Percutaneous Surgery Provides Better Functional Outcomes for Displaced Intra-Articular Calcaneal Fractures

Zeyong Xie

Department of Internal Medicine, Linxiang Zhongya Hospital, Yueyang 414300, China; biya34443809@163.com

Received: 22 December 2020; Accepted: 3 February 2021; Published: 5 February 2021

Abstract: We performed a network meta-analysis to compare the effects of different surgical treatments has on displaced intra-articular calcaneal fractures (DIACFs). PubMed, Embase, and Cochrane Library databases were searched for randomized controlled trials (RCTs) from the inception to February 2017. The RCTs providing effects of the different surgical treatments for DIACFs were also included as a significant outlier in this study. A network meta-analysis combining direct and indirect evidence were also used to conduct and evaluate the weighted mean difference (WMD) between odds ratio (OR) value and surface under the cumulative ranking curves (SUCRA) of the different surgical treatments for DIACFs. Fifteen eligible RCTs were acquired and incorporated into this network meta-analysis. In comparison with the traditional open reduction and internal fixation (ORIF), the operating time of the percutaneous surgery was relatively short; the American Orthopaedic Foot and Ankle Society hindfoot scale (AOFAS) of percutaneous surgery was relatively better; the MOS 36-item Short-Form Health Survey (SF-36) physical component score (PCS) of traditional ORIF and traditional ORIF + primary subtalar arthrodesis observations were all higher than the usual conservative treatment. As far as the operating time, hospitalization, and △bohler's angle go, the effects of percutaneous surgery showed better results than the ones discovered by the traditional ORIF for DIACFs; as for the functional score of AOFAS score, SF-36 (PCS), SF-36 (MCS), and visual analogue scale (VAS), the effects of both percutaneous surgery and traditional ORIF were shown to be relatively better. This network meta-analysis indicated that that the effect of the percutaneous surgery for DIACFs was relatively better.

Keywords: displaced intra-articular calcaneal fractures; effects; surgical treatment; open reduction and internal fixation; network meta-analysis

1. Introduction

Displaced intra-articular calcaneal fractures (DIACFs) is a severe injury, and the ensuing prognosis for typically young patients with DIACFs remains dismal [1]. Calcaneal fractures with an indicated occurrence of 2% of all fractures are relatively rare injuries [2], and calcaneal fractures can have long-term consequences for pain and disability [3]. Calcaneal fractures, the most frequent injuries of the tarsal bone, experiencing an incidence of 11.5 per 100,000 people per year, account for approximately 1–2% of all fractures occurring in the human body [4]. Calcaneal fractures are rare injuries for children, and those afflicted by DIACFs patterns are found even less [5]. Most calcaneal fractures are involved with children, which can be managed non-operatively with expectation of good long-term results [6]. The optimal choice of therapy for DIACFs has long been a source of uncertainty in Orthopaedic’s surgery, both in terms of the impact of the therapy on clinical outcomes and on health-care and non-health-care costs [7]. Surgical treatment using open anatomical reduction and stable internal fixation only commenced at the start of the 1980s although screw or plate fixation of the fractured calcaneus was first implemented in the 1920s [8]. Surgical treatment for DIACFs of the calcaneus is a standard operating procedure in many institutions [9].

Throughout this study, we aimed to evaluate the effects different surgical treatments produced on DIACFs patients. Different surgical treatments are commonly practiced and involved in the treatment procedures for DIACFs, some of which being traditional open reduction and internal fixation (ORIF), conservative treatment, percutaneous surgery, etc. ORIF of DIACFs has become a standard surgical method [2]; it is combined with the conservative treatment in the treatment for calcaneal fractures, which can clear anatomic structure as well as having a fast function recovery, so it should be viewed as the preferred method for the treatment of calcaneal fractures [10]. The conservative treatment for DIACFs is still a viable option, but a significant secondary displacement in time should also be taken into account, as reflected by a decrease in Böhler's angle of 11 up to one year following trauma [11]. Percutaneous surgery offers the possibility of equivalent outcomes with a reduction in soft tissue complications [12]; the percutaneous reduction for treatment of DIACFs might allow the acceleration of weight bearing activity, reducing joint stiffness, and improving the patients’ overall satisfaction [12]. ORIF and percutaneous surgery are two of the most common surgical procedures involved in the treatment for DIACFs [13].

DIACFs of the calcaneus remain a diagnostic and therapeutic dilemma [14]. The best treatment for DIACFs of the calcaneus is yet to be discussed [15]. Due to this incomplete scenario, this network meta-analysis is aiming to compare...
the effects of different surgical treatments for DIACFs, as well as to evaluate the current clinical data. We expect this study to be helpful for physicians in discovering the optimal treatment regarding DIACFs.

2. Materials and Methods

2.1. Search Strategy

PubMed, EMBASE, and Cochrane library databases were all searched within the time period of the inception of each database up until February 2017. A manual search was also performed in order to obtain the reference lists. The search was conducted using keywords, mainly including: surgery, ORIF, percutaneous poking, as well as internal fixation, sinus tarsi approach, DIACFs, cohort study, etc.

2.2. Inclusion and Exclusion Criteria

The inclusion criteria went as follows: (1) study design must be a cohort study; (2) interventions should be traditional ORIF (by extensile lateral approach), conservative treatment (early non-weight bearing movement exercises, physiotherapy rehabilitation regimen or plaster immobilization), percutaneous surgery, sinus tarsi approach, and internal fixation, traditional ORIF + primary subtalar arthrodesis, traditional ORIF + grafting (grafting includes autologous bone grafting or bone substitute material-injectable bioresorbable calcium phosphate paste, α-BSM), traditional ORIF + conservative treatment and percutaneous surgery + grafting (calcium sulphate cement (CSC) grafting); (3) study subjects should be patients dealing with DIACFs; (4) outcome indicators: operating time, hospitalization, full weight bearing time, \( \Delta \) bohler’s angle (\( \Delta \) representing the differences of intraoperative and postoperative bohler’s angle), AOFAS score [16], SF-36 (PCS), SF-36 (MCS) [17,18], visual analogue scale (VAS), [19] and complications. The exclusion criteria went as follows: (1) patients showing extra articular calcaneal fractures or concomitant foot injuries; (2) patients experiencing a history of previous foot surgery or severe neurological deficits; (3) incomplete literature data, e.g. non-RCTs; duplicate publications; conference reports, system evaluation, or abstract; non-human study; non-English literatures.

