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ORIGINAL ARTICLE

Comparison between intramedullary nail and conventional plate for displaced intra-articular calcaneal fractures: A meta-analysis

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ABSTRACT

Objectives: This study aimed to compare the efficacy and safety of the intramedullary nail and conventional plate for the treatment of displaced intra-articular calcaneal fractures from clinical comparative trials.

Materials and methods: A comprehensive search of English databases was carried out in the Springer, PubMed, ScienceDirect, Web of Science, and Cochrane Library databases until September 2023. Studies on calcaneal fractures treated by an intramedullary nail or a plate were considered for inclusion. Endpoints included duration of operation, length of hospital stay, the Visual Analog Scale (VAS) score, postoperative functional score, radiological parameters, and complications. The mean difference (MD) and risk difference (RD) as the combined variables, as well as the 95% confidence intervals, (CIs) were calculated.

Results: Five retrospective controlled studies covering 473 feet at the one-year follow-up met the inclusion criteria. The meta-analysis demonstrated that there were significant differences in the duration of operation (MD: –10.81; 95% CI: –16.32, –5.31; p=0.0001), length of hospital stay (MD: –3.65; 95% CI: –4.35, –2.95; p<0.00001). No significant differences were found regarding postoperative American Orthopaedic Foot and Ankle Society (AOFAS) Ankle-Hindfoot Scale (MD: 0.36; 95% CI: –3.89, 4.61; p=0.87), VAS (MD: 1.95; 95% CI: –0.30, 4.21; p=0.09), or postoperative Böhler angle (MD: 0.94; 95% CI: –0.04, 1.92; p=0.06) between the two groups. The incidence of total complications (RD: –0.31; 95% CI: –0.46, –0.17; p<0.0001) and wound-healing complications (RD: –0.16; 95% CI: –0.30, –0.03; p=0.02) were lower in the intramedullary nail group. There were no significant differences in the incidences of revision surgery, implant removal, superficial wound infection, deep infection, and nonunion.

Conclusion: Compared to conventional plates, the intramedullary nail showed a shorter duration of operation, reduced length of hospital stay, and fewer postoperative total complications and wound-healing complications in treating displaced intra-articular calcaneal fractures.

Keywords: Calcaneal fractures, intramedullary nail, meta-analysis, plate.

Calcaneal fractures are the most common foot injuries and account for about 2% of all adult fractures.[1] As the most common injury mechanism is high fall injury, 60 to 75% of calcaneal fractures involve the subtalar articular surface under vertical violence.[2] Currently, the ideal treatment of displaced calcaneal fractures (DCF) in adults remains challenging since DCF has high rates of nonunion, malunion, and posttraumatic arthritis, which significantly affects the quality of life of patients.[3] Therefore, satisfactory treatment for DCF requires anatomic reduction and rigid internal fixation.

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Open reduction and internal fixation (ORIF) with a plate is the most commonly applied procedure and has been considered to be the gold standard surgical treatment that can perform anatomical reduction and bone grafting under direct vision.[4] However, a conventional large L-shaped incision may damage the supply of blood vessels and sural nerve and may lead to postoperative complications, such as hematoma, skin necrosis, septic arthritis, and osteomyelitis.[5] The incidence of postoperative complications is relatively high, and the incidence of incision complications after ORIF ranges from 6 to 20%.[6]

Recently, intramedullary nails, a new type of internal fixation device for DCF, have been introduced and applied through a minimally invasive technique, achieving anatomic reduction and rigid internal fixation.[7] Several studies have reported that intramedullary locking nails can lead to satisfactory clinical and radiological outcomes in treating DCF.[8-11] In 2022, Bernasconi et al.[12] performed a systematic review of biomechanical and clinical studies of intramedullary locking devices for DCF. Although they reported that intramedullary locking devices lead to satisfactory clinical and radiological outcomes at a short-term follow-up for DCF, they did not extract data for further quantitative analysis. Therefore, whether intramedullary nails are superior to plates remains controversial. The present study aimed to compare the efficacy and safety of intramedullary nails and plate in treating DCF in a large sample.

