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SYSTEMATIC REVIEW

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The fibular intramedullary nail versus plate fixation for ankle fractures in adults: a systematic review and meta-analysis of randomized controlled trials

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Abstract

Objective The effectiveness and safety of fibular intramedullary nail fixation (FINF) compared to plate fixation (PF) in treating ankle fractures among adults remains unclear. Therefore, we conducted a meta-analysis to assess the efficacy and safety of FINF versus PF, aiming to provide orthopedic surgeons with valuable insights when choosing between the two internal fixation methods for patient treatment.

Methods PubMed, EMBASE, and SCOPUS were systematically searched for articles comparing FINF and PF in ankle fractures among adults. Functional outcomes, complications, and bony union were compared between the implants.

Results A total of seven studies were included in the study, involving 586 patients. The results revealed no statistically significant differences in functional outcomes between two groups at 3, 6, and 12 months postoperatively. The outcomes favoring FINF comprised a lower infection rate (RR = 0.23, 95%CI, 0.11 to 0.47, $P < 0.0001$). Conversely, the PF group exhibited a superior performance in terms of hardware failure rate (RR = 2.05, 95%CI, 1.16 to 3.60, $P = 0.01$). A statistically significant difference was observed in the results of hardware failure rate in the subgroup of studies conducted in Europe (RR = 2.74, 95%CI, 1.45 to 5.18, $P = 0.002$). Comparable findings were also noted in a subgroup of older adults (RR = 4.25, 95%CI, 1.57 to 11.50, $P = 0.004$).

Conclusion This systematic review suggests that FINF exhibits comparable effectiveness in the management of ankle fractures among adults, as compared to PF. Consequently, it is imperative to further delineate the surgical indications for both FINF and PF with precision to mitigate the risk of complications. Nevertheless, larger sample sizes and multi-center RCTs are imperative to corroborate this conclusion in the future.

Keywords Fibular intramedullary nail, Plate fixation, Ankle fractures, Meta-analysis

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Background

Ankle fractures are a common fracture type, accounting for 6% of all cases of fractures [1], and the annual prevalence is estimated at approximately 137/100,000 [2]. When ankle fractures extend to encompass the distal end of the fibula, particularly in circumstances where instability of the ankle are present, surgical intervention often becomes imperative. Open reduction and internal fixation is a conventional surgical method for distal fibular fractures [3]. There are many kinds of internal fixation techniques, such as compression (lag) screws and plate fixation (PF), for distal fibular fractures. However, it's crucial to acknowledge that no single implant can be deemed as the most suitable for all cases, and postoperative complications such as wound infection, pain, hardware failure, and nerve injury are well-known potential adverse events that may occur [4–6]. This led to the research for minimally invasive alternatives to the open reduction and internal fixation [7, 8].

Fibular intramedullary nail fixation (FINF) for fibular fractures has garnered significant attention in the past decade [4, 9]. The original intention was to create a minimally invasive and stable surgical procedure. According to some studies, FINF has been found to decrease postoperative complications and surgical time, thanks to its percutaneous approach that significantly minimizes soft tissue dissection [10]. However, other studies have revealed that the treatment with FINF did not exhibit significant differences in these aspects when compared to PF [11, 12].

Therefore, we conducted a meta-analysis to integrate existing data to study the efficacy and safety of FINF and PF in the treatment of distal fibular fractures. The study is a comprehensive evaluation, encompassing its functional outcome, complications, and bony union, ensuring a thorough assessment of its overall impact and effectiveness. The primary objective of our research is to furnish orthopedic surgeons with conclusive evidence that enables them to attain superior clinical outcomes when deciding between the two types of internal fixation methods for treating patients afflicted with distal fibular fractures.

Material and method

The systematic review was conducted following the PRISMA statement on preferred reporting items on systematic reviews and meta-analyses. An additional file shows this in more detail [see Additional file 1]. The protocol has been registered to PROSPERO (registration number: CRD42024516923).

Database and searching strategies

We performed a comprehensive, systematic literature search in the electronic databases of PubMed, EMBASE, and Scopus. The publication dates were limited from 2014 to February, 2024. The language of published studies were restricted to English. Search terms included synonyms for ankle fracture, fibular nail, and open reduction and internal fixation as follows:((("Ankle Fractures"[Mesh]) OR ((((Ankle Fracture) OR (Fibula Fracture)) OR (Distal fibula Fractures)) OR (Distal fibular Fracture))) AND (((Plate Fixation) OR (Open Reduction and Internal Fixation)) OR (Internal Fixation))) AND (((Fibular nail) OR (intramedullary nail)) OR (Locked Fibula nail))). After the electronic search was completed, the relevant literature and references were searched manually to find potential eligible studies.

Inclusion criteria

We follow the population/intervention/comparator/outcome/study design (PICOS) principle to develop the inclusion criteria [13]. (1) Population: patients were adults and diagnosed with ankle fractures. (2) Intervention: patients were treated with FINF. (3) Comparator: Patients treated with PF (i.e., compression plate, 1/3 tubular neutralization plate, locking plate). (4) Outcomes: studies had at least one of the following clinical outcomes, including functional outcome, complications, and bony union. (5) Study design: only randomized controlled trails (RCTs).