2.3. Data Extraction and Quality Assessment

Two reviewers extracted the data independently with the unified data collection form, and any disagreements were settled by discussion among a number of investigators. More than two reviewers evaluated the quality of RCT using the Newcastle-Ottawa Scale (NOS) assessment for risk of bias [20]. Standard rating scale for NOS were: (1) cohort selection: whether the cohort of exposure has a good or better representation (NOS1), whether the non-exposed cohort is associated with the exposed cohort from the same population (NOS2), whether there is a reliable record or structured interview (NOS3), whether the initial study outcome is not observed (NOS4); (2) comparability of cohort: whether the study selected and analyzed the most important factors (NOS5), whether the study controls any other confounding factors (NOS6); (3) cohort outcome: whether the study is independent, blind evaluation (NOS7), whether the follow-up was long enough in order for any outcomes to occur (NOS8), whether or not there was loss to follow-up for their cohort, and whether there is potential in introducing bias into their study (NOS9). The total point was 9, and anything more than 5 points was to be included in the meta-analysis.

2.4. Statistical Analysis

Initially, we used the software provided by the R version 3.2.1 and the Meta package in order to do a pair-wise meta-analysis of direct evidence using the fixed-effects model. The pooled estimates between weighted mean difference (WMD), odds ratios (ORs), and 95% confidence intervals (CIs) of nine endpoint outcomes were demonstrated. Heterogeneity among the studies was tested by using the Chi-square test and I-square test [21]. Next, the R 3.2.1 software was used so as to draw a network diagram, in which each node was representative of an intervention measure, and the size of each node represented the sample size and the thickness of line between nodes represented the number of included studies. Furthermore, we employed a random-effects network meta-analysis with the gemtc package. This meta-analysis models the relative effects (e.g. log-odds ratio) fitting a generalized linear model (GLM) under the Bayesian framework by linking to JAGS, OpenBUGS, or WinBUGS as first described by Lu and Ades [22] and subsequently extended by others [23,24]. The current study used the node-splitting method in order to evaluate the consistency of both the direct and indirect evidences. If the node-splitting result showed \( P > 0.05 \) as significantly different, it was analyzed by the consistency model [25]. In order to assist in the interpretation of WMD/OR, we calculated the probability of each intervention being the most effective or safest treatment method on the basis of a Bayesian approach by implementing probability values summarized as surface under the cumulative ranking curve (SUCRA), with the stipulation being, the larger the SUCRA value, the better the rank of the intervention [26,27]. Cluster analyses were employed in order to group the treatments in coordination to their similarities regarding both outcomes [26]. All computations were conducted by using the R (V.3.2.2) package gemtc (V.0.6) as well as the Markov Chain Monte Carlo engine Open BUGS (V.3.4.0).
3. Results

3.1. Fifteen Eligible RCTs Concerning 1741 Patients with DIACFs were Enrolled in this Network Meta-Analysis

We retrieved a total of 1777 related literatures in total, among which 8 repeated literatures, 185 letters or reviews, 220 non-human literatures, and 210 non-English literatures were eliminated. After a comparative evaluation of full-text, 1139 studies from the rest of the remaining 1154 literatures were further excluded, including 325 non-cohort literatures, 401 literatures unrelated to DIACFs, 133 literatures irrelevant to surgical treatment, and 278 literatures uncorrelated to curative effects as well as two literatures with incomplete data or blank content. Finally, 15 eligible RCTs were enrolled in this network meta-analysis [10, 12, 13, 28–39] (Supplementary Figure 1), which was published between 2003 and 2016. In these 15 studies, the research objects of 8 trials included were Caucasians, and the research subjects for the remaining trials were Asians; 13 trials were double-arm trials and 2 trials were three-arm trials. The baseline characteristics of the included literatures are shown in Supplementary Table 1 and the NOS assessment is shown in Figure 1. A total of 1,741 patients with DIACFs were included, with the majority of patients being treated with the traditional ORIF surgical treatment (Figure 2).

Figure 1. Quality assessment of the 15 included studies with the Newcastle-Ottawa Scale (NOS).

Figure 2. Evidence network plots of eight surgery treatments for DIACFs in terms of operating time (a), hospitalization (b), full weight bearing time (c), \( \triangle \) bohler’s angle (d), AOFAS score (e), SF-36(PCS) (f), SF-36 (MCS) (g), VAS (h) and complication (i) (AOFAS = American Orthopaedic Foot and Ankle Society hindfoot scale; ORIF = open reduction and internal fixation; SF-36 (PCS) = Short Form 36 (physical component score); SF-36 (MCS) = Short Form 36 (mental component score)).

3.2. Traditional ORIF and Percutaneous Surgery have Better Effects for DIACFs

As for the intraoperative and postoperative clinical index, drawing comparison with the traditional ORIF, the operating time and hospitalization of percutaneous surgery was relatively shorter; the operating time and hospitalization of sinus tarsi approach and internal fixation were also relatively shorter and the change of bohler’s angle was relatively smaller, while the hospitalization of traditional ORIF + grafting was relatively longer and the full weight bearing time was relatively shorter (Table 1). As for the functional score, compared with conservative treatment, SF-36 (PCS), SF-
36(MCS) and VAS of traditional ORIF and AOFAS score, SF-36 (PCS), SF-36 (MCS) and VAS of percutaneous surgery were relatively higher, which demonstrated that traditional ORIF and percutaneous surgery have better effects; as for complications, the complication rate of traditional ORIF was higher than the conservative treatment (Table 2).

