Systematic Review and Meta-Analysis

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Bone graft versus non-bone graft for treatment of calcaneal fractures

A protocol for meta-analysis

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Abstract

Background: Calcaneal fractures are a prevalent form of injury caused by high-energy trauma. This study aimed at investigating whether bone graft and non-bone graft are essential for the internal fixation of calcaneal fractures. A meta-analysis of relevant clinical studies evaluated radiographic parameters, functional outcomes, and complications that offer practical recommendations on the suitability of bone grafts for the management of Calcaneal fractures.

Methods and analysis: This study performed a comprehensive search on PubMed, EMBASE, and Cochrane electronic to retrieve related clinical studies. The studies incorporated in our meta-analysis were identified after doing a preliminarily screening, reading of the full-text articles, and eliminating repeated studies. After quality assessment and data extraction, the standardized mean difference and risk ratio were selected as effect sizes. The data on Böhler angle, Gissane angle, calcaneal height, American Orthopaedic Foot and Ankle Society hindfoot scores, Maryland Foot Evaluation, and rate of wound infection were analyzed using Revman 5.3 software (Cochrane Collaboration).

Results and Conclusions: This study did not reveal any significant differences ($P < .05$) in both Böhler and Gissane angles, calcaneal height, American Orthopaedic Foot and Ankle Society hindfoot scores, Maryland foot evaluation, and rate of wound infection between the 2 groups. Due to the lack of a large sample of comparative studies, the use of bone grafting for the management of calcaneal fractures requires additional substantiation.

Abbreviations: AOFAS = American Orthopaedic Foot and Ankle Society, CI = confidence interval, NOS = Newcastle–Ottawa scale, RCTs = randomized controlled trials, SBG = small incision bone graft, SMD = standardized mean difference.

Keywords: bone graft, calcaneal fractures, meta-analysis

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No ethical approval and patient safety considerations were required in this study since it was based on previously published studies. The results of this meta-analysis will be published in a peer-reviewed journal and disseminated at scientific conferences.

Patient consent for publication is not required.

Provenance and peer review are not commissioned; externally peer-reviewed.

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The authors have no conflicts of interest to disclose.

The datasets generated during and/or analyzed during the current study are publicly available.

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1. Background

The treatment goals for a calcaneal fractures include a correction of the height, width, and length of the calcaneus for the accurate anatomic restoration of the displaced joints and robust osteosynthesis. Operative treatment of calcaneal fractures should also achieve anatomical reconstruction of the subtalar and calcaneocuboid joints of the foot.[1,2]

There is currently a controversy over the necessity of performing a bone graft following reduction and internal fixation of calcaneal fractures. The main contention is whether failure to perform a bone graft can predispose the patient to postoperative re-displacement or late articular surface defect and whether it affects postoperative function.[3–10] This study did a meta-analysis of relevant clinical studies to determine whether bone grafts are needed during the surgery for calcaneal fractures. The parameters evaluated in the present study include Böhler and Gissane angles, calcaneal height, American Orthopaedic Foot and Ankle Society (AOFAS) hindfoot scores, Maryland foot evaluation, and rate of wound infection.

2. Materials and methods

2.1. Search strategy

2.1.1. Retrieval method. The search strategies employed in this meta-analysis were based on the criteria developed by the Cochrane Collaboration. The search included selected keywords and free words, and these retrieval words were combined using Boolean operators. The PubMed, EMBASE, and Cochrane databases were electronically searched on March 20, 2019, to retrieve journal references on related studies.

2.1.2. Basic PubMed search. The electronic search on PubMed used the strategy: (((Heel Bone[Title/Abstract] OR ((“bone and bones”[MeSH Terms] OR (“bone”[All Fields] AND “bones”[All Fields]) OR “bone and bones”[All Fields] OR “bone”[All Fields]) AND Heel[Title/Abstract])) OR “Calcaneus”[MeSH]) AND ((((((((((((((Broken Bones[Title/Abstract] OR ((“bone and bones”[MeSH Terms] OR (“bone”[All Fields] AND “bones”[All Fields]) OR “bone and bones”[All Fields] OR “bone”[All Fields]) AND Broken[Title/Abstract])) OR ((“bone and bones”[MeSH Terms] OR (“bone”[All Fields] AND “bones”[All Fields]) OR “bone and bones”[All Fields] OR “bones”[All Fields]) AND Broken[Title/Abstract])) OR Broken Bone[Title/Abstract]) OR Bone Fractures[Title/Abstract]) OR Bone Fracture[Title/Abstract]) OR Fracture, Bone[Title/Abstract]) OR Spiral Fractures [Title/Abstract]) OR (Fracture,[All Fields] AND Spiral[Title/Abstract])) OR (Fractures,[All Fields] AND Spiral[Title/Abstract])) OR Spiral Fracture[Title/Abstract]) OR Torsion Fractures[Title/Abstract]) OR (Fracture,[All Fields] AND Torsion [Title/Abstract])) OR (Fractures,[All Fields] AND Torsion[Title/Abstract])) OR Torsion Fracture[Title/Abstract]) OR “Fractures, Bone”[MeSH])) AND ((((Transplantation,[All Fields] AND Bone [Title/Abstract]) OR ((“transplantation”[Subheading] OR “transplantation”[All Fields] OR “grafting”[All Fields] OR “transplantation”[MeSH Terms] OR “grafting”[All Fields]) AND Bone[Title/Abstract])) OR Bone Grafting[Title/Abstract]) OR “Bone Transplantation”[MeSH])

2.2. Inclusion and exclusion criteria

2.2.1. Inclusion criteria. Studies were considered eligible if they satisfied the following inclusion criteria:

(1) Cohort studies and randomized controlled trials (RCTs) reported in either the Chinese or English languages.
(2) Intra-articular calcaneal fractures; not limited by sex, age, ethnicity, or nationality, and with a postoperative follow-up of at least 3 months.
(3) Comparison on efficacy of the presence and absence of bone graft for treatment of intra-articular calcaneal fractures; not limited by internal fixation methods.
(4) Complete original data including at least 1 of the following parameters: Böhler angle, Gissane angle, calcaneal height, AOFAS hindfoot scores, Maryland foot evaluation, and rate of wound infection.
(5) True and credible bibliographic data, or one that can be transformed into binary continuous variables to represent each index.

2.2.2. Exclusion criteria. The following criteria were used for exclusion:

(1) Case reports, reviews, and conference papers lacking full texts.
(2) Old fractures (over 3 weeks) and pathological fractures (including primary fractures and fractures resulting from metastatic tumors, osteoporosis, or endocrine disorders).

2.3. Measurement of outcomes

2.3.1. Primary outcomes.

(1) Böhler angle: The Böhler angle is an imaging index that serves as an anatomical landmark for the posterior articular surface of the subtalar joint. The Böhler angle can reflect the heel height and foot arch angle. A Böhler angle of <0 indicates that the outcome will be less successful regardless of whether surgery is performed. However, a Böhler angle of >15 suggests that long-term effects will be more successful. The size of the Böhler angle is a good indicator of the severity of the trauma load on the subtalar joint.[11] Most manuscripts included in our study did not extensively detail the Böhler angle measurement methods used. However, the same methods and standards were used for each subject in different manuscripts, which brings quality internal consistency. We used the standardized mean difference (SMD) to merge data and to eliminate the interference of the measurement method on the mean outcome.
(2) Gissane angle: The Gissane angle is a radiographic parameter formed by the posterior facet and the line from the calcaneal sulcus to the tip of the anterior process of the calcaneus. Gissane angle typically ranges from 120° to 145°.[12]
(3) Calcaneal height: The Calcaneal height is a radiographic parameter measured on the lateral radiographic view from the most posterior point of the tuberosity to the calcaneocuboid joint.[13]