Exclusion criteria

(1) Patients with pathologic ankle fracture, old ankle fracture, fractures combined with rheumatoid osteoarthritis, or previous ankle osteoarthritis; (2) Animal studies. (3) Studies not published in English. (4) Studies in which the relevant data cannot be extracted, and the original author contacted without response; and (5) biomechanics research and finite element analysis, review articles, expert opinions, case reports, and letters to editors.

Data extraction

. Study selection and data extraction were carried out by two independent researchers, who utilized a standardized data extraction form to ensure uniformity and consistency in the collection process. The eligible full-text articles needed to have sufficient data to extract and pool. If the relevant data were not provided in the article, the authors were contacted via email to request the data. The following data were extracted from all eligible studies. Study characteristics: authors, publication year, country, sample size of different groups, patient demographics (age, gender), and management characteristics (randomization, follow-up, implants, and surgical indication). Clinical outcomes: functional outcome (patient-reported outcome scores), postoperative complications, and bony union at one year.. A third investigator resolved any disagreements through discussion or verification.

Quality assessment

We evaluated the RCTs using the Cochrane Collaboration's tool for assessing the risk of bias, which includes the following aspects: (i) random-sequence generation (selection bias); (ii) allocation concealment (selection bias); (iii) blinding of participants and personnel (performance bias); (iv) blinding of outcome assessment (detection bias); (v) incomplete outcome data (attrition bias); (vi) selective reporting (reporting bias); and (vii) other bias. Two independent reviewers conducted a quality assessment and resolved differences through discussion with a third reviewer.

Statistical analysis

The results of the studies were analyzed using RevMan 5.3 (Copenhagen, The Nordic Cochrane Center, The Cochrane Collaboration, 2014). If the data were sufficiently homogeneous (clinical and statistical), we summarized these in a meta-analysis. Continuous outcomes were calculated and expressed as the weighted mean difference (WMD) with a 95% confidence interval (CI). Dichotomous data were expressed as the relative risk (RR) with 95% CI. To measure heterogeneity between studies, we used the $\chi 2$ (P value less than 0.10 indicates heterogeneity) and I^2 statistic (a value of less than 50% represents low heterogeneity and a value of 75% or more indicates high heterogeneity). A fixed-effects model was used in the meta-analysis, but we used the random-effects model when significant heterogeneity among the studies was found. Forest plots were used to graphically represent the difference in outcomes of groups of FINF and PF and for all included studies. If P was < 0.05, the results were considered statistically significant. In case of heterogeneity, we planned a subgroup analysis to explore possible differences in duration of follow-up or methodological features and the results are presented in a descriptive summary of findings table. The sensitivity analysis was performed to investigate the source's heterogeneity and verify the reliability of the results to exclude low-quality studies. Additionally, publication bias was not assessed due to the insufficient number of studies, specifically when the count fell below 10, rendering such an evaluation unnecessary [14].

Results

Included study

Using our search strategy, we retrieved a total of six hundred and sixty-nine studies. After carefully eliminating three hundred and ninety-four duplicate records, we further narrowed down the selection by screening the titles and abstracts, resulting in the removal of two hundred and sixty-two studies. Following a thorough reading of the remaining studies' full texts, we excluded six studies that failed to meet our inclusion criteria: three were not RCTs, and three were not relevant to our area of interest. Consequently, our systematic review and meta-analysis ultimately encompassed seven studies [11, 12, 15–19]. The literature search process is shown in Fig. 1.

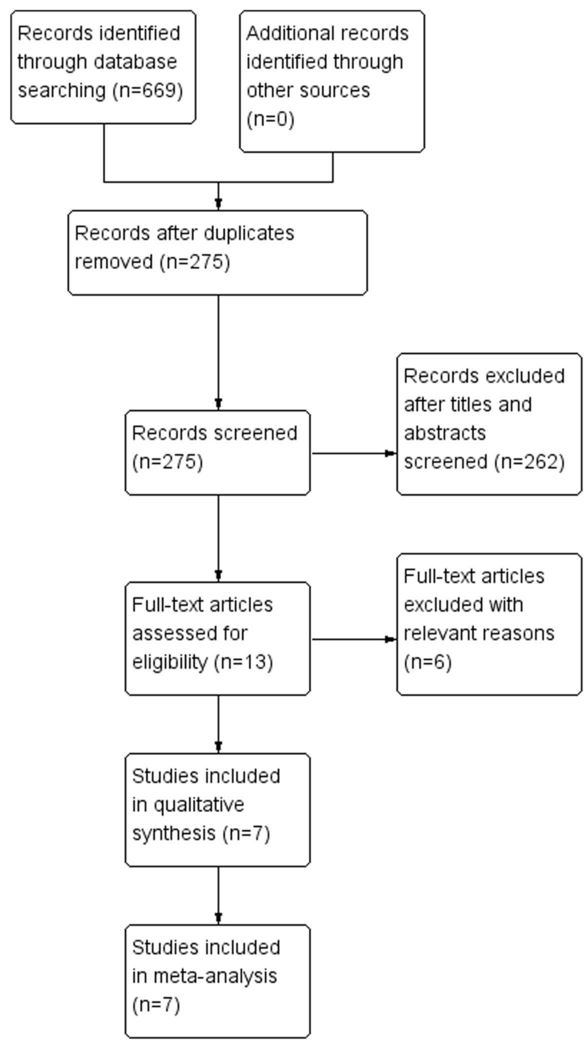

Fig. 1 Flow diagram for the identification and selection of studies included in the meta-analysis

Study characteristics

A total of 586 patients were enrolled, with 293 patients in the FINF group and 293 patients in the PF group. Among these studies, four were conducted in Europe [12, 15, 16, 18], two in East Asia [17, 19], and one in South Africa [11]. The duration of follow-up ranged from three to twenty-four months. The types of fractures investigated in these studies encompassed lateral malleolus, bimalleolar, and trimalleolar fractures. The internal fixations used in the included articles compared FINF with PF. For a more detailed overview of the included studies, please refer to Table 1.

Quality assessment in the included studies

Except for the Chen et al. trial [19], which exhibited a low risk of bias, all RCTs included in our analysis were associated with a moderate or high risk of bias. For a comprehensive overview of the risk of bias across the RCTs, please refer to Fig. 2.

Meta-analysis of functional outcomes

The results of each functional outcomes are shown in Table 2. An additional file shows this in more detail [see Additional file 2]. Six studies provided data on postoperative OMAS score and three studies on AOFAS Ankle-Hindfoot score. Six studies furnished data regarding postoperative OMAS scores [11, 12, 15–18], while three studies contributed information on AOFAS Ankle-Hindfoot scores [17–19]. However, as Badenhorst and Stake's study only provided interquartile ranges, these two studies were excluded from this meta-analysis [11, 18]. WMD, weighted mean difference; RR, risk ratio; OMAS, Olerud-Molander ankle score; AOFAS, American Orthopaedic Foot and Ankle Society

Of the studies included, three conducted OMAS scoring at 3 months postoperatively [12, 16, 17], three at 6 months [12, 16, 17], and four at 12 months [12, 15–17]. The results revealed no statistically significant difference in OMAS scoring between the two groups at any postoperative time point. (OMAS-3mon: WMD = 4.27; 95%CI,-0.15 to 8.69; $P = 0.06$; OMAS-6mon: WMD = 2.63; 95%CI, −1.93 to 7.19; $P = 0.26$; OMAS-12mon: WMD = 4.46; 95%CI, −3.23 to 12.14; $P = 0.26$) (Fig. 3A) An additional figure file shows this in more detail [see Additional file 3].

Additionally, two studies assessed functional outcomes using the AOFAS score. Consistent with the OMAS findings, we did not observe any significant difference between the groups at any postoperative time point. (AOFAS-3mon: WMD = 6.43; 95%CI,-9.84 to 22.69 $P = 0.44$; AOFAS-6mon: WMD = 2.06; 95%CI, −5.82 to 9.95; $P = 0.61$; AOFAS-12mon: WMD = -0.07; 95%CI, −3.01 to 2.87; $P = 0.96$) (Fig. 3B).

Meta-analysis of complications and bony union

The results of complications and bony union are shown in Table 2.

Regarding complications, our analysis did not demonstrate a significantly lower overall complication rate in the FINF group compared to the PF group, despite the observation of fewer complications within the FINF group.

In the PF group, the overall complication rate was 83/293 (28.3%) vs. 48/293 (16.4%) in the FINF group. There was a no statistically significant difference between groups. (RR = 0.52, 95%CI, 0.24 to 1.09, $P = 0.08$) (Fig. 4A).

We therefore conducted a subgroup analysis by categorizing the complications into four major types: infection, pain, hardware failure, and nerve injury. Infections encompassed a range of conditions including deep infections, superficial infections, and wound infections. As for pain, it encompassed various manifestations such as algodystrophy, chronic regional pain syndrome, hardware-related pain, and post-traumatic arthritis. Hardware failure referred to any circumstance necessitating the revision or removal of hardware, including malunion, loss of reduction, and other forms of hardware malfunction. Lastly, nerve injury encompassed any type of nerve damage. All studies reported the total number of complications and bony union [11, 12, 15–19].

The infection rate was reported by all studies [11, 12, 15–19]. In the PF group, the overall infection rate stood at 13.0%, with 38 infections reported out of 293 patients. In contrast, the FINF group reported only seven cases of infection, constituting a rate of 2.4%. There was a statistically significant difference that favored the FINF group (RR = 0.23, 95%CI, 0.11 to 0.47, $P < 0.0001$) (Fig. 4B).

The pain rate was reported by six studies [12, 15–19]. In the PF group, the overall pain rate was 25/271 (9.2%) vs. 14/264 (5.3%) in the FINF group. There was no statistically significant difference between the groups. (RR = 0.60, 95%CI, 0.33 to 1.09, $P = 0.09$).

The hardware failure rate was reported by five studies [12, 16–19]. In the PF group, the overall hardware failure rate was 15/239 (6.3%) vs. 31/236 (13.1%) in the FINF group. There was a statistically significant difference in favor of the PF group. (RR = 2.05, 95%CI, 1.16 to 3.60, $P = 0.01$) (Fig. 5).

The nerve injury rate was reported by two studies [16, 17]. In the PF group, the overall nerve injury rate was 4/81 (4.9%) while there were no nerve injury in the FINF group. There was a no statistically significant difference between groups. (RR = 0.20, 95%CI, 0.20 to 1.71, $P = 0.14$).

The bony union rate was reported by all studies [11, 12, 15–19]. In the PF group, the overall bony union

Table 1 Characteristics of included studies

Study			Management characteristics					Population		
Authors	**Year**	**Country**	**Intervention**	**Implant**	**Randomized (N)**	**Analyzed (N)**	**Surgical indication**	**Age:mean (range or SD)**	**N (M:F)**	**Follow-up (Month)**
Asloum et al	**2014**	**France**	**FINF** **PF**	**Epifisa®(FH Orthopedics)*** **Reconstruction Locking Compression Plate (Synthes)**	**36** **35**	**28** **32**	**(1) 12(41.4%) LM** **(2) 12 (41.4%) BM** **(3) 5 (17.2%) TM** **(1) 6(14.3%) LM** **(2) 24 (57.1%) BM** **(3) 12 (28.6%) TM**	**NR** **NR**	**NR** **NR**	**12** **12**
White et al	2016	United Kingdom	FINF PF	Fibula Rod System(Acumed) 1/3 tubular plate	50 50	50 50	"Unstable Ankle Fracture "	74(65–93) 74(65–88)	11:39 14:36	3,6,12 3,6,12
Badenhorst et al	2020	South Africa	FINF PF	Fibula Rod System(Acumed) Anatomical contoured locking fibula Plate (Acumed)	38 26	29 22	(1) 17 (63%) Weber B (2) 10 (27%) Weber C (3) 8 (29%) with PM (1) 21 (96%) Weber B (2) 1 (6%) Weber C (3) 4 (18%) with PM	42.8(13.8) 42.9(13.9)	13:16 6:16	1.5, 3,6,12 1.5, 3,6,12
Kho et al	2020	South Korea	FINF PF	Fibular nail (Acumed) locking plate	35 35	30 31	"Distal fibular fracture-with displaced fragment "	49.6(16.5) 48.1(18.5)	14:16 15:16	3,6,9,12 3,6,9,12
White et al	2021	UnitedKingdom or Den-mark	FINF PF FINF	NR NR Fibula Rod System(Acumed)	63 62 59	56 54 51	"Unstable fractures of the ankle "	40.4(14.1) 42.8(12.9) 69(6)	31:32 31:31 19:32	3,6,12,24 3,6,12,24 6,12,24
Stake et al	2023	Norway	PF	1/3 tubular plate(DePuy Synthes) Lateral Compression Plate Distal Fibula Plate(DePuy Synthes) Variax distal fibula plate(Stryker)	61 57		AO/OTA type B(LM, BM, TM)	71(8)	11:48	6,12,24
Chen et al	2024	China	FINF PF	locking intramedullary nail locking plate	42 39	42 39	"SER IV injuries with MM fractures, Haraguchi type III PM fracture "	52.8(8.2) 49.5(7.8)	22:20 19:20	12 12

* Intramedullary nailing was impossible in 7 patients for technical reasons and was converted to plate fixation. The 7 converted cases were analyzed independently

MM,medial malleolus; PM,posterial malleolus; LM,lateral malleolus; BM,bimalleolar; TM,trimalleolar; SER,supination external rotation; NR,not reported; FINF, fibular intramedullary nail fixation; PF, plate fixation; SD, standard difference

Fig. 2 Risk of bias assessment in included studies according to review authors' judgement

Table 2 Weighted mean differences or risk ratios of outcomes following each analysis comparing FINF to PF

Subgroup and outcomes	No.of studies	Sample size		WMD or RR (95%CI)	I^2,%	*P* value
		FINF	PF			
Functional outcome						
OMAS-3mon	3	139	129	WMD = 4.27(− 0.15,8.69)	48	0.06
OMAS-6mon	3	137	128	WMD = 2.63(− 1.93,7.19)	0	0.26
OMAS-12mon	4	164	159	WMD = 4.46(− 3.23,12.14)	84	0.26
AOFNS-3mon	2	72	70	WMD = 6.43(− 9.84,22.69)	95	0.44
AOFNS-6mon	2	72	70	WMD = 2.06(− 5.82,9.95)	82	0.61
AOFNS-12mon	2	72	70	WMD = − 0.07(− 3.01,2.87)	0	0.96
Safety outcome						
Complication-total(n)	7	293	293	RR = 0.52(0.24,1.09)	74	0.08
Complication-infection(n)	7	293	293	RR = 0.23(0.11,0.47)	6	< 0.0001
Complication-pain(n)	6	264	271	RR = 0.60(0.33,1.09)	23	0.09
Complication-hardware failure(n)	5	236	239	RR = 2.05(1.16,3.60)	33	0.01
Subgroup-hardware failure(n) (European)	3	164	169	RR = 0.33(0.05, 2.00)	0	0.002
Subgroup-hardware failure(n) (Asian)	2	72	70	RR = 2.74(1.45, 5.18)	0	0.23
Subgroup-hardware failure(n) (Adults)	3	135	132	RR = 1.24(0.60, 2.56)	30	0.56
Subgroup-hardware failure(n) (Elders)	2	101	107	RR = 4.25(1.57, 11.50)	0	0.004
Complication-nerve injury(n)	2	80	81	RR = 0.20(0.02,1.71)	0	0.14
Bony union(n)	7	293	293	RR = 1.00(0.98,1.02)	0	0.92

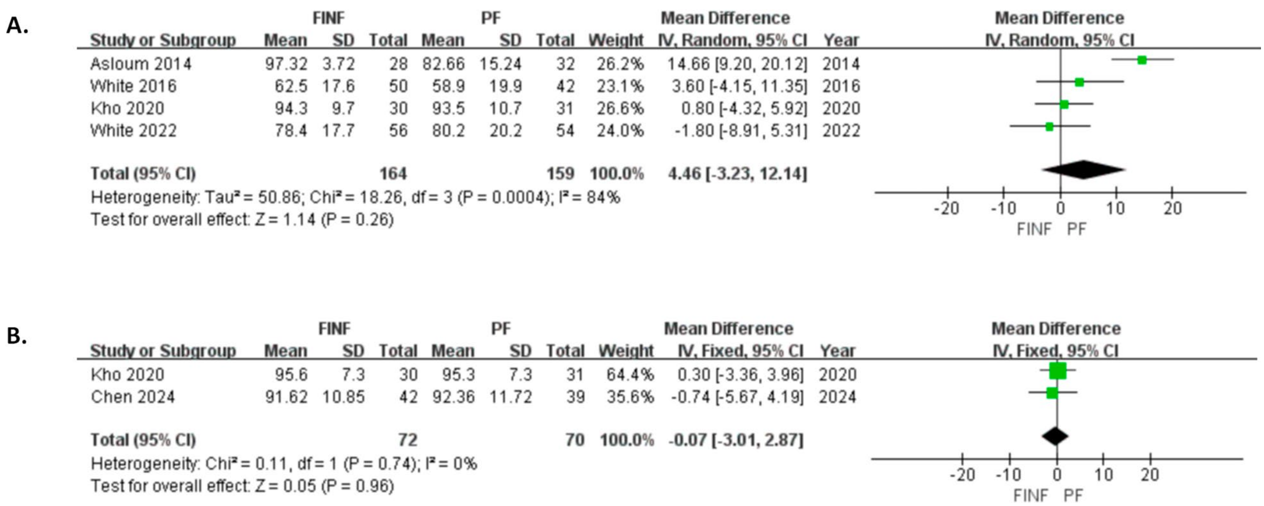

Fig. 3 Forest plot of the functional outcomes between the FINF and PF groups at 12 months postoperatively. **A** OMAS. **B** AOFAS

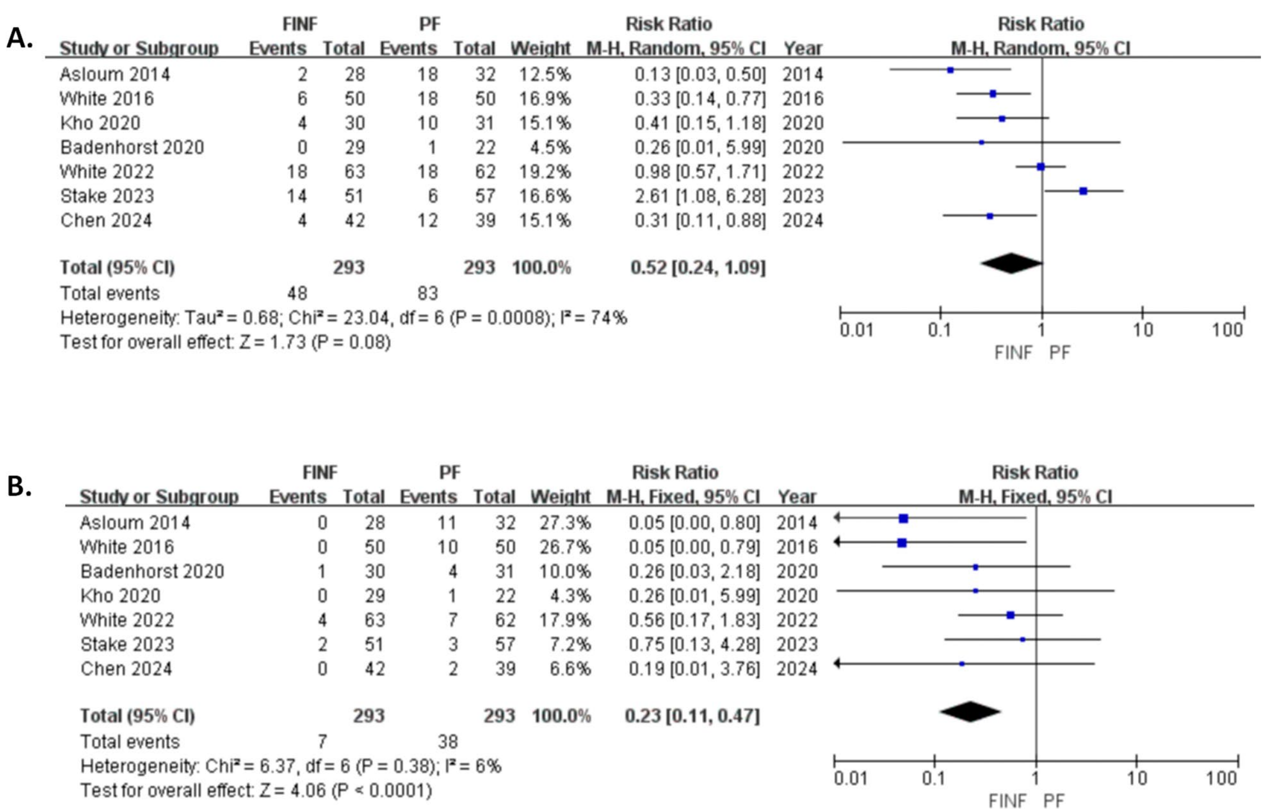

Fig. 4 Forest plot of the postoperative outcomes between the FINF and PF groups. **A** Overall complication rate. **B** Infection rate

rate was 233/236 (98.7%) vs. 241/242 (99.6%) in the FINF group. There was no statistically significant difference between groups. (RR = 1.00, 95%CI, 0.98 to 1.02, P = 0.92) An additional figure file shows this in more detail [see Additional file 4].

Subgroup analysis

To compare the hardware failure rate in patients with various characteristics, subgroup analysis were performed. A minimum of two comparisons per subgroup were available in the current analysis. There was a statistically

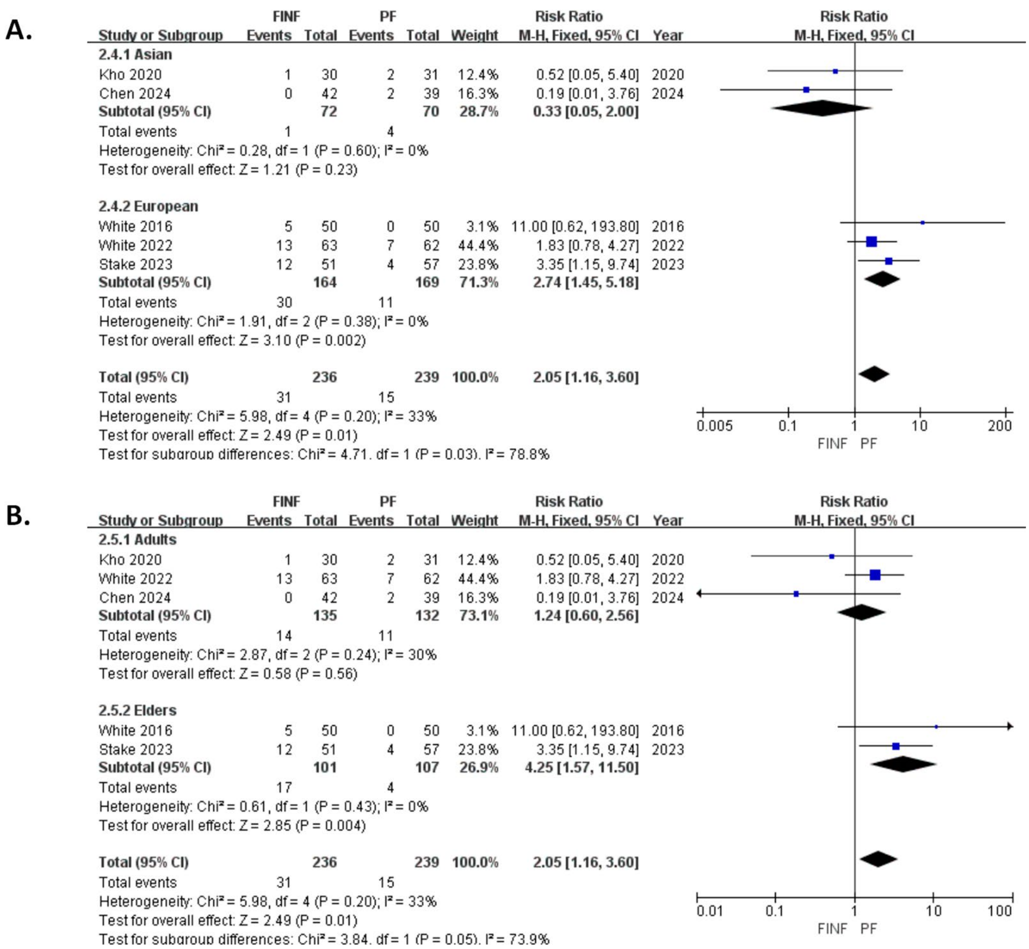

Fig. 5 Forest plot of the hardware failure rate between subgroups. **A** Race. **B** Age

significant difference in the results of hardware failure rate in the subgroup of studies conducted in the Europe (RR = 2.74, 95%CI, 1.45 to 5.18, $P=0.002$) [12, 16, 18]. Similarly, significant difference between subgroups was shown in the results of studies that only enrolled elders (RR = 4.25, 95%CI, 1.57 to 11.50, $P=0.004$) [16, 18] (Fig. 5). Details are displayed in Table 2.

Sensitivity analysis

A sensitivity analysis was conducted by excluding each study individually to assess any changes in the pooled results. Upon removing the study conducted by White et al. [12], the heterogeneity of OMAS at 3 months decreased significantly ($P=0.01$, $I^2=6\%$). Similarly, excluding the study by Asloum et al. [15] maintained the consistency of OMAS at 12 months without introducing additional heterogeneity ($P=0.69$, $I^2=0\%$). Finally, when Stake et al.'s study [18] was omitted, the heterogeneity of pain rate decreased significantly ($P=0.01$, $I^2=0\%$).

Discussion

The current study serves as an updated meta-analysis, utilizing only Level 1 evidence to compare the FINF to the gold standard PF for ankle fractures in adults. The outcomes favoring FINF comprised a lower infection rate. Conversely, the PF group exhibited a superior performance in terms of hardware failure rate.

Functional outcomes

The OMAS, scored out of 100 points, assesses activities and disability with acceptable validity and reliability specifically in ankle fractures [20].

The American Orthopaedic Foot and Ankle Society (AOFAS) Ankle-Hindfoot Score, which typically ranges from 0 to 100 points, comprehensively evaluates various aspects of ankle function, including pain, gait, range of motion, stability, and the ability to perform daily activities. It has demonstrated reliable and valid results, making it a valuable tool for clinicians to monitor progress, evaluate treatment effectiveness, and compare outcomes across different studies [21, 22]. Apart from the AOFAS and OMAS scoring systems, our study encompassed those utilizing the Grimby [23] and Kitaoka scores [24]. Nevertheless, since these two latter scoring systems were not widely utilized in numerous studies, we refrained from conducting meta-analyses on them. This suggests that in future studies, it is not only necessary to standardize scoring criteria but also to validate their validity and reliability across different racial and ethnic groups.

Furthermore, contrary to a previous meta-analysis [25], our study revealed no statistically significant differences in functional outcomes between the two groups at 3, 6, and 12 months postoperatively. This finding may be attributed to two reasons. Firstly, we exclusively included RCTs, which are studies with a higher level of evidence, potentially further reducing bias. Secondly, we included a larger number of cases, which may have minimized potential biases. A similar conclusion is further supported by the study conducted by Walsh et al., which also exclusively comprised RCTs for their meta-analysis [26].

Of the studies included in our analysis, two studies had a follow-up period of 24 months [12, 18]. Consequently, the current findings primarily represent the short- to mid-term outcomes between the two groups. Therefore, longer-term follow-up results are necessary to further compare and assess the differences between the two groups in the future.

Complications

In terms of postoperative complications, we observed a significant reduction in infections within the FINF group. Although there was no statistically significant difference in the rate of nerve injury and pain between the two implant types, the incidence was lower in the FINF group. However, the PF group exhibited a significantly lower hardware failure rate compared to the FINF group. This finding holds significant implications for clinical treatment.

Concerning infection rates, numerous studies consistently demonstrate that the infection rate associated with FINF is exceedingly low, typically ranging from 0 to 6% [11, 12, 15, 19]. Furthermore, research has revealed that the infection rate remains significantly under 1% regardless of the specific type of intramedullary fixation implant used [8]. This suggests that central fixation may offer a superior advantage in reducing infection rates compared to eccentric fixation. We attribute this advantage of intramedullary fixation primarily to its smaller surgical incision, which effectively minimizes soft tissue damage.

Correspondingly, the infection rate associated with PF tends to be higher, presumably due to the requirement for a larger surgical incision and placement at the distal end of the fibula, where soft tissue coverage is comparably thinner. If the patient is elderly, diabetic, or a smoker, the risk of infection is likely to be exacerbated [27, 28]. Additionally, in clinical practice, it is a common approach to postpone surgical treatment for ankle fractures until the soft tissue swelling has subsided. Schepers et al. reported in a comparative study and systematic review encompassing 1186 ankle fracture cases across ten comparative studies that such a delay may increase the risk of infection [29]. Therefore, it is crucial to carefully consider the status of soft tissue swelling to minimize the risk of infections and other complications. On the contrary, intramedullary nail surgery, which involves a percutaneous approach, exhibits a higher tolerance for the extent of soft tissue swelling. Consequently, it allows for earlier surgical intervention, thereby minimizing the risk of infection [15, 16].

We did not observe a significant difference in pain rate between two groups. Across various research centers, despite the use of diverse implant types, such as reconstruction locking compression plates, anatomical contoured locking fibula plates, and 1/3 tubular plates, it is evident that plates of varying thicknesses can all potentially contribute to skin and soft tissue irritation [11, 15, 16]. Ahn et al. reported the hardware irritation rate was 12.2% in the locking plate group and 7.1% in the non-locking 1/3 tubular plate group [30]. However, intramedullary nails may also cause pain to patients due to invasive surgical procedures and prominent screws, especially in elderly patients. In a study conducted by Stake et al. [18], it was discovered that symptomatic hardware is one of the most common complications associated with the use of intramedullary nails for the treatment of ankle fractures in patients aged 60 years or older. Therefore, this underscores the need for careful consideration of various factors in the future design of intramedullary nails, including the choice of hardware location, the physiological traits of patients, and the design or dimensions of implants. As an example, the exploration of headless screws that securely lock into the nail can be pursued as a strategy to minimize the prominence of hardware.

We observed the PF group exhibited a significantly lower hardware failure rate compared to the FINF group. This result diverges from the findings of previous studies. Tas et al. [8] conducted a systematic review of 19 studies and reported an elective implant removal rate of 24% for intramedullary fixation and 34.7% for plate fixation. Notably, intramedullary fixation exhibited a significantly lower reoperation rate compared to open reduction and internal fixation. Similarly, Rehman et al. [31] observed a significantly lower rate of implant removal in the FINF group (23.4%) compared to the PF group (36.9%). However, in two studies conducted by White et al. [12, 16], it was observed that seventy out of the twenty-four reoperations in the FINF group involved the removal of locking screws, whereas only twelve out of thirty-six reoperations in the PF group entailed such removal. Upon delving into the reasons, we have identified two potential explanations. Firstly, age appears to be a significant factor. Among the studies we have included, only two compared the safety of two types of internal fixation in elderly patients. Notably, both studies found a higher rate of internal fixation failure in the FINF group compared to the PF group. This suggests that PF remains a safe and effective method of internal fixation in the elderly population. On the other hand, we must seek to identify risk factors for FINF failure in elderly patients in the future, such as osteoporosis, cognitive impairment, and comorbid conditions. Secondly, the ethnicity of the included patients also seem to play a role. In three studies conducted in Europe, the rate of internal fixation failure was significantly higher in the FINF group compared to the PF group. This underscores the need to further investigate other risk factors for FINF failure, such as patient Body Mass Index and postoperative rehabilitation plans. It is crucial to underscore that the differing definitions of "hardware failure" across the studies we have integrated potentially give rise to a bias termed as heterogeneity bias.

We did not observe a significant difference in nerve injury between two groups. The incidence of nerve injury is generally low in both the FINF and PF groups, with a particularly noteworthy absence of reports in the FINF group. Nevertheless, Mirza et al. s [32] cadaveric study highlights the potential risk to the superficial peroneal nerve, saphenous nerve, and saphenous vein during percutaneous submuscular plating of the distal fibula and tibia, which deserves our attention.

Bony union

Our systematic review revealed no significant difference in bony union between the two groups. Numerous studies have demonstrated that the utilization of FINF can attain equivalent fixation strength to the gold standard surgical approach, while both methods maintain a high rate of bony union [12, 17, 19]. Consequently, FINF can be regarded as a viable alternative to PF.

Limitation

This study had the following limitations: (1) The included studies exhibit a relatively limited follow-up duration, which may preclude the occurrence of certain postoperative complications; (2) the relative risk estimations are clouded by inconsistent reporting and varying definitions of all secondary measures across different literature, leading to obfuscation in their interpretation; (3) The current number of included studies is limited, necessitating further high-quality research in the future to enhance the reliability and validity of the results.

Conclusion

This systematic review suggests that FINF exhibits comparable effectiveness in the management of ankle fractures among adults, as compared to PF. Consequently, it is imperative to further delineate the surgical indications for both FINF and PF with precision to mitigate the risk of complications.Nevertheless, given the constraints of the included studies' quality and quantity, larger sample sizes and multicenter RCTs are imperative to corroborate this conclusion in the future.

Abbreviations

AOFAS	American Orthopaedic Foot and Ankle Society
CI	Confidence interval
FINF	Fibular intramedullary nail fixation
IQR	Interquartile ranges
PF	Plate fixation
RCTs	Randomized controlled trails
SD	Standard difference
WMD	Weighted mean difference

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13018-024-05032-z.

Additional file 1 PRISMA checklist.

Additional file 2 The details of postoperative outcomes.

Additional file 3 Forest plot of the postoperative functional outcomes between the FINF and PF groups. A. OMAS at 3 months. B. OMAS at 6 months. C. AOFAS at 3 months. D. AOFAS at 6 months.

Additional file 4 Forest plot of the postoperative complications and bony union rate between the FINF and PF groups. A.pain rate . B. nerve injury rate. C. bony union rate.

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Author contributions
All authors contributed to the study conception and design. JC had the idea for the article. A literature search and data analysis were performed by JZ, JC and RL. The first draft of the manuscript was written by JZ, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Declarations

Ethics approval and consent to participate
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Competing interests
The authors declare that they have no competing interests.

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