Table 1. Weighted mean difference and 95% CI of pairwise meta-analysis in terms of operating time, hospitalization, full weight bearing time and △bohler's angle.

| Studies | Comparison | Pairwise meta-analysis | $P^2$ | $P_h$ |
|---------|------------|------------------------|-------|-------|
| Operating time(min) |         |                        |       |       |
| 4 studies | A vs C | 30.80 (10.16 – 51.44) | 81.8% | 0.0009 |
| 3 studies | A vs D | 19.98 (8.16 – 31.80) | 57.3% | 0.0963 |
|         | C vs D | −8.63 (−36.04 – 18.78) | 71.1% | 0.0628 |
| Hospitalization(days) |         |                        |       |       |
| 1 study | A vs C | 9.00 (6.28 – 11.72) | NR | NR |
| 1 study | A vs D | 8.00 (4.86 – 11.14) | NR | NR |
| 1 study | A vs F | 1.18 (2.17 – 0.19) | NR | NR |
| Full weight bearing time(weeks) |         |                        |       |       |
| 1 study | A vs C | 1.15 (−0.34 – 2.64) | NR | NR |
| 1 study | A vs F | 14.40 (13.13 – 15.67) | NR | NR |
| 1 study | A vs G | −6.69 (−7.64 – 5.74) | NR | NR |
| △Bohler’s angle (°) |         |                        |       |       |
| 1 study | A vs C | −6.90 (−13.80 – 0.00) | NR | NR |
| 2 studies | A vs D | 3.66 (0.47 – 6.85) | 0% | 0.3733 |
| 1 study | A vs F | 0.90 (−5.79 – 7.59) | NR | NR |
| 1 study | A vs H | −1.00 (−3.44 – 1.44) | NR | NR |

Notes: 95% CI = 95% confidence intervals; WMD = Weighted mean difference; NR = not report; A = traditional ORIF (open reduction and internal fixation); B = conservative treatment; C = percutaneous surgery; D = sinus tarsi approach and internal fixation; E = traditional ORIF + primary subtalar arthrodesis; F = traditional ORIF + grafting; G = traditional ORIF + conservative treatment; H = percutaneous surgery + grafting.

Table 2. Weighted mean difference or odds ratio and 95% CI of pairwise meta-analysis in terms of functional score (AOFAS score, SF36-PCS, SF36-MCS, VAS) and complications.

| Studies | Comparison | Pairwise meta-analysis | $P^2$ | $P_h$ |
|---------|------------|------------------------|-------|-------|
| AOFAS score |         |                        |       |       |
| 2 studies | A vs B | 9.06 (−3.27 – 21.39) | 91.5% | 0.0006 |
| 3 studies | A vs C | −1.13 (−6.72 – 4.47) | 90.5% | <0.0001 |
| 3 studies | A vs D | −3.96 (−4.78 – 3.14) | 0% | 0.5424 |
| 1 study | B vs C | −20.00 (−22.96 – 17.04) | NR | NR |
| 1 study | A vs E | −3.30 (−17.01 – 10.41) | NR | NR |
| 1 study | A vs F | 5.20 (−4.19 – 6.21) | NR | NR |
| SF36-PCS |         |                        |       |       |
| 2 studies | A vs B | 10.61 (3.48 – 17.75) | 88.2% | 0.0036 |
| 3 studies | A vs C | 2.27 (1.36 – 3.19) | 61.3% | 0.0753 |
| 1 study | B vs C | −12.00 (−14.16 – 9.84) | NR | NR |
| 1 study | A vs E | −7.60 (−15.28 – 0.08) | NR | NR |
| SF36-MCS |         |                        |       |       |
| 2 studies | A vs B | 3.70 (2.53 – 4.86) | 70.4% | 0.0662 |
| 3 studies | A vs C | 0.05 (−1.31 – 1.41) | 60.15% | 0.0814 |
| 1 study | B vs C | −3.00 (−4.41 – 1.59) | NR | NR |
| VAS |         |                        |       |       |
| 1 study | A vs B | 1.70 (1.22 – 2.18) | NR | NR |
| 2 studies | A vs C | −0.01 (−0.99 – 0.97) | 95.5% | <0.0001 |
| 1 study | A vs D | 0.00 (−0.19 – 0.19) | NR | NR |
| 1 study | B vs C | −2.20 (−2.66 – 1.74) | NR | NR |
| Complications |         |                        |       |       |
| 3 studies | A vs B | 2.45 (1.64 – 3.66) | 42.0% | 0.1784 |
| 1 study | A vs C | 0.68 (0.24 – 1.95) | NR | NR |
| 3 studies | A vs D | 1.78 (0.83 – 3.81) | 0% | 0.9203 |
| 1 study | B vs C | 0.39 (0.10 – 1.43) | NR | NR |

Notes: 95% CI = 95% confidence intervals; WMD = Weighted mean difference; OR = odds ratio; NR = not report; AOFAS = American Orthopaedic Foot and Ankle Society hindfoot scale; SF-36 (PCS) = Short Form 36 (physical component score); SF-36 (MCS) = Short Form 36 (mental component score); VAS = 0–10 Visual Analogue Scale; A = traditional ORIF (open reduction and internal fixation); B = conservative treatment; C = percutaneous surgery; D = sinus tarsi approach and internal fixation; E = traditional ORIF + primary subtalar arthrodesis; F = traditional ORIF + grafting; G = traditional ORIF + conservative treatment; H = percutaneous surgery + grafting.
3.3. A Consistency Model was Adopted with Respect to Operating Time, SF-36 (PCS) and SF-36 (MCS) Among all Included Studies

We employed the node-splitting method in order to perform an inconsistency test for the operating time, SF-36 (PCS), and SF-36 (MCS), and the results determined that the direct evidence was inconsistent with the indirect evidence, thus a consistency model was adopted (all \( P > 0.05 \)) (Figure 3).

![Figure 4](Image)

**Figure 4**. The node-splitting plots of (a), operating time, (b), SF-36 (PCS) and (c), SF-36 (MCS) of eight surgery treatments for DIACFs (SF-36 (PCS) = Short Form 36 (physical component score); SF-36 (MCS) = Short Form 36 (mental component score); B = conservative treatment; C = percutaneous surgery; D = sinus tarsi approach and internal fixation).

3.4. The Main Results of Network Meta-Analysis for Eight Surgical Treatments for DIACFs

This meta-analysis provided evidence that, as for the intraoperative and postoperative clinical index, in comparison with the traditional ORIF surgical treatment, the operating time of the percutaneous surgery was relatively short (WMD = -21.02, 95%CI = -14.62, 38.06) for DIACFs (Table 3 and Figure 4). As for the hospitalization, full weight bearing time, and \( \Delta \) Bohler’s angle, there were no significant differences discovered in the effects of the eight surgical treatments involved in DIACFs (Table 3 and Figure 4). For the functional score, in comparison with conservative treatment, AOFAS score of percutaneous surgery was relatively higher (WMD = 12.02, 95%CI = 11.07, 14.76) for DIACFs (Table 3 and Figure 4).

**Table 3**. Weighted mean difference and 95% confidence intervals in terms of operating time, hospitalization, full weight bearing time, back to work duration and \( \Delta \) Bohler’s angle.

| Operating time (min) | Study | P-value | Mean Difference (95% CI) | \( \Delta \) Bohler’s angle (°) | Study | P-value | Mean Difference (95% CI) |
|----------------------|-------|---------|--------------------------|--------------------------------|-------|---------|--------------------------|
| A                    | 29.17 (5.83, 1.58) | -29.17 (−51.84, −5.83) | -21.02 (−46.83, 3.84) | A | 7.00 (3.13, 17.29) | 3.68 (−2.55, 10.04) | 0.58 (−9.29, 10.95) | -1.11 (−9.10, 7.21) | -2.94 (−14.62, 9.51) | 1.58 (−11.07, 14.76) |
| B                    | 29.17 (5.83, 1.58) | -29.17 (−51.84, −5.83) | -21.02 (−46.83, 3.84) | A | 7.00 (3.13, 17.29) | 3.68 (−2.55, 10.04) | 0.58 (−9.29, 10.95) | -1.11 (−9.10, 7.21) | -2.94 (−14.62, 9.51) | 1.58 (−11.07, 14.76) |
| C                    | 29.17 (5.83, 1.58) | -29.17 (−51.84, −5.83) | -21.02 (−46.83, 3.84) | A | 7.00 (3.13, 17.29) | 3.68 (−2.55, 10.04) | 0.58 (−9.29, 10.95) | -1.11 (−9.10, 7.21) | -2.94 (−14.62, 9.51) | 1.58 (−11.07, 14.76) |
| D                    | 29.17 (5.83, 1.58) | -29.17 (−51.84, −5.83) | -21.02 (−46.83, 3.84) | A | 7.00 (3.13, 17.29) | 3.68 (−2.55, 10.04) | 0.58 (−9.29, 10.95) | -1.11 (−9.10, 7.21) | -2.94 (−14.62, 9.51) | 1.58 (−11.07, 14.76) |
| E                    | 29.17 (5.83, 1.58) | -29.17 (−51.84, −5.83) | -21.02 (−46.83, 3.84) | A | 7.00 (3.13, 17.29) | 3.68 (−2.55, 10.04) | 0.58 (−9.29, 10.95) | -1.11 (−9.10, 7.21) | -2.94 (−14.62, 9.51) | 1.58 (−11.07, 14.76) |
| F                    | 29.17 (5.83, 1.58) | -29.17 (−51.84, −5.83) | -21.02 (−46.83, 3.84) | A | 7.00 (3.13, 17.29) | 3.68 (−2.55, 10.04) | 0.58 (−9.29, 10.95) | -1.11 (−9.10, 7.21) | -2.94 (−14.62, 9.51) | 1.58 (−11.07, 14.76) |
| G                    | 29.17 (5.83, 1.58) | -29.17 (−51.84, −5.83) | -21.02 (−46.83, 3.84) | A | 7.00 (3.13, 17.29) | 3.68 (−2.55, 10.04) | 0.58 (−9.29, 10.95) | -1.11 (−9.10, 7.21) | -2.94 (−14.62, 9.51) | 1.58 (−11.07, 14.76) |
Notes: WMD = weighted mean difference; 95%CI = confidence intervals; A = traditional ORIF (open reduction and internal fixation); C = percutaneous surgery; D = sinus tarsi approach and internal fixation; E = traditional ORIF + primary subtalar arthrodesis; F = traditional ORIF + grafting; G = traditional ORIF + conservative treatment; H = percutaneous surgery + grafting.

Figure 4. Forest plots of relative relationship of (a) operating time, (b) AOFAS score, (c) SF-36(PCS) and (d) complications of eight surgery treatments for DIACFs (AOFAS = American Orthopaedic Foot and Ankle Society hindfoot scale; SF-36 (PCS) = Short Form 36 (physical component score); A = traditional ORIF (open reduction and internal fixation); B = conservative treatment; C = percutaneous surgery; D = sinus tarsi approach and internal fixation; E = traditional ORIF + primary subtalar arthrodesis; F = traditional ORIF + grafting).
Table 4. Weighted mean difference or odds ratio and 95% confidence intervals in terms functional scores (AOFAS, SF36-PCS, SF36-MCS, VAS) and complications.

|                  | AOFAS score | SF-36(PCS) | SF-36(MCS) | VAS |
|------------------|-------------|------------|------------|-----|
|                  | WMD/ OR (95% CI) |
|                  | A           | 11.13 (−0.45, 21.87) | 14.47 (−0.87, 29.22) | 14.70 (−12.66, 45.12) | 5.60 (−10.65, 20.90) |
|                  | B           | 13.41 (0.60, 25.79) | 14.60 (−8.88, 37.11) | 1.17 (−20.88, 22.63) | −7.52 (−25.95, 10.93) |
|                  | C           | −13.41 (−25.79, 0.60) | 1.05 (−12.66, 14.52) | 1.17 (−20.88, 22.63) | −7.52 (−25.95, 10.93) |
|                  | D           | −3.29 (−13.54, 6.52) | −1.05 (−14.52, 12.66) | D | 0.25 (−22.70, 22.33) |
|                  | E           | −3.62 (−23.53, 17.22) | −1.17 (−22.63, 20.88) | −0.25 (−22.33, 22.70) | E | −8.81 (−34.41, 17.75) |
|                  | F           | 5.25 (<10.65, 20.90) | 7.52 (−10.93, 25.95) | 8.54 (−10.79, 27.94) | 8.81 (−17.75, 34.41) |
|                  | A           | −11.47 (−18.97, 3.07) | −2.10 (−8.91, 4.71) | 7.74 (−5.66, 21.11) | |
|                  | B           | 11.47 (3.07, 18.97) | 9.38 (−0.27, 18.20) | 19.11 (3.09, 34.27) | |
|                  | C           | −7.47 (−21.11, 5.66) | −9.88 (−24.75, 5.26) | E | |
|                  | SF-36(MCS)  | A           | −2.75 (−5.67, 0.84) | 0.13 (−2.08, 2.79) | |
|                  | B           | −0.13 (<−2.79, 2.08) | 2.94 (−0.89, 6.25) | |
|                  | C           | −1.96 (−4.51, 0.57) | 0.03 (−1.90, 1.91) | 0.00 (−2.67, 2.64) | |
|                  | 1.98 (−0.66, 4.56) | 1.96 (−1.66, 5.57) | 1.02 (−3.33, 3.32) | D | |
|                  | 0.35 (0.11, 0.93) | 1.25 (0.20, 6.23) | 0.56 (0.16, 1.93) | 0.56 (0.16, 1.93) | 0.56 (0.16, 1.93) | 0.56 (0.16, 1.93) | |
|                  | 0.28 (0.05, 1.50) | 0.28 (0.05, 1.50) | 0.44 (0.06, 3.96) | 0.44 (0.06, 3.96) | 0.44 (0.06, 3.96) | 0.44 (0.06, 3.96) | 0.44 (0.06, 3.96) | |
|                  | 1.80 (0.52, 6.15) | 0.65 (0.11, 2.88) | 2.28 (0.25, 16.21) | D | |

Notes: WMD = weighted mean difference; OR = odds ratio; AOFAS = American Orthopaedic Foot and Ankle Society hindfoot scale; SF36(PCS) = Short Form 36(physical component score); SF-36(MCS) = Short Form 36(mental component score); VAS = 0–10 Visual Analogue Scale; A = traditional ORIF (open reduction and internal fixation); B = sinus tarsi approach and internal fixation; C = percutaneous surgery; D = traditional ORIF + grafting; G = traditional ORIF + conservative treatment; H = traditional ORIF + primary subtalar arthrodesis; F = percutaneous surgery + grafting.

3.5. Percutaneous Surgery had Better Effects in the Treatment for DIACFs with Lower Complications Rate based on SUCRA Value Results

As shown in Table 5, the SUCRA value for the effects of the eight surgical treatments for DIACFs revealed that as for the operating time, hospitalization, △bohler’s angle, SF-36 (MCS), and VAS, the percutaneous surgery method ranked the highest in terms of the criteria (operating time: 91.00%; hospitalization: 85.75%; △bohler’s angle: 92.20%; SF-36 (MCS): 83.33%; VAS: 74.00%). As for complications, percutaneous surgery ranked the lowest (40.75). Therefore, checking out as effective in both areas, percutaneous surgery had better effects in the treatment for DIACFs with lower complications rate.

3.6. Cluster Analysis of the SUCRA Values of Effects of Eight Surgical Treatments for DIACFs

The results of cluster analysis demonstrated that, as for the operating time for both hospitalization and △bohler’s angle, the effect of percutaneous surgery was relatively better than that of traditional ORIF, while for AOFAS score, SF-36 (PCS), SF-36 (MCS), and VAS the effect of the traditional ORIF and percutaneous surgery were relatively better (Figure 5).
Table 5. SUCRA values of eight treatment modalities under nine endpoint outcomes.

| Treatments | Operating time (%) | Hospitalization (%) | Full weight bearing time (%) | △Bohler's angle (%) | AOFAS score (%) | SF-36(PCS) | SF-36(MCS) | VAS (%) | Complications |
|------------|---------------------|---------------------|-----------------------------|---------------------|----------------|-----------|-----------|---------|---------------|
| A          | 35.00               | 44.00               | 56.75                       | 57.20               | 60.50          | 72.50     | 79.67     | 73.25   | 44.75         |
| B          | NR                  | NR                  | NR                          | NR                  | 23.33          | 26.25     | 37.00     | 30.25   | 91.75         |
| C          | 91.00               | 85.75               | 63.50                       | 92.20               | 73.50          | 56.00     | 83.33     | 74.00   | 40.75         |
| D          | 73.67               | 81.5                | 31.20                       | 77.83               | NR             | NR        | NR        | NR      | NR            |
| E          | NR                  | NR                  | NR                          | NR                  | 72.33          | 95.00     | NR        | NR      | NR            |
| F          | NR                  | 38.25               | 95.25                       | NR                  | NR             | NR        | NR        | NR      | NR            |
| G          | NR                  | NR                  | 34.50                       | NR                  | NR             | NR        | NR        | NR      | NR            |
| H          | NR                  | NR                  | 56.75                       | 66.00               | NR             | NR        | NR        | NR      | NR            |

