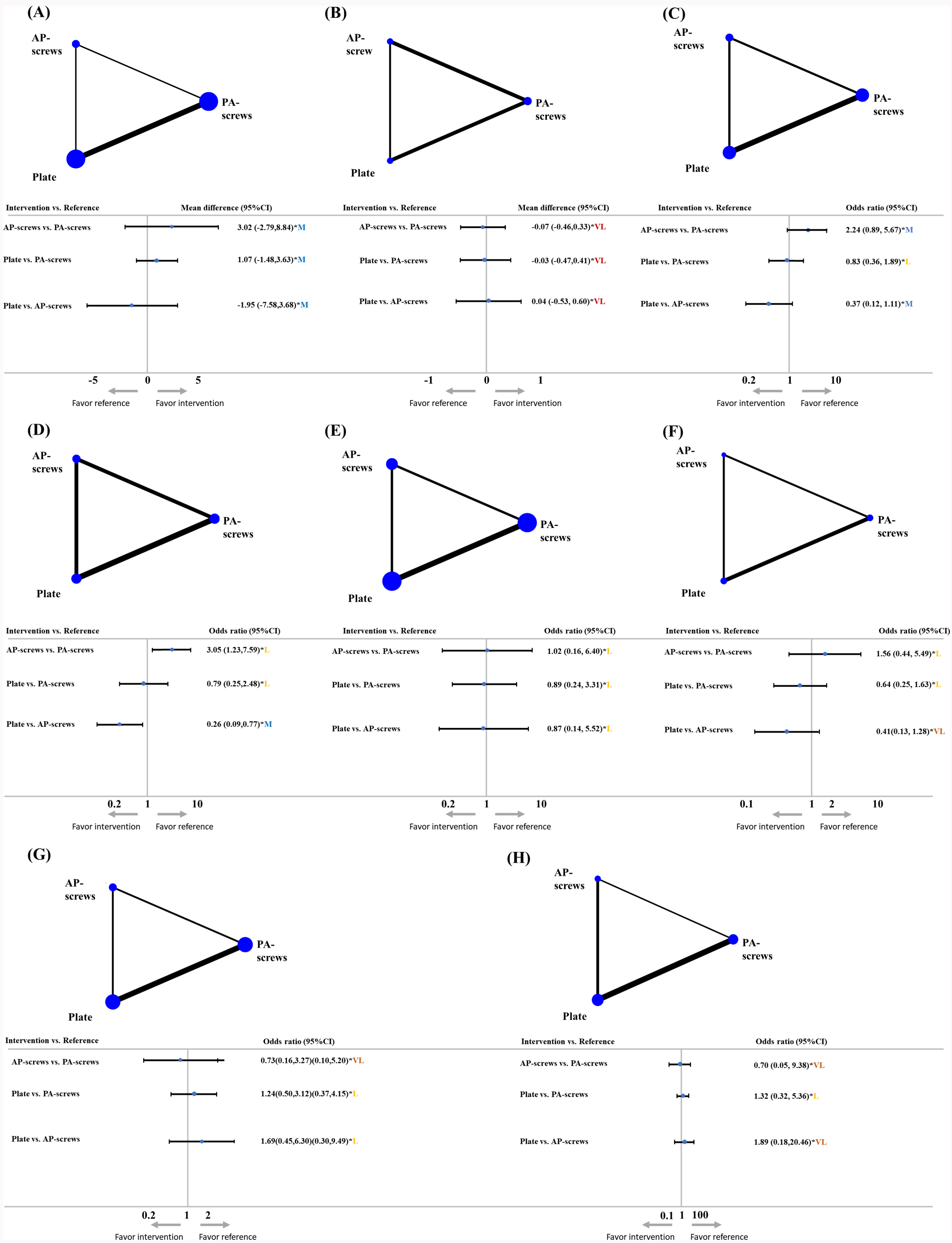

Fig. 2

Network plots and the network meta-analysis result with confidence rating for a) American Orthopaedic Foot and Ankle Score (AOFAS) changes, b) visual analogue scale (VAS) changes, c) the incidence of osteoarthritis grade progression, d) the incidence of step-off ≥ 2 mm, e) the incidence of nonunions, f) the incidence of loss of dorsiflexion ≥ 5°, g) the incidence of infections, and h) the incidence of peroneal nerve injuries. *$p < 0.05$. A-P, anteroposterior; CI, confidence interval; L, low confidence rating; M, moderate confidence rating; P-A, posteroanterior; VL, very low confidence rating.

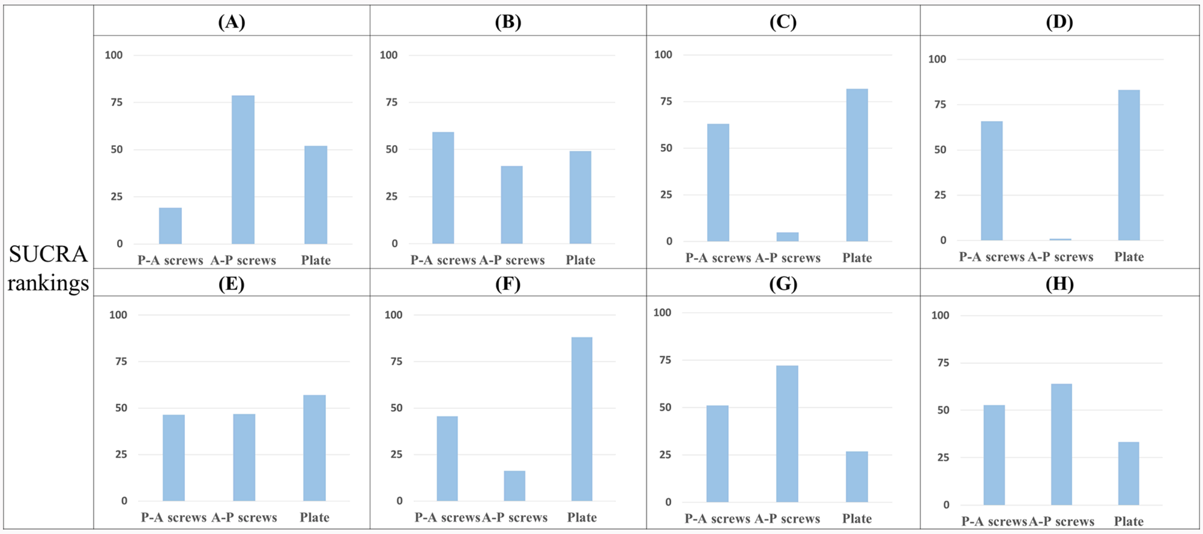

Fig. 3

Relative ranking probability of different posterior malleolar fractures fixation methods for a) American Orthopaedic Foot and Ankle Score (AOFAS) changes, b) visual analogue scale (VAS) changes, c) the incidence of osteoarthritis grade progression, d) the incidence of step-off ≥ 2 mm, e) the incidence of nonunions, f) the incidence of loss of dorsiflexion ≥ 5°, g) the incidence of infections, and h) the incidence of peroneal nerve injuries. A-P, anteroposterior; P-A, posteroanterior; SUCRA, surface under the cumulative ranking curve.

Table II. Qualitative summary of the postoperative outcomes from the network meta-analysis.

Outcomes	P-A screws	A-P screws	Plate
AOFAS changes/ improvement	Fewest (least favoured)	Most (most favoured)	Less (less favoured)
VAS changes/ improvement	Most (most favoured)	Fewest (least favoued)	Less (less favoured)
OA grade progression incidence	Lower (less favoured)	Highest (least favoured)	Lowest (most favoured)
Step-off ≥ 2 mm incidence	Lower (less favoured)	Highest (least favoured	Lowest (most favoured)
Nonunion incidence	Highest (least favoured)	Lower (less favoured)	Lowest (most favoured)
Loss of dorsiflexion ≥ 5° incidence	Lower (less favoured)	Highest (least favoured)	Lowest (most favoured)
Infection incidence	Lower (less favoured)	Lowest (most favoured)	Highest (least favoured)
Peroneal nerve injury incidence	Lower (less favoured)	Lowest (most favoured)	Highest (least favoured)

AOFAS, American Orthopaedic Foot and Ankle Score; A-P, anteroposterior ; OA, osteoarthritis; P-A, posteroanterior; VAS, visual analogue scale.

15%) compared to P-A screw groups.[17] Our NMA reveals better radiological outcomes for the plate group, but not necessarily superior functional or pain scores. It also highlighted increased soft-tissue complications, like wound infections and peroneal nerve injuries, possibly due to larger surgical exposure and soft-tissue dissections,[8] plus risks of tendon impingement and peroneal nerve injury.[29] Many orthopaedic surgeons prefer posterior buttress plates for PMFs, possibly due to their potential to prevent axial migration and maintain reduction,[9] supported by biomechanical[32] and finite element studies.[7] However, radiological outcomes and biomechanical stability do not always align with clinical prognosis, which is more often linked to pain and function.[9,10,15]

Another common method for PMF fixation is P-A screw fixation using a posterior approach, which offers advantages due to its ability to enable a direct reduction via a posterior route of lesser magnitude, facilitate disimpaction of smaller osteochondral fragments, and secure fixation with lag screws. This NMA showed that PA screw constructs ranked the best for greater pain score (VAS) improvement, while they performed suboptimally regarding functional and radiological results. Such findings are consistent with numerous clinical studies delineating equivalent or substandard functional and radiological outcomes of PA screws when juxtaposed with posterior plates[2,8-10,15] and AP screws.[12,30] The foremost advantage of PA screw fixation compared to plate fixation is its equivalent proficiency in attaining anatomical reduction through open reduction using a posterior approach, yet with a diminished dissection and iatrogenic trauma. Other advantages include reduced surgical time and intraoperative blood loss in the PA screw group compared to the plate group.[8] Furthermore, a prior study suggested that for Haraguchi Type-I PMFs, plate fixation strength may be inferior to that of PA screws.[30] Although PA screw fixation still demonstrates multiple benefits, it also presents drawbacks in the context of functional and radiological outcomes.

The use of AP screws for percutaneous fixation in PMF surgery is widely endorsed due to its distinct advantages, chiefly pertaining to soft-tissue conditions. These conditions significantly influence postoperative recuperation by impeding soft-tissue adhesion, accelerating wound healing, and mitigating iatrogenic neurovascular injuries derived from soft-tissue dissection.[17,33] Nevertheless, obstacles such as periosteal interposition, haematoma, fracture callus, and free osseous fragments within PMF gaps may preclude the successful execution of anatomical reduction via indirect approaches,[8,10,15] and the fixation of minute or comminuted fragments could pose technical difficulties.[17] According to our NMA, AP screws ranked best in enhancing functional scores (AOFAS) and improving soft-tissue outcomes, corroborating previous studies that reported superior functional improvements[12] and reduced soft-tissue complications.[2,14] However, the NMA yielded paradoxical findings concerning radiological outcomes associated with A-P screws, contradicting the assumption that superior radiological results necessarily translate to improved functional recovery. These findings echo prior ankle fracture research, one of which compared external fixation to internal fixation, indicating a higher functional score in the external fixation group despite superior reductions in the internal fixation group.[34] Another study found that perfect reductions did not invariably lead to exceptional outcomes.[35] Therefore, these findings may underscore the importance of considering not only anatomical reduction, but also the impact of soft-tissue damage and the severity of articular injury in optimizing treatment outcomes.

This NMA has certain limitations. First, the limited trials included may affect the robustness of some conclusions. Second, inconsistencies surfaced in AOFAS scores, possibly due to variations in trial designs and treatments. Although a meta-regression was conducted for further subgroup analysis, it did not include fracture size due to the varied percentages among the trials. Third, we included both randomized and non-randomized trials. To mitigate bias, we followed ROB 2 and ROBINS-I guidelines, and the meta-regression revealed no significant bias between trial types. Fourth, confidence ratings mostly ranged from low to moderate, with some rated as very low, suggesting caution when interpreting those specific results. Fifth, while most outcomes used a random-effects model, the incidence of ankle dorsiflexion loss employed a fixed-effect model due to limited trials, making the random-effects model estimation unviable. Sixth, most studies concentrate on trimalleolar fractures or a mix of various malleolar fracture patterns for fixation. This focus might affect postoperative outcomes, such as AOFAS, VAS, and range of motion, as isolated posterior malleolar fractures are not the sole subject of these studies. Consequently, future research should consider concentrating on the treatment of isolated posterior malleolar fracture fixation. Finally, as most of the included trials (12 in total) reported outcomes over a medium term, with an average follow-up period ranging from one to five years, future research should focus on long-term follow-up to assess outcomes over an extended period.

In conclusion, the NMA suggests that open plating is more likely to provide better radiological outcomes, while screw fixation may have a greater potential for superior functional and pain results. Nevertheless, clinicians should still consider the fragment size and fracture pattern, weighing the advantages of rigid biomechanical fixation against the possibility of soft-tissue damage to optimize treatment results.

Supplementary material

Additional data, analyses, and methodologies that support our findings, including technical details and extended results to ensure reproducibility and transparency.

References

1. **De Vries JS**, **Wijgman AJ**, **Sierevelt IN**, **Schaap GR**. Long-term results of ankle fractures with a posterior malleolar fragment. *J Foot Ankle Surg*. 2005;44(3):211–217.
2. **Kalem M**, **Şahin E**, **Songür M**, **Keser S**, **Kinik H**. Comparison of three posterior malleolar fixation methods in trimalleolar ankle fractures. *Acta Orthop Belg*. 2018;84(2):203–212.
3. **Rammelt S**, **Bartoníček J**. Posterior malleolar fractures: a critical analysis review. *JBJS Rev*. 2020;8(8):e19.
4. **Solan MC**, **Sakellariou A**. Posterior malleolus fractures: worth fixing. *Bone Joint J*. 2017;99-B(11):1413–1419.
5. **Knight R**, **Keene DJ**, **Dutton SJ**, **Handley R**, **Willett K**. Radiological malunion after ankle fractures in older adults: definitions and new thresholds derived from clinical outcome data from the AIM trial. *Bone Jt Open*. 2022;3(10):841–849.
6. **Patel S**, **Baburaj V**, **Sharma S**, **Mason LW**, **Dhillon MS**. Influence of posterior malleolar fragment morphology on the outcomes of trimalleolar fractures: a systematic review and meta-analysis. *Foot Ankle Surg*. 2022;28(8):1337–1344.
7. **Anwar A**, **Hu Z**, **Adnan A**, **et al**. Comprehensive biomechanical analysis of three clinically used fixation constructs for posterior malleolar fractures using cadaveric and finite element analysis. *Sci Rep*. 2020;10(1):18639.
8. **Liu Z**, **Tang G**, **Guo S**, **Cai B**, **Li Q**. Therapeutic effects of internal fixation with support plates and cannulated screws via the posterolateral approach on supination external rotation stage IV ankle fracture. *Pak J Med Sci*. 2020;36(3):438–444.
9. **Zhang K**, **Cui R**, **Gu Y**, **et al**. Posteroanterior lag screws versus posterior buttress plate fixation of posterior malleolar fragments in spiral tibial shaft fracture. *J Foot Ankle Surg*. 2020;59(4):768–773.
10. **Ma Z**, **Guo S**, **Gao F**, **et al**. Comparison of effectiveness between plate and screw internal fixation in treatment of posterior malleolus fractures through posterolateral approach. *Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi*. 2021;35(4):431–438.
11. **Yu T**, **Ying J**, **Liu J**, **et al**. Percutaneous posteroanterior screw fixation for Haraguchi type 1 posterior malleolar fracture in tri-malleolar fracture: operative technique and randomized clinical results. *J Orthop Surg (Hong Kong)*. 2021;29(1):2309499021997996.
12. **Neumann AP**, **Rammelt S**. Ankle fractures involving the posterior malleolus: patient characteristics and 7-year results in 100 cases. *Arch Orthop Trauma Surg*. 2022;142(8):1823–1834.
13. **O'Connor TJ**, **Mueller B**, **Ly TV**, **Jacobson AR**, **Nelson ER**, **Cole PA**. "A to p" screw versus posterolateral plate for posterior malleolus fixation in trimalleolar ankle fractures. *J Orthop Trauma*. 2015;29(4):e151–6.
14. **Huber M**, **Stutz PM**, **Gerber C**. Open reduction and internal fixation of the posterior malleolus with a posterior antiglide plate using a postero-lateral approach—a preliminary report. *Foot and Ankle Surg*. 1996;2(2):95–103.
15. **Erdem MN**, **Erken HY**, **Burc H**, **Saka G**, **Korkmaz MF**, **Aydogan M**. Comparison of lag screw versus buttress plate fixation of posterior malleolar fractures. *Foot Ankle Int*. 2014;35(10):1022–1030.
16. **Wang B**, **Liu N**, **Zhang L**. Effectiveness of spring hook plate for posterior malleolus fracture. *Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi*. 2016;30(10):1210–1214.
17. **Wang Z**, **Sun J**, **Yan J**, **et al**. Comparison of the efficacy of posterior-anterior screws, anterior-posterior screws and a posterior-anterior plate in the fixation of posterior malleolar fractures with a fragment size of ≥ 15 and < 15. *BMC Musculoskelet Disord*. 2020;21(1):570.
18. **Meijer DT**, **Gevers Deynoot BDJ**, **Stufkens SA**, **et al**. What factors are associated with outcomes scores after surgical treatment of ankle fractures with a posterior malleolar fragment? *Clin Orthop Relat Res*. 2019;477(4):863–869.
19. **Nasrallah K**, **Einal B**, **Shtarker H**. Trimalleolar fracture: The endless posterior malleolus fracture debate, to repair or not to repair? *Orthop Rev (Pavia)*. 2021;13(1):8784.
20. **Wang J**, **Jia H-B**, **Zhao J-G**, **Wang J**, **Zeng X-T**. Plate versus screws fixation for the posterior malleolar fragment in trimalleolar ankle fractures. *Injury*. 2023;54(2):761–767.
21. **Kitaoka HB**, **Alexander IJ**, **Adelaar RS**, **Nunley JA**, **Myerson MS**, **Sanders M**. Clinical rating systems for the ankle-hindfoot, midfoot, hallux, and lesser toes. *Foot Ankle Int*. 1994;15(7):349–353.