MATERIALS AND METHODS

Search strategy

This meta-analysis was based on PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. PubMed, Springer, ScienceDirect, Web of Science, and Cochrane Library databases were comprehensively searched from the establishment of the databases to September 2023. The references of the identified articles were checked to find possible relevant articles. No language restrictions were applied during the search. The keywords used for the search terms included the following: "calcaneal fractures," "intramedullary nail," and "plate."

Inclusion criteria

Studies that met the following criteria were considered for inclusion: *(i)* patients treated with calcaneal fractures undergoing surgery; *(ii)* the intervention group being treated with intramedullary nail and the control group being treated using ORIF with plate; *(iii)* outcome parameter included duration of operation, length of hospital stay, the visual analog scale (VAS) score, postoperative functional score, radiological parameters, and complications; *(iv)* the included study being a published randomized controlled trial (RCT) or non-RCT. Two independent researchers determined the eligibility of the identified articles. Any disagreement between the researchers was resolved by the third researcher.

Exclusion criteria

Studies were excluded for the following reasons: *(i)* duplicate published articles or articles with the same patients, results, and content; *(ii)* studies with difficult data extraction or incomplete data; *(iii)* basic research, letters, case reports, systematic reviews, meta-analyses, economic analyses, or conference reports; *(iv)* studies that reported nonrelevant outcomes.

Data extraction

Two independent researchers individually extracted data from the included articles. The following information and data were extracted: the first author's name, study design type, publication year, sample size, comparable baselines, intervention, follow-up duration, and the study endpoints. Endpoints included duration of operation, length of hospital stay, the VAS score, postoperative functional score (such as American Orthopedic Foot and Ankle Society ankle-hindfoot scale, AOFAS), radiological parameters (such as Böhler angle), and complications. Other relevant information was also extracted from the included studies. For incomplete data, we contacted the corresponding author of the included study through electronic mail for additional details.

Quality assessment

The methodological quality of the RCTs was evaluated according to a modification of the generic evaluation tool described in the Cochrane Handbook for Systematic Reviews of Interventions.[13] The methodological quality assessment of non-RCTs was performed by the methodological index for nonrandomized studies (MINORS).[14] Two independent researchers individually performed the methodological quality assessment. Any disagreement between the researchers was resolved by the third researcher.

Statistical analysis

Statistical analyses were conducted with RevMan version 5.1 (Cochrane Collaboration, Oxford, UK). Risk difference (RD) and 95% confidence intervals

(CIs) were calculated for dichotomous outcomes. Mean difference (MD) and 95% CIs were calculated for continuous variables. The *p* values and I^2 values were used to assess the heterogeneity of pooled results. When I^2<50% and p>0.1, the heterogeneity of pooled results was considered absent, and the fixed-effect model was used for data analysis. Otherwise, significant heterogeneity was considered, and the random-effects model was used for the data analysis. Subgroup analysis was performed to investigate the sources of significant heterogeneity.

RESULTS

Search results

One hundred six potential studies were identified online. By thoroughly browsing titles and abstracts, 101 reports were excluded. No eligible study was obtained after the reference list review. Finally, five retrospective controlled studies with a total of 473 feet were included for data extraction and meta-analysis.[15-19] The search process is displayed in Figure 1.

Risk of bias assessment

The MINORS scores of non-RCTs ranged from 18 to 22. The methodological quality assessment of non-RCTs is presented in Table I.

Study characteristics

Demographic characteristics and other details of the included studies are presented in Table II. In each study, the baseline characteristics of the two groups are similar.

Outcomes of meta-analysis

Three studies reported the duration of the operation.[15,16,18] Pooled results showed that intramedullary nail had a reduced duration of operation compared to plate (MD: –10.81 min; 95% CI: –16.32, –5.31; p=0.0001) without significant heterogeneity (p=0.13, I^2=50%, Figure 2).

Three studies reported the length of hospital stay.[15,16,18] Pooled results showed that intramedullary nail had a reduced length of hospital stay compared to plate (MD: –3.65 days; 95% CI: –4.35,

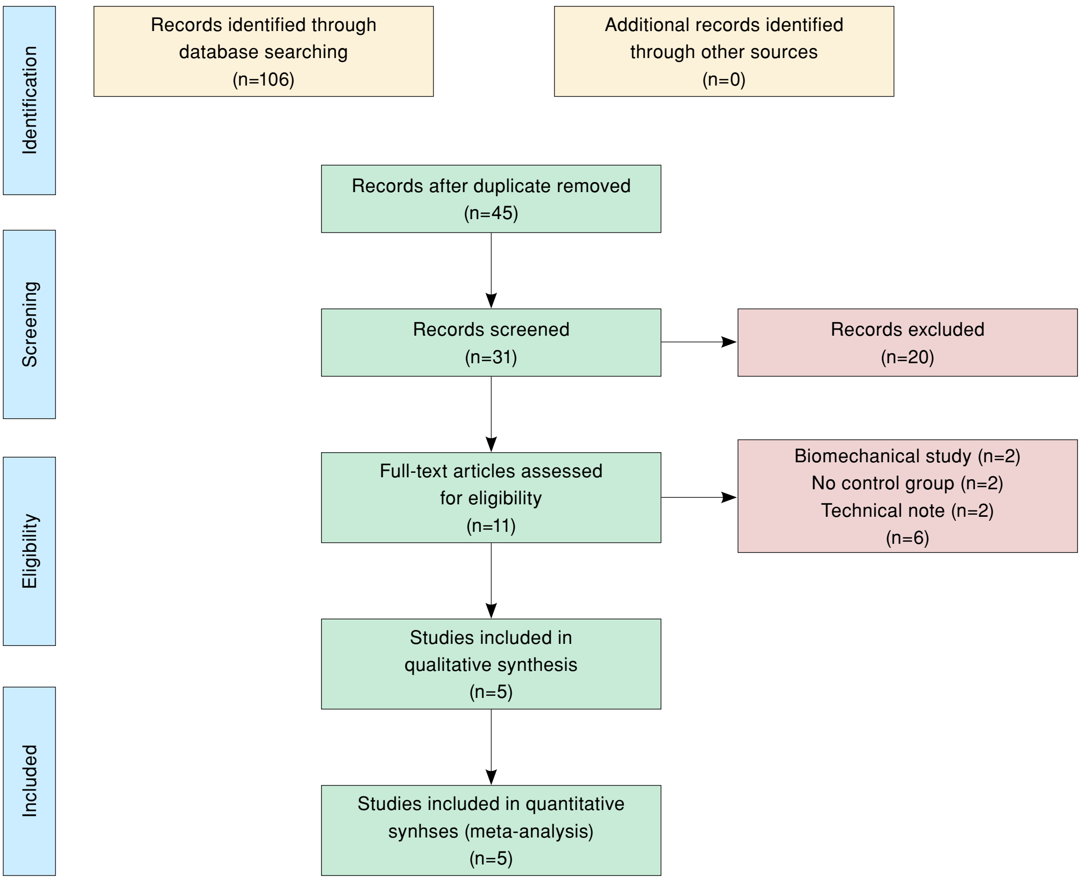

FIGURE 1. Flowchart of the study selection process.

TABLE I
Quality assessment for non-RCTs

Quality assessment for non-randomized trials	Herlyn et al.[15] 2019	Le Roux et al.[17] 2023	Stachel et al.[18] 2022	Steinhausen et al.[16] 2021	Zeman et al.[19] 2019
A clearly stated aim	2	2	2	2	2
Inclusion of consecutive patients	2	2	2	2	2
Prospective data collection	2	0	0	0	0
Endpoints appropriate to the aim of the study	2	2	2	2	2
Unbiased assessment of the study endpoint	2	2	2	2	2
A follow-up period appropriate to the aims of study	2	2	2	2	2
Less than 5% loss to follow-up	2	2	2	2	2
Prospective calculation of the sample size	0	0	0	0	0
An adequate control group	2	2	2	2	2
Contemporary groups	2	0	2	2	0
Baseline equivalence of groups	2	2	2	2	2
Adequate statistical analyses	2	2	2	2	2
Total score	22	18	20	20	18

TABLE II
Characteristics of included studies

Study	Year	Design	Intervention	Feet	Mean age	Follow-up (m)
Herlyn et al.[15]	2019	PCT	Nail	20	52.5	11.3
			Plate	20	52.5	38.3
Le Roux et al.[17]	2023	RCS	Nail	25	50.7	12
			Plate	32	48.2	12
Stachel et al.[18]	2022	RCS	Nail	19	50.2	NS
			Plate	20	52.8	NS
Steinhausen et al.[16]	2021	RCS	Nail	52	49.2	15
			Plate	49	43.9	15
Zeman et al.[19]	2019	RCS	Nail	19	39.2	12
			Plate	217	39.2	12

PCT: Prospective controlled trial; RCS: Retrospective controlled study; M: month; NS: Not state.

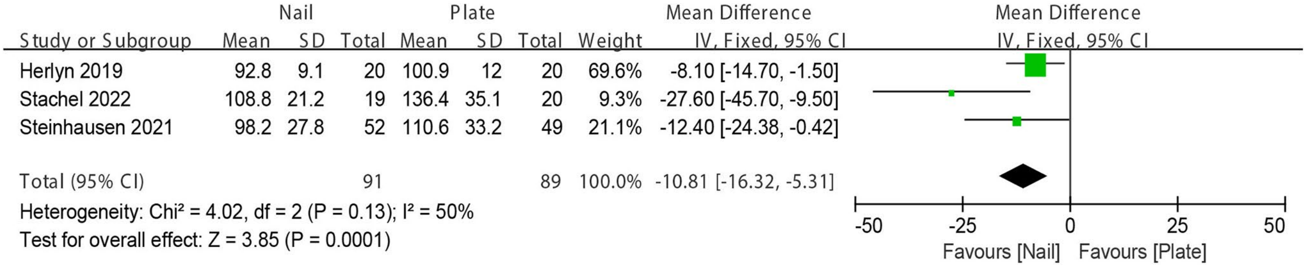

FIGURE 2. Forest plot showing the duration of operation.
SD: Standard deviation; CI: Confidence interval.

–2.95; p<0.00001) without significant heterogeneity (p=0.85, I^2=0%, Figure 3).

Two studies reported the postoperative VAS score.[15,17] Pooled results showed that intramedullary nail did not increase postoperative VAS compared to plate (MD: 1.95; 95% CI: –0.30, 4.21; p=0.09) without significant heterogeneity (p=0.30, I^2=7%, Figure 4).

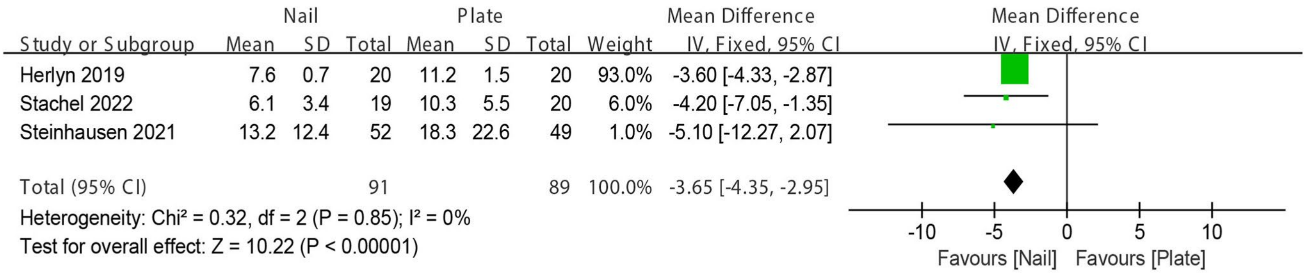

FIGURE 3. Forest plot showing the length of hospital stay.
SD: Standard deviation; CI: Confidence interval.

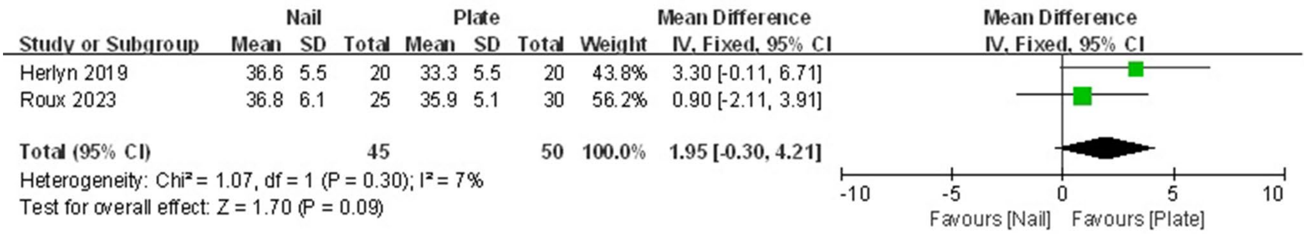

FIGURE 4. Forest plot showing postoperative VAS scores.
VAS: Visual analog scale; SD: Standard deviation; CI: Confidence interval.

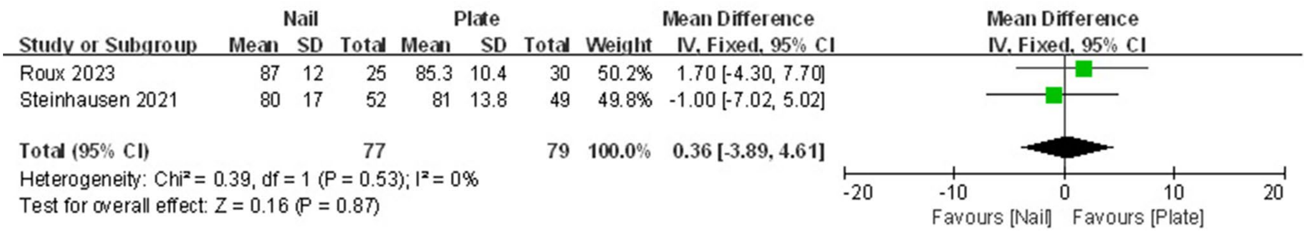

FIGURE 5. Forest plot showing postoperative AOFAS scores.
AOFAS: American Orthopaedic Foot & Ankle Society; SD: Standard deviation; CI: Confidence interval.

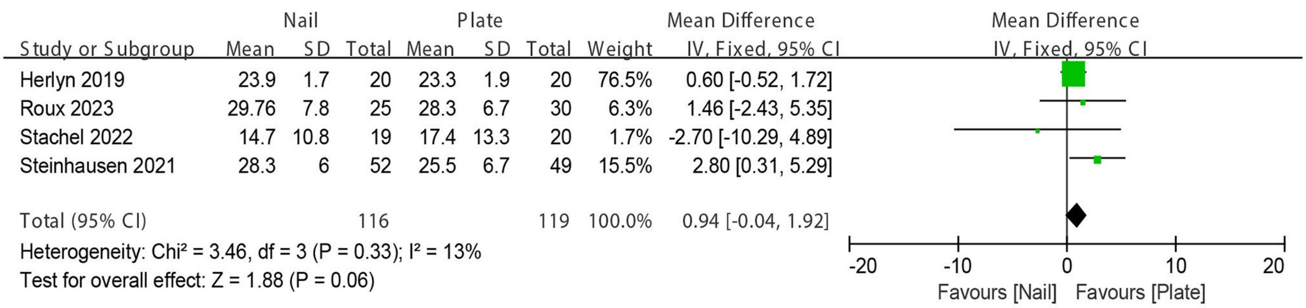

FIGURE 6. Forest plot showing postoperative Böhler angles.
SD: Standard deviation; CI: Confidence interval.

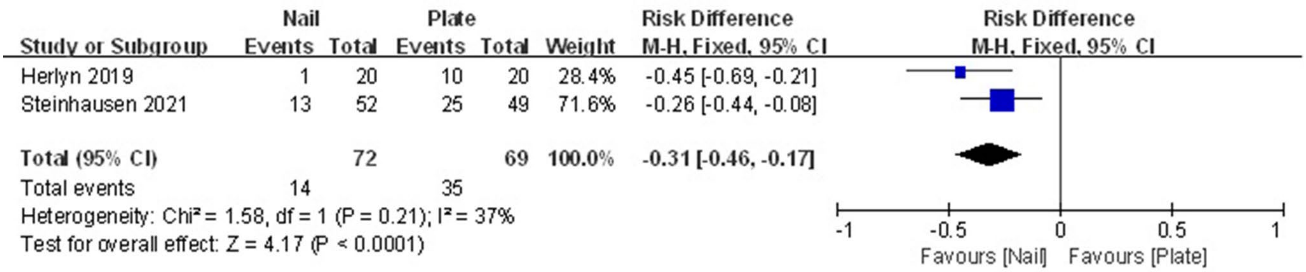

FIGURE 7. Forest plot showing total complications.
SD: Standard deviation; CI: Confidence interval.