Notes: SUCRA = surface under the cumulative ranking curves; NR = not report; AOFAS = American Orthopaedic Foot and Ankle Society Hindfoot Scale; SF-36(PCS) = Short Form 36(physical component score); SF-36(MCS) = Short Form 36(mental component score); VAS = 0–10 Visual Analogue Scale; A = traditional ORIF(open reduction and internal fixation); B = conservative treatment; C = percutaneous surgery; D = sinus tarsi approach and internal fixation; E = traditional ORIF + primary subtalar arthrodesis; F = traditional ORIF + grafting; G = traditional ORIF + conservative treatment; H = percutaneous surgery + grafting.

Figure 5. Cluster analysis of (a), eight surgery treatments for DIACFs (AOFAS = American Orthopaedic Foot and Ankle Society hindfoot scale; (b), functional score. SF-36 (PCS) = Short Form 36 (physical component score); SF-36 (MCS) = Short Form 36 (mental component score); VAS = 0–10 Visual Analogue Scale; A = traditional ORIF (open reduction and internal fixation); B = conservative treatment; C = percutaneous surgery; D = sinus tarsi approach and internal fixation.)

4. Discussion

In this study, we have explored the various effects of the eight surgery treatments for DIACFs by implementation of both pairwise and network meta-analysis. We retrieved 1777 related literatures in total, and finally 15 eligible RCTs were incorporated in this network meta-analysis. The results indicated that ORIF and percutaneous surgery were the most common surgical procedures involved for the treatment for DIACFs [13]. Our results showed that, as for operating time between hospitalization and △Bohler’s angle, the effects of percutaneous surgery were better than traditional ORIF; while AOFAS score, SF-36 (PCS), SF-36 (MCS), and VAS the effects of traditional ORIF and percutaneous surgery were relatively better. Bohler’s angle was also a useful screening tool for fracture diagnosis [40], as well as a new scoring system using VAS in order to determine the functional outcome in patients with DIACFs [19]. A 36-item short-form (SF-36) was constructed in order to evaluate health status in the Medical Outcomes Study [17]. Bohler’s angle was indicative
of elevated restoration as well as returning the patients their full weight-bearing ability earlier when bone grafting was performed in the treatment of intra-articular calcaneal fracture [36]; preoperative templating of the uninjured contralateral calcaneus did not allow for more anatomic reduction or restoration of pre-injury morphology of the calcaneus having undergone operative fixation based on Bohler's angle and calcaneal length [32]. Evidence indicated that patients with an operative treatment (ORIF and percutaneous treatment) reported with better functional outcome scores (Foot Function Index and American Orthopaedic Foot and Ankle Society Hindfoot scale) than those among non-operative treated patients [33]. ORIF combined with that of the conservative treatment in the treatment of calcaneal fractures can clear anatomic structure as well as have fast function recovery, for this very reason it should be the preferred method for the treatment of calcaneal fractures [10]. Reasonably early results could be attained from the percutaneous treatment of intra-articular calcaneal fractures using screws alone based on articular reduction and level of residual pain [41]. Using the percutaneous reduction and cannulated screw fixation to treat the comminuted calcaneal fractures may carry a risk of inadequate reduction of the articular surface [42]. In comparison with ORIF, the percutaneous reduction, fixation, and calcium sulphate cement (CSC) grafting in the treatment for DIACFs might allow for the acceleration in weight bearing activity, decrease in joint stiffness, and elevate the patients' satisfaction [12].

The cumulative probability ranking of the effects of the eight surgery treatments for DIACFs showed that, as for operating time, hospitalization, △Bohler's angle, SF-36 (MCS), and VAS, percutaneous surgery had the highest SUCRA values, but as for complications, the complication rate of percutaneous surgery was the lowest, which indicated that percutaneous surgery had better effects in the treatment for DIACFs with relatively lower complications. Complications occur regardless of the management strategy chosen for DIACFs and the management by experienced surgeons; it is a cause of significant morbidity in patients [39]. In most DIACFs, surgical treatment is the method of choice, and in non-surgical treatment, the prevalence of these complications among the patients is higher. As a result of the aforementioned complications, inevitable social, occupational, and familial damages occur [43]. Percutaneous surgery ranked the lowest in terms of SUCRA values (40.75%); therefore, percutaneous surgery had a higher effect in the treatment for DIACFs. Although ORIF of a calcaneal fracture was followed by a high complication rate, complications do not affect mid- to long-term clinical outcome [44]. High-risk DIACFs patients that meet the criteria for surgical management can be treated with percutaneous surgical techniques with a low risk of wound complications [45].

In conclusion, this network meta-analysis revealed that the effect of percutaneous surgery for DIACFs was relatively higher, followed by traditional ORIF. Our meta-analysis compared the effects between eight surgical treatments (traditional ORIF, conservative treatment, percutaneous surgery, sinus tarsi approach and internal fixation, traditional ORIF + primary subtalar arthrodesis, traditional ORIF + grafting, and traditional ORIF + conservative treatment, percutaneous surgery + grafting) in the treatment for DIACFs, which will play a great role in the clinical significance for physicians in the treatment for DIACFs. However, some limitations of this meta-analysis deserve comment: the intervention measures of numbers of direct comparison were different, potentially having a certain impact on the result of this study. Traditional ORIF, conservative treatment, percutaneous surgery, and sinus tarsi approach and internal fixation were the main surgical treatments regarding DIACFs, whereas, the study only included a few literatures and sample size, and due to this uncertainty, might have certain impacts on the result of the study. We hope this study will be helpful for the treatment for DIACFs, and more new targets and synthesis are discovered in the near future.