2.3.2. Secondary outcomes.

(1) Functional outcomes: The functional outcomes of walking ability, walking distance, gait, and pain were assessed according to the AOFAS and Maryland Foot Evaluation.
(2) Rate of wound infections: The incidence of wound infections, including superficial and deep infections following treatment of calcaneal fractures, was used as an indicator of recovery time.[14,15]

2.3.3. Data extraction. Data extraction indexes included the first author, year of publication, sample size, sex, intervention measures, follow-up time, Böhler angle, Gissane angle, calcaneal height, AOFAS hindfoot scores, Maryland foot evaluation, and rate of wound infection. Two researchers, Heng Tian and Jinlan Zhou, independently extracted the data. Discrepancies between the data obtained by the 2 reviewers were resolved by consensus with the third researcher (Zhe Zhu).

2.3.4. Quality evaluation. Two researchers, Heng Tian and Jinlan Zhou, independently assessed the selection, comparability, and exposure qualities of the 7 included cohort studies according to the Newcastle–Ottawa scale (NOS). Disagreements regarding eligibility were resolved by discussion with a third researcher (Zhe Zhu).

2.4. Statistical analysis

Meta-analysis was done using Revman 5.3 software, and forest plots were drawn for comparison of odds ratios. The Mantel–Haenszel test was used to analyze binary variables, and continuous variables were analyzed using inverse variance. A $P \geq .05$ and $I^2 < 50\%$ indicated low heterogeneity, and a fixed-effects model was selected. On the contrary, a $P \leq .05$ and $I^2 > 50\%$ showed high heterogeneity, and a random-effects model was selected. When $I^2 > 50\%$, the included studies were removed one by one to the sensitivity analysis that was conducted to determine the sources of heterogeneity. For result indicators of no less than 10 primary documents, subgroup analysis was performed. The risk ratio was used to measure the effect sizes