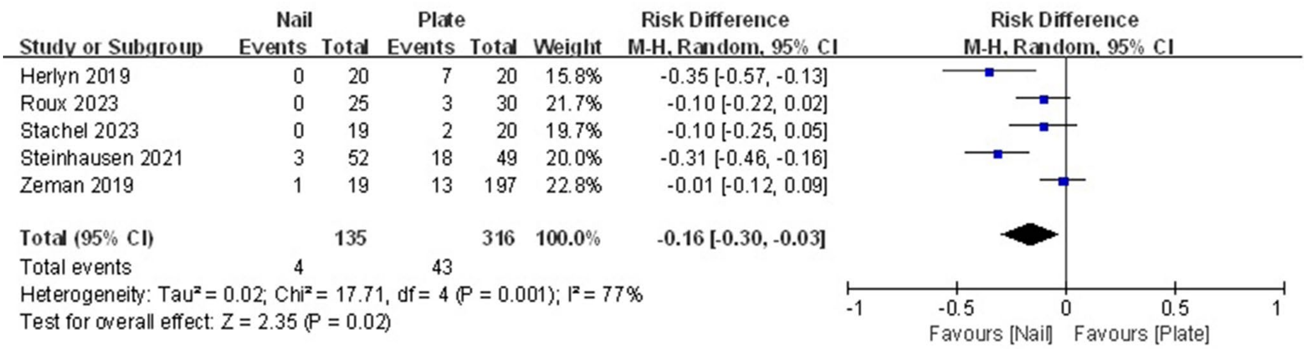

FIGURE 8. Forest plot showing wound-healing complications.
SD: Standard deviation; CI: Confidence interval.

Two studies reported the postoperative AOFAS.[16,17] Pooled results showed that intramedullary nail did not increase postoperative AOFAS compared to plate (MD: 0.36; 95% CI: –3.89, 4.61; p=0.87) without significant heterogeneity (p=0.53, I^2=0%, Figure 5).

Four studies reported the postoperative Böhler angle.[15-18] Pooled results showed that intramedullary nail did not increase postoperative Böhler angle compared to plate (MD: 0.94°; 95% CI: –0.04, 1.92; p=0.06) without significant heterogeneity (p=0.33, I^2=13%, Figure 6).

Complications were reported in all included studies.[15-19] Pooled results showed that intramedullary nail decreased the incidence of total complication (RD: –0.31; 95% CI: –0.46, –0.17; p<0.0001, Figure 7) and wound-healing complications (RD: –0.16; 95% CI: –0.30, –0.03;

TABLE III
Meta-analysis results of complications

			Overall effect			Heterogeneity	
Outcomes	Studies	Groups (IMN/P)	Effect estimate	95% CI	*p* value	I^2 (%)	*p* value
Total complication	2	72/69	-0.31	–0.46, –0.17	0.0001	37	0.21
Wound-healing complications	5	135/316	–0.16	–0.30, –0.03	0.02	77	0.001
Revision surgery	2	72/69	0.03	–0.09, 0.16	0.60	0	0.83
Implant removal	2	72/69	–0.02	–0.13, 0.09	0.74	0	0.85
Superficial wound infection	2	72/69	–0.06	–0.20, 0.08	0.38	51	0.15
Deep infection	3	91/266	–0.03	–0.08, 0.03	0.33	0	0.92
Non-union	2	72/69	0.01	–0.06, 0.09	0.77	0	0.80

IMN: Intramedullary nail; P: Plate; CI: Confidence interval.

p=0.02, Figure 8) compared to plate. There were no significant differences in the incidences of revision surgery, implant removal, superficial wound infection, deep infection, and nonunion (Table III).