Supplementary Materials: This section must be cited in the main text. The following are available online at http://mbn.techlandgroup.com.

Funding: None.

Conflicts of Interest: The author declares no conflict of interest.

Copyright Statement

©2021 the authors. This article is an open access article licensed under the terms and conditions of the CREATIVE COMMONS ATTRIBUTION (CC BY) LICENSE (http://creativecommons.org/licenses/by/4.0/).

References

1. Liu Y, Li Z, Li H, Zhang Y, Wang P. Protective Effect of Surgery Against Early Subtalar Arthrodesis in Displaced Intra-articular Calcaneal Fractures: A Meta-Analysis. Medicine (Baltimore), 2015, 94: e1984–1980.
2. Rak V, Ira D, Masek M. Operative treatment of intra-articular calcaneal fractures with calcaneal plates and its complications. Indian Journal of Orthopaedics, 2009, 43: 271–280.
3. Potter MQ, Nunley JA. Long-term functional outcomes after operative treatment for intra-articular fractures of the calcaneus. The Journal of Bone and Joint Surgery, 2009, 91: 1854–1860.
4. Mitchell MJ, McKinley JC, Robinson CM. The epidemiology of calcaneal fractures. The Foot, 2009, 19: 197–200.
5. Al-Ashhab ME. "ORIF" for displaced intra-articular calcaneal fractures in children. The Foot, 2015, 25: 84–88.
6. Abdelgawad AA, Kanlic E. Minimally invasive (sinus tarsi) approach for open reduction and internal fixation of intra-articular calcaneal fractures: A systematic review. Mol Biol Nanomedicine, 2021, 2(1), 17.
calcaneal fractures in children: surgical technique and case report of two patients. *The Journal of Foot and Ankle Surgery*, 2015, 54: 135–139.

7. Brauer CA, Manns BJ, Ko M, Donaldson C, Buckley R. An economic evaluation of operative compared with nonoperative management of displaced intra-articular calcaneal fractures. *The Journal of Bone and Joint Surgery*, 2005, 87: 2741–2749.

8. Zwipp H, Rammelt S, Barthel S. [Fracture of the calcaneus]. *Unfallchirurg*, 2005, 108: 737–747; quiz 748.

9. Tomesen T, Biert J, Frolik JP. Treatment of displaced intra-articular calcaneal fractures with closed reduction and percutaneous screw fixation. *The Journal of Bone and Joint Surgery*, 2011, 93: 920–928.

10. Pan Y, Yuan L, Ye C. Comparison of open reduction internal fixation and conservative treatment plus open reduction internal fixation for calcaneal fractures. *International Journal of Clinical and Experimental Medicine*, 2014, 7: 4479–4482.

11. Bakker B, Halm JA, Van Lieshout EM, Schepers T. The fate of Bohler's angle in conservatively-treated displaced intra-articular calcaneal fractures. *International Orthopaedics*, 2012, 36: 2495–2499.

12. Chen L, Zhang G, Hong J, Lu X, Yuan W. Comparison of percutaneous screw fixation and calcium sulfate cement grafting versus open treatment of displaced intra-articular calcaneal fractures. *Foot & Ankle International*, 2011, 32: 979–985.

13. Biz C, Barison E, Ruggieri P, Iacobellis C. Radiographic and functional outcomes after displaced intra-articular calcaneal fractures: a comparative cohort study among the traditional open technique (ORIF) and percutaneous surgical procedures (PS). *Journal of Orthopaedic Surgery and Research*, 2016, 11: 92.

14. Sanders R, Gregory P. Operative treatment of intra-articular fractures of the calcaneus. *Orthopedic Clinics of North America*, 1995, 26: 203–214.

15. Simon P, Goldzak M, Eschler A, Mittelmeier T. Reduction and internal fixation of displaced intra-articular calcaneal fractures with a locking nail: a prospective study of sixty nine cases. *International Orthopaedics*, 2015, 39: 2061–2067.

16. Kitaoka HB, Alexander IJ, Adelaar RS, Nunley JA, Myerson MS, et al. Clinical rating systems for the ankle-hindfoot, midfoot, hallux, and lesser toes. *Foot & Ankle International*, 1994, 15: 349–353.

17. Ware JE, Jr., Sherbourne CD. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. *Medical Care*, 1992, 30: 473–483.

18. Aaronson NK, Muller M, Cohen PD, Essink-Bot ML, Fekkes M, et al. Translation, validation, and norming of the Dutch language version of the SF-36 Health Survey in community and chronic disease populations. *Journal of Clinical Epidemiology*, 1998, 51: 1055–1068.

19. Hildebrand KA, Buckelew RE, Mohtadi NG, Faris P. Functional outcome measures after displaced intra-articular calcaneal fractures. *The Journal of Bone and Joint Surgery. British volume*, 1996, 78: 119–123.

20. Lo CK, Mertz D, Loeb M. Newcastle-Ottawa Scale: comparing reviewers' to authors' assessments. *BMC Medical Research Methodology*, 2014, 14: 45.

21. Minami S, Kijima T, Shiroyama T, Okafuji K, Hirashima T, et al. Randomized Phase II trial of paclitaxel and carboplatin followed by gemcitabine switch-maintenance therapy versus gemcitabine and carboplatin followed by gemcitabine continuation-maintenance therapy in previously untreated advanced non-small cell lung cancer. *BMC Research Notes*, 2013, 6: 3.

22. Lu G, Ades AE. Combination of direct and indirect evidence in mixed treatment comparisons. *Statistics in Medicine*, 2004, 23: 3105-3124.

23. Dias S, Sutton AJ, Ades AE, Welton NJ. Evidence synthesis for decision making 2: a generalized linear modeling framework for pairwise and network meta-analysis of randomized controlled trials. *Medical Decision Making*, 2013, 33: 607–617.