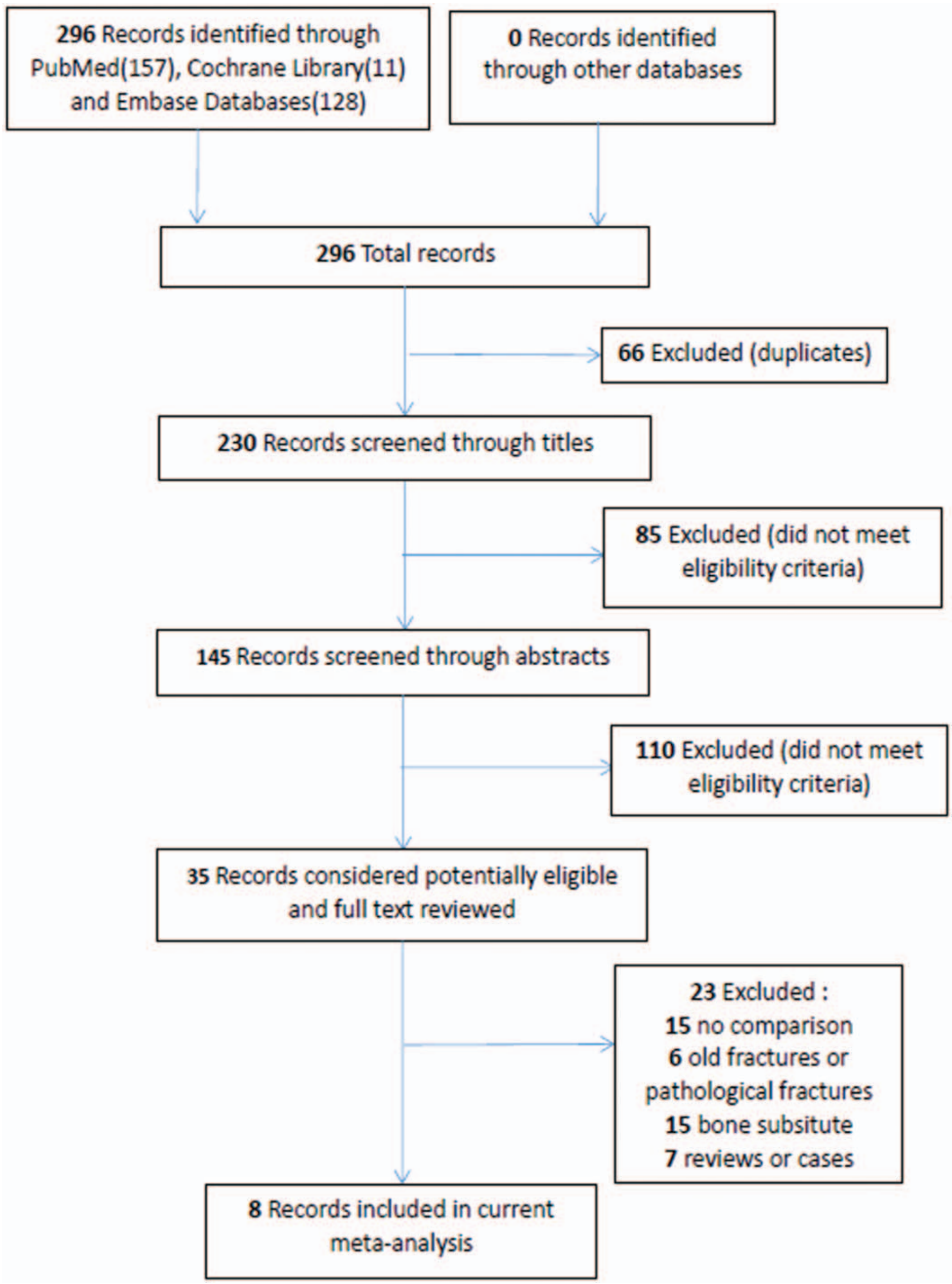

Figure 1. Literature search strategy and results.

of binary variables, while the effect sizes of continuous variables were measured using the SMD. When result indicators of no less than 10 primary documents, publication bias was assessed at a 95% confidence interval (CI) using funnel plots.

2.5. Patient and public involvement

Patients were not involved in any stage of this study, including the development of the research question, design and implementation of the study, and interpretation of the results.

3. Results

3.1. Literature search

The literature search yielded a total of 296 studies, as shown in Figure 1: 157. After excluding duplicates, 230 studies were retained. Then, 145 studies were retained after reading titles, and 35 studies were included after reading abstracts. Among these, 6 studies on old and pathological fractures were excluded. Also excluded were 7 case studies/reviews, 1 study that used a bone substitute, and 15 studies that had no comparisons. The

Table 1

Characteristics of the included trials and participants.

	Cases	Sex	Interventions		Type of bone graft	Follow-up Time
Included Trials	T/C	M/W	T	C	–	–
Longino et al 2001[16]	20/20	38/2	ORIF+BG	ORIF	Autologous	3 mo
Kennedy et al 2003[17]	12/10	16/6	ORIF+BG	ORIF	Allograft	>48 mo
Duymus et al 2017[18]	21/22	35/5	ORIF+BG	ORIF	Allograft	3 mo
Singh et al 2013[19]	202/188	282/108	ORIF+BG	ORIF	Autologous	>24 mo
Gusic et al 2015[20]	20/67	–	ORIF+BG	ORIF	Autologous	12 mo
Nie et al 2009[21]	56/56	74/38	CRPNF+SBG	CRPNF	Autologous or allograft	5–52 mo
Zhang et al 2011[22]	11/11	17/5	IFLTPR+BG	IFLTPR	Autologous	25 mo
Cao H et al 2018[23]	28/29	–	ORIF+BG	ORIF	Autologous	>12 mo

BG=bone graft, C=control group, CRPNF=closed reduction and percutaneous needle fixation, IFLTPR=internal fixation of locking titanium plate after reduction, LCSI=lateral calcaneal skin incision, M=men, ORIF=open reduction and internal fixation, SBG=small incision bone graft, T=treatment group, W=woman.

remaining 8 articles, 6 in English and 2 in Chinese, were included in this meta-analysis.

3.2. Study characteristics

The primary characteristics of sample size, sex, interventions, and follow-up time of the 8 studies are shown in Table 1.

3.3. Literature quality evaluation

The quality of the included 8 cohort studies was assessed by the NOS,[24] and literature with points ranging from 5 to 9 was regarded as of high quality. According to the NOS analysis, the 8 studies included in this meta-analysis were of high quality: 5 studies had 9 points, 1 study had 8 points, while the other 2 studies had 7 points. The specific results are presented in Table 2.

3.4. Meta-analysis results

3.4.1. Böhler angle

3.4.1.1. Böhler angle in short-term follow-up. Five studies[16,18–20,22] reported Böhler angle within 1-year post-surgery, including 274 cases in the bone graft group and 308 cases in the non-bone graft group. The I^2 = 0%, and the fixed effects model was, therefore, selected. According to (2.1), SMD=0.03, 95% CI [−0.14, 0.20], and P=.72, suggesting that there were no significant differences (P > .05) between the 2 groups. (Figure 2.1) Figure 3 shows that no publication bias was noted.

3.4.1.2. Böhler angle in long-term follow-up. Four studies[18,19,22,23] reported Böhler angle in over 1-year post-surgery, including 262 cases in the bone graft group and 250 cases in the non-bone graft group. The I^2 = 0%, and the fixed effects model was, therefore, selected. According to (2.2), SMD=0.55, 95% CI [0.37, 0.73], and P < .00001, suggesting that the bone graft group was superior to the non-bone graft group (Figure 2.2).

Table 2

Document quality evaluation table.

Included trials	Selection score	Comparability score	Outcome score	Overall score
Longino et al 2001[16]	4	2	1	7
Kennedy et al 2003[17]	4	2	3	9
Duymus et al 2017[18]	4	2	2	8
Singh et al 2013[19]	4	2	3	9
Gusic et al 2015[20]	4	1	2	7
Nie et al 2009[21]	4	2	3	9
Zhang et al 2011[22]	4	2	3	9
Cao H et al 2018[23]	4	2	3	9

3.4.2. Gissane angle

3.4.2.1. Gissane angle in short-term follow-up. Two studies[19,22] reported Gissane angle within 1-year post-surgery, including 213 cases in the bone graft group and 199 cases in the non-bone graft group. The I^2 = 0%, and the fixed effects model was, therefore, selected. According to (2.3), SMD=0.16, 95% CI [−0.03, 0.36], and P=.10, suggesting that no significant differences (P > .05) were recorded between the 2 groups. (Figure 2.3).

3.4.2.2. Gissane angle in long-term follow-up. Three studies[19,22,23] reported Gissane angle in over 1-year post-surgery, including 241 cases in the bone graft group and 228 cases in the non-bone graft group. The I^2 = 0%, and the fixed effects model was, therefore, selected. As shown in (2.4), SMD=0.20, 95% CI [0.02, 0.38], and P=.03 indicating that the bone graft group was superior to the non-bone graft group. (Figure 2.4).

3.4.3. Calcaneal height

3.4.3.1. Calcaneal height in short-term follow-up. Two studies[18,19] reported calcaneal height within 1 year after surgery, including 224 cases in the bone graft group and 209 cases in the non-bone graft group. The I^2 = 0%, and the fixed effects model was, therefore, selected. As shown in (2.5), SMD=0.07, 95% CI [−0.12, 0.26], and P=.47 indicating that no significant differences (P > .05) were noted between the 2 groups. (Figure 2.5).

3.4.3.2. Calcaneal height in long-term follow-up. Three studies[18,19,23] reported calcaneal height in over 1-year post-surgery, including 252 cases in the bone graft group and 238 cases in the non-bone graft group. The I^2 = 98%, and the random-effects model was, therefore, selected. As shown in (2.6), SMD=1.73, 95% CI [−0.35, 3.81], and P=.10, suggesting that no significant differences (P > .05) were recorded between the 2 groups. The sensitivity analysis did not find any sources of heterogeneity. (Figure 2.6).

3.4.4. AOFAS hindfoot scores.

Three studies[18,19,23] reported postoperative foot functional scores based on the AOFAS hindfoot scores. The studies included 251 cases in the bone

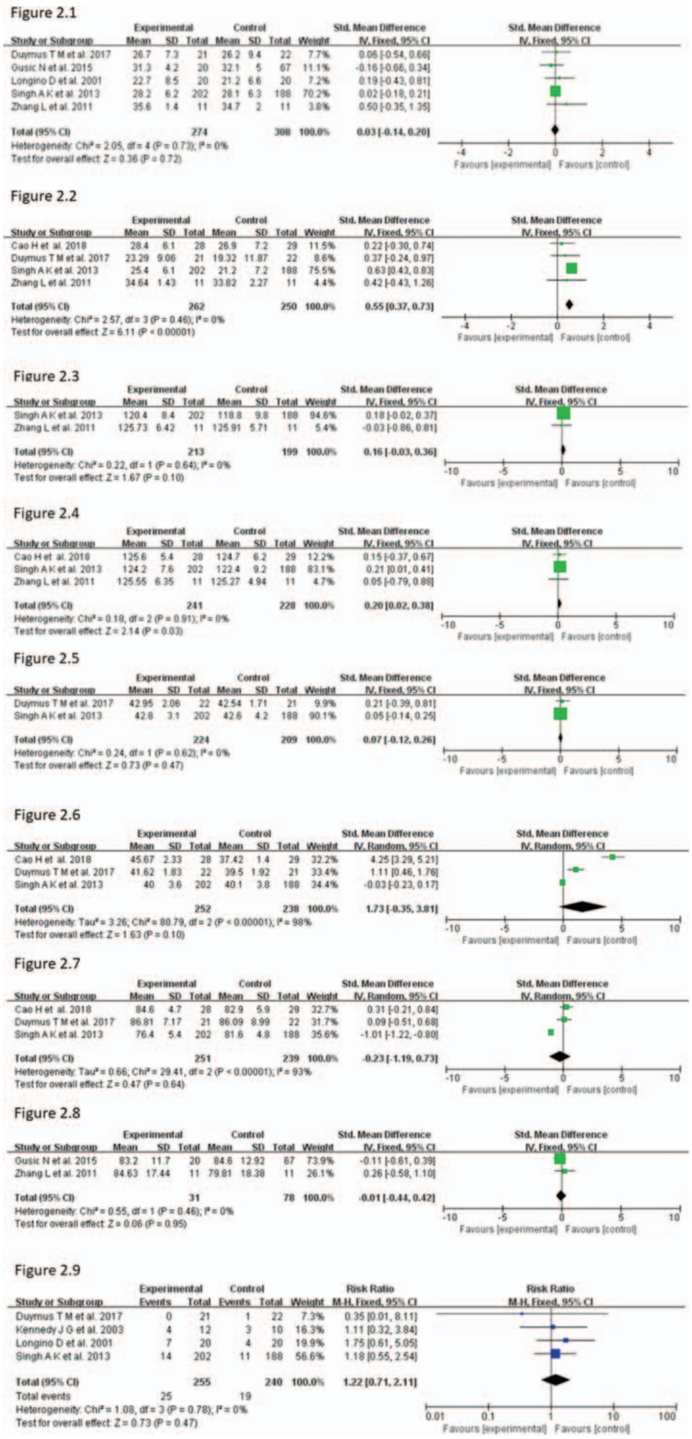

Figure 2. (2.1) Graph showing Böhler angle of operative (experimental) versus nonoperative (control) groups ($P=.72$) in short-term follow-up. The size of each square is proportional to the weight of the study. $Z=P$-value of weighted test for overall effect. (2.2) Graph showing Böhler angle of operative (experimental) versus nonoperative (control) groups ($P<.00001$) in long-term follow-up time. The size of each square is proportional to the weight of the study. $Z=P$-value of weighted test for overall effect. (2.3) Graph showing Gissane angle in operative (experimental) versus nonoperative (control) groups ($P=.10$) in short-term follow-up. The size of each square is proportional to the weight of the study. $Z=P$-value of weighted test for overall effect. (2.4) Graph showing Gissane angle of operative (experimental) versus nonoperative (control) groups ($P=.03$) in long-term follow-up. The size of each square is proportional to the weight of the study. $Z=P$-value of weighted test for overall effect. (2.5) Graph showing the calcaneal height of operative (experimental) versus nonoperative (control) groups ($P=.47$) in short-term follow-up. The size of each square is proportional to the weight of the study. $Z=P$-value of weighted test for overall effect. (2.6) Graph showing the calcaneal height of operative (experimental) versus nonoperative (control) groups ($P=.10$) in long-term follow-up. The size of each square is proportional to the weight of the study. $Z=P$-value of weighted test for overall effect. (2.7) Graph comparing AOFAS hindfoot scores of operative (experimental) versus nonoperative (control) groups ($P=.64$). The size of each square is proportional to the weight of the study. $Z=P$-value of weighted test for overall effect. (2.8) Graph comparing Maryland Foot Evaluation in operative (experimental) versus nonoperative (control) groups ($P=.95$). The size of each square is proportional to the weight of the study. $Z=P$-value of weighted test for overall effect. (2.9) Graph comparing. Rate of wound infection in operative (experimental) versus nonoperative (control) groups ($P=.47$). The size of each square is proportional to the weight of the study. $Z=P$-value of weighted test for overall effect. CI=confidence interval, df=degrees of freedom, I^2=test statistic, IV=inverse variance.

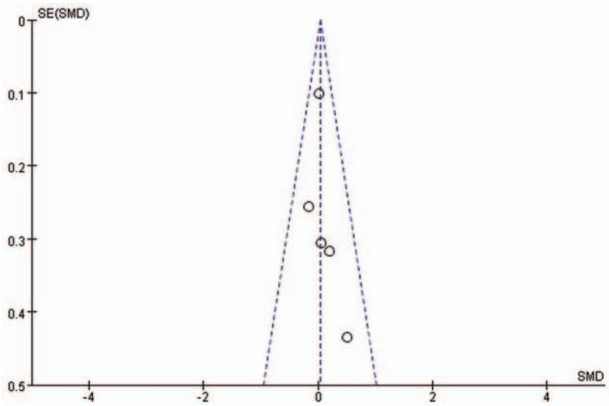

Figure 3. Funnel chart showing Böhler angle in short-term follow-up.

graft group and 239 cases in the non-bone graft group. The I^2 = 93%, and the random-effects model was, therefore, selected. As shown in (2.7), SMD = −0.23, 95% CI [−1.19, 0.73], and P = .64 indicating that no significant differences (P > .05) were observed between the 2 groups. In the sensitivity analysis, Singh A K et al's study[18] was excluded, and I^2 was reduced to 0.0% (P = .571). Using the fixed effect model, the conclusion was unchanged (SMD = 0.22, 95% CI [−0.18, 0.61], P = .571). Figure 2.7

3.4.5. Maryland foot evaluation. Two studies[20,22] reported post-surgery foot functional scores based on the Maryland Foot Evaluation, including 31 cases in the bone graft group and 78 cases in the non-bone graft group. The I^2 = 0%, and the fixed effects model was, therefore, used. According to (2.8), SMD = −0.11, 95% CI [−0.44, 0.42], and P = .95, suggesting that no significant differences (P > .05) were noted between the 2 groups. Figure 2.8

3.4.6. Rate of wound infection. Four studies[16–19] recorded the frequency of post-surgery wound infection, including 255 cases in the bone graft group and 240 cases in the non-bone graft group. The I^2 = 0%, and the fixed effects model was, therefore, used. As shown in (2.9), risk ratio = 1.22, 95% CI [0.71, 2.11], and P = .47 indicating that no significant differences (P > .05) were recorded between the 2 groups. Figure 2.9