DISCUSSION

The aim of surgical treatment for DCF is to reconstruct calcaneal bone shape, restore foot function, and prevent subtalar arthritis.[20] Open reduction and internal fixation with plate via lateral extended L-shaped incision can sufficiently expose the surgical field of view and precise reduction quality, which has become the gold standard of surgical treatment.[21] However, related postoperative complications cannot always be avoided. As a newly introduced internal fixation device, the intramedullary locking nail system not only achieves satisfactory reduction quality but also has a smoother learning curve. Due to minimally invasive surgery, the soft tissue around the calcaneus is well protected. The incidence of complications is lower, and it has gradually become a new choice for displaced calcaneal fractures.[22] Recently, a systematic review showed that intramedullary locking devices for DCF offer adequate primary stability, stiffness, interfragmentary motion, and load to failure in biomechanical studies.[12] This study also reported that intramedullary locking devices lead to satisfactory clinical outcomes at short-term follow-up, enabling restoration of calcaneal height, improved subtalar joint congruency, and fewer wound complications compared to ORIF. In the present meta-analysis, we pooled the most recent evidence from comparative studies and provided the most reliable evidence. This meta-analysis demonstrated that intramedullary nail could decrease operative time, length of hospital stays, and postoperative complications compared to ORIF with plate in the treatment of DCF.[22]

The intramedullary locking nail system includes the Caspar bidirectional retractor, which makes it relatively easy to restore the length and height of the calcaneal bone by using the pulling effect of the soft tissues around the calcaneus.[23] In a case-control study, Le Roux et al.[17] compared the reduction quality of intramedullary fixation and ORIF. They found that there was no statistically significant difference in the postoperative calcaneal parameters between the two groups and concluded that both surgical methods could obtain satisfactory reduction quality. Zeman et al.[19] found that different degrees of reduction loss could be observed in intramedullary nail and plate fixation at the one-year follow-up, but both could maintain an adequate Böhler angle and flat articular surface. Pooled results suggested that the postoperative Böhler angle in the intramedullary locking nail system group was comparable to those in the ORIF group. Finite element analysis studies suggested that the intramedullary locking nail system can provide comparatively sufficient stability compared with plate fixation.[24,25]

The incidence of incision complications after conventional ORIF with plate ranges from 6% to 20%, particularly for diabetes mellitus, high energy soft tissue injury, and long-term smokers may higher. The length of the incision, large range of soft tissue dissection, injury of the lateral peroneal artery calcaneus branch, and formation of a potential dead space under the flap all affect the healing of the incision.[26] Intramedullary fixation does not require extensive dissection of the soft tissues around the calcaneus, which can avoid damage to the blood circulation of the fractured mass. At the same time, it has the advantages of a smaller incision and no direct contact between the internal fixation device and soft tissues. The present study found that the incidence of postoperative incision complications in patients with intramedullary fixation was significantly reduced. Furthermore, pooled results suggest that the length of hospital stay and duration of operation were shorter in the intramedullary fixation group. This is also related to the minimally invasive technique of the intramedullary locking nail system.

The goal of calcaneal fracture treatment is to restore limb function, and the AOFAS score is the most commonly used tool for the evaluation of foot function. In a retrospective controlled study by Le Roux et al.,[17] AOFAS scores in the intramedullary nail group were comparable to those in the ORIF group at the one-year follow-up. The present meta-analysis showed that postoperative AOFAS scores in the intramedullary nail groups were similar to those in the ORIF groups, consistent with previous studies. Herlyn et al.[15] reported that the patients in the intramedullary fixation group had significantly lower frequency of analgesic drug use and better treatment satisfaction.

There are some limitations to the present study. No RCTs were retrieved, and only five non-RCTs were included. The suboptimal methodological quality of non-RCTs weakens the evidence level of the meta-analysis. In addition, the sample size of the included studies was relatively small. Lastly, the intramedullary nail is a newly designed implant for calcaneal fracture, and all included studies were published after 2019 with a short follow-up period, which may lead to the underestimation of complications.

In conclusion, the intramedullary nail showed a shorter duration of operation, reduced hospital stay, and fewer complications compared to the conventional plate in treating displaced intra-articular calcaneal fractures.

Ethics Committee Approval: No ethical approval was required, as all data in this meta-analysis were derived from previously published research. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Response: Contributed to conception and design of this study: X.F., Z.B.D., C.G.W., Z.J.L.; Study selection and data extraction of the finally included studies were done independently assessed the methodological quality of each included study: X.F., Z.B.D., C.G.W.; Contributed to preparation of the manuscript: X.F., G.X.W., Z.J.L.; The final version of the article was approved by all the authors. Thank you very much.

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