24. Dias S, Welton NJ, Caldwell DM, Ades AE. Checking consistency in mixed treatment comparison meta-analysis. *Statistics in Medicine*, 2010, 29: 932–944.

25. Zhu GQ, Shi KQ, Huang S, Wang LR, Lin YQ, et al. Systematic review with network meta-analysis: the comparative effectiveness and safety of interventions in patients with overt hepatic encephalopathy. *Alimentary Pharmacology & Therapeutics*, 2015, 41: 624–635.

26. Chaimani A, Higgins JP, Mavridis D, Spyridonos P, Salanti G. Graphical tools for network meta-analysis in STATA. *PLoS One*, 2013, 8: e76654.

27. Salanti G, Ades AE, Ioannidis JP. Graphical methods and numerical summaries for presenting results from multiple-treatment meta-analysis: an overview and tutorial for *Journal of Clinical Epidemiology*. 2011, 64: 163–171.

28. Guo Q, Lu T, Lin S, Zong J, Chen Z, et al. Long-term survival of nasopharyngeal carcinoma patients with Stage II in intensity-modulated radiation therapy era. *Japanese Journal of Clinical Oncology*, 2016, 46: 241–247.

29. Yeap EJ, Rao J, Pan CH, Soelar SA, Younger ASE. Is arthroscopic assisted percutaneous screw fixation as good as open reduction and internal fixation for the treatment of displaced intra-articular calcaneal fractures? *Foot and Ankle Surgery*, 2016, 22: 164–169.

30. Basile A, Albo F, Via AG. Comparison Between Sinus Tarsi Approach and Extensile Lateral Approach for Treatment of Closed Displaced Intra-Articular Calcaneal Fractures: A Multicenter Prospective Study. *The Journal of Foot & Ankle Surgery*, 2016, 55: 513–521.

31. Yeo JH, Cho HJ, Lee KB. Comparison of two surgical approaches for displaced intra-articular calcaneal fractures: sinus tarsi versus extensile lateral approach. *BMCMusculoskeletal Disorders*, 2015, 16: 63.

32. Kwon JY, Zurakowski D, Ellington JK. Influence of contralateral radiographs on accuracy of anatomic reduction in surgically treated calcaneal fractures. *Foot & Ankle International*, 2015, 36: 75–82.

33. De Boer AS, Van Lieshout EM, Den Hartog D, Weerts B, Verhofstad MH, et al. Functional outcome and patient satisfaction after
displaced intra-articular calcaneal fractures: a comparison among open, percutaneous, and nonoperative treatment. *The Journal of Foot & Ankle Surgery*, 2015, 54: 298–305.

34. Griffin D, Parsons N, Shaw E, Kulikov Y, Hutchinson C, et al. Operative versus non-operative treatment for closed, displaced, intra-articular fractures of the calcaneus: randomised controlled trial. *The BMJ*, 2014, 349: g4483.

35. Buckley R, Leighton R, Sanders D, Poon J, Coles CP, et al. Open reduction and internal fixation compared with ORIF and primary subtalar arthrodesis for treatment of Sanders type IV calcaneal fractures: a randomized multicenter trial. *Journal of Orthopaedic Trauma*, 2014, 28: 577–583.

36. Singh AK, Vinay K. Surgical treatment of displaced intra-articular calcaneal fractures: is bone grafting necessary? *Journal of Orthopaedic Trauma*, 2013, 14: 299–305.

37. Johal HS, Buckley RE, Le IL, Leighton RK. A prospective randomized controlled trial of a bioresorbable calcium phosphate paste (alpha-BSM) in treatment of displaced intra-articular calcaneal fractures. *The Journal of Trauma*, 2009, 67: 875–882.

38. Lee KB, Chung JY, Song EK, Seon JK, Bai LB. Arthroscopic release for painful subtalar stiffness after intra-articular fractures of the calcaneum. *The Journal of Bone and Joint Surgery. British volume*, 2008, 90: 1457–1461.

39. Howard JL, Buckley R, McCormack R, Pate G, Leighton R, et al. Complications following management of displaced intra-articular calcaneal fractures: a prospective randomized trial comparing open reduction internal fixation with nonoperative management. *Journal of Orthopaedic Trauma*, 2003, 17: 241–249.

40. Isaacs JD, Baba M, Huang P, Symes M, Guzman M, et al. The diagnostic accuracy of Bohler’s angle in fractures of the calcaneus. *Journal of Emergency Medicine*, 2013, 45: 879–884.

41. Tantavisut S, Phisitkul P, Westerlind BO, Gao Y, Karam MD, et al. Percutaneous Reduction and Screw Fixation of Displaced Intra-articular Fractures of the Calcaneus. *Foot & Ankle International*, 2017, 38: 367–374.

42. Feng Y, Shui X, Wang J, Cai L, Yu Y, et al. Comparison of percutaneous cannulated screw fixation and calcium sulfate cement grafting versus minimally invasive sinus tarsi approach and plate fixation for displaced intra-articular calcaneal fractures: a prospective randomized controlled trial. *BMC Musculoskeletal Disorders*, 2016, 17: 288.

43. Bahari Kashani M, Kachooei AR, Ebrahimi H, Peivandi MT, Amelfarzad S, et al. Comparative study of peroneal tenosynovitis as the complication of intraarticular calcaneal fracture in surgically and non-surgically treated patients. *Iranian Red Crescent Medical Journal*, 2013, 15: e11378.

44. De Groot R, Frima AJ, Schepers T, Roerdink WH. Complications following the extended lateral approach for calcaneal fractures do not influence mid- to long-term outcome. *Injury*, 2013, 44: 1596–1600.

45. Hammond AW, Crist BD. Percutaneous treatment of high-risk patients with intra-articular calcaneal fractures: a case series. *Injury*, 2013, 44: 1483–1485.