4. Discussion

The meta-analysis revealed that the odds of functional scores and rate of wound infection after surgery in the graft group did not significantly differ from those recorded in the non-graft group. In the short-term follow-up, Böhler angle, Gissane angle, and calcaneal height did not significantly differ (P > .05) between the 2 groups. In long-term follow-up, Böhler and Gissane angles were better in the bone graft group than in the non-bone graft group. However, Calcaneal height was not significantly different between the 2 groups. Although radiographic parameters such as Böhler and Gissane angles were better in the long term follow-up of the bone graft group, no significant differences between the 2 groups were noted in the short-term follow-up. Radiographic parameters provide prognostic information on bone healing. More attention should, however, be on functional scores, which assess walking ability, walking distance, gait, and pain. The findings of this study indicate that bone grafts do not offer any apparent advantages in intra-articular calcaneal surgery.

4.1. Clinical significance

Bone grafts are typically used for defective areas of displaced intra-articular calcaneus to fill significant bone gaps, provide mechanical support, and promote bone healing. The use of bone grafts for the treatment of calcaneal fractures is a widespread clinical practice worldwide and is estimated to be used in 2.2 million cases annually.[25] Besides, a survey in the Netherlands reported that only 38% of cases do not use bone grafts at all.

Some researchers believe that bone grafts are not generally needed because the calcaneal cancellous bone has a strong regenerative ability.[26,27] Rammelt[28] reported that the calcaneal cancellous bone has a strong ability to regenerate. Bone grafts are only necessary in case of a significant bone defect and if the fracture block becomes unstable after reduction (usually 20%–50%). Longino[16] did not observe any significant differences in postoperative radiological indicators and clinical results between the bone graft group and the non-bone graft group. Letournel[6] considered that it was difficult to grasp the suitability of a bone graft because the medial wall was also broken. There is currently no clinical evidence that bone grafts contribute to either early functional exercise or weight loss. Bone grafting is, therefore, not recommended.

Furthermore, grafts may pose additional risks to the patient.[29,30] For instance, previous studies reported that calcaneal transplantation has a high infection rate, can lead to high blood losses, and has a long operation time.[31,32] Also, calcaneal transplantation increases postoperative pain in patients.[33–35]

The use of bone grafts in operative treatment of calcaneal fractures remains a debatable subject. The results of our meta-analysis demonstrated that the bone graft group did not exhibit any apparent advantages in radiographic parameters, functional scores, and complications as compared to the non-bone graft group.

Before deciding to perform a bone graft on a calcaneal fracture patient, physicians should consider the patient's expected outcome, postoperative rehabilitation training, and patient's economic situation. It is unnecessary to conduct bone grafting for each patient with a calcaneal fracture.

5. Conclusions

Böhler angle, Gissane angle, calcaneal height, AOFAS hindfoot scores, Maryland foot evaluation, and rate of wound infection in the bone graft group did not significantly differ from those of the non-bone graft group. Since this study did not involve a large-sample-size multicenter RCT, the necessity of bone grafting for the treatment of calcaneal fractures remains to be further verified.

6. Strengths and limitations of this study

(1) This study analyzed the necessity of bone grafting in the treatment of calcaneal fractures. We evaluated radiographic parameters in the short and long terms and assessed 2 different functional outcomes and complications.
(2) Two reviewers independently conducted study selection, data extraction, and quality assessment.
(3) The study was limited with regards to RCT since only cohort studies were included. The level of the evidence in the present study is, therefore, limited.
(4) Although most high-quality articles in the subject of calcaneal fractures have been written in either English or Chinese, the inclusion of only English and Chinese language might have caused a selection bias.

Author contributions

Conceptualization: Wenlai Guo, Zhe Zhu.
Data curation: Heng Tian, Wenlai Guo, Jinlan Zhou, Xiaoyue Wang.
Project administration: Zhe Zhu.
Software: Heng Tian, Jinlan Zhou, Xiaoyue Wang.
Writing – original draft: Heng Tian.
Writing – review & editing: Zhe Zhu.

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