22. **Sterne JA**, **Hernán MA**, **Reeves BC**, **et al**. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. *BMJ*. - 2016;355:i4919.
23. **Sterne JAC**, **Savović J**, **Page MJ**, **et al**. RoB 2: a revised tool for assessing risk of bias in randomised trials. *BMJ*. 2019;366:l4898.
24. **Lu G**, **Ades AE**. Combination of direct and indirect evidence in mixed treatment comparisons. *Stat Med*. 2004;23(20):3105–3124.
25. **White IR**. Multivariate random-effects meta-regression: updates to Mvmeta. *The Stata Journal*. 2011;11(2):255–270.
26. **Chaimani A**, **Higgins JPT**, **Mavridis D**, **Spyridonos P**, **Salanti G**. Graphical tools for network meta-analysis in STATA. *PLoS One*. 2013;8(10):e76654.
27. **Nikolakopoulou A**, **Higgins JPT**, **Papakonstantinou T**, **et al**. CINeMA: an approach for assessing confidence in the results of a network meta-analysis. *PLoS Med*. 2020;17(4):e1003082.
28. **Papakonstantinou T**, **Nikolakopoulou A**, **Higgins JPT**, **Egger M**, **Salanti G**. CINeMA: software for semiautomated assessment of the confidence in the results of network meta-analysis. *Campbell Syst Rev*. 2020;16(1):e1080.
29. **Vidović D**, **Elabjer E**, **Muškardin IVA**, **Milosevic M**, **Bekic M**, **Bakota B**. Posterior fragment in ankle fractures: anteroposterior vs posteroanterior fixation. *Injury*. 2017;48 Suppl 5:S65–S69.
30. **Wang P**, **Xiang Z**, **Yun S**. Comparison of cannulated lag screw versus buttress plate fixation for posterior malleolar fractures. *Chin J Orthop Trauma*. 2017;19:192–197.
31. **Hartford JM**, **Gorczyca JT**, **McNamara JL**, **Mayor MB**. Tibiotalar contact area. Contribution of posterior malleolus and deltoid ligament. *Clin Orthop Relat Res*. 1995;320:182–187.
32. **Anwar A**, **Zhang Z**, **Lv D**, **et al**. Biomechanical efficacy of AP, PA lag screws and posterior plating for fixation of posterior malleolar fractures: a three dimensional finite element study. *BMC Musculoskelet Disord*. 2018;19(1):73.
33. **Stake IK**, **Ræder BW**, **Gregersen MG**, **et al**. Higher complication rate after nail compared with plate fixation of ankle fractures in patients aged 60 years or older: a prospective, randomized controlled trial. *Bone Joint J*. 2023;105-B(1):72–81.
34. **Wyrsch B**, **McFerran MA**, **McAndrew M**, **et al**. Operative treatment of fractures of the tibial plafond. A randomized, prospective study. *J Bone Joint Surg Am*. 1996;78-A(11):1646–1657.
35. **Etter C**, **Ganz R**. Long-term results of tibial plafond fractures treated with open reduction and internal fixation. *Arch Orthop Trauma Surg*. 1991;110(6):277–283.

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Data sharing

The datasets in this study are unavailable to the public due to data protection regulations. Data access is restricted to authorized researchers. For inquiries can be made by contacting the corresponding author.

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Ethical review statement

This study was non-applicable for ethical approval.

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