

## Review

# Orthogonal plating method versus parallel plating method in the treatment of distal humerus fracture: A systematic review and meta-analysis

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## ABSTRACT

**Purpose:** This systematic review and meta-analysis was performed to investigate the outcomes of orthogonal plating method and parallel plating method in the treatment of distal humerus fracture from the current literatures.

**Methods:** The electronic literature database of Pubmed, Embase, and Cochrane library were searched in November 2018. The data operation time, union time, Mayo Elbow Performance Score (MEPS), range of motion (ROM) of elbow, arc of elbow flexion, arc of elbow extension, rate of excellent and good results and complications (including heterotopic ossification, transient ulnar nerve neuropathy and ankylosis) were extracted. Stata 14.0 software was used for our meta-analysis.

**Results:** A total of 8 studies including 6 RCTs and 2 cohort studies met our inclusion criteria. This meta-analysis showed that there was no significant difference between the two groups regarding operation time, MEPS, ROM of elbow, arc of elbow flexion, arc of elbow extension and rate of excellent and good results at final follow-up ( $P = 0.50$ ,  $P = 0.39$ ,  $P = 0.87$ ,  $P = 0.18$ ,  $P = 0.58$  and  $P = 0.59$  respectively). However, the present meta-analysis demonstrated that parallel plating method had significantly shorter union time than orthogonal plating method ( $P = 0.018$ ). As for the complications (heterotopic ossification, transient ulnar nerve neuropathy and ankylosis), there was no significant difference between the two groups ( $P = 0.89$ ,  $P = 0.08$  and  $P = 0.29$  respectively).

**Conclusion:** Our meta-analysis suggested that both orthogonal plating and parallel plating method could achieve satisfactory outcomes with the similarly low complications in the treatment of distal humerus fracture. More RCTs are required for further research.

## 1. Introduction

Distal humeral fractures account for 2%–6% of all fractures and for approximately 30% of all elbow fractures [1]. In young patients, distal humeral fractures are commonly caused by high velocity injuries, such as sports injuries or road traffic accidents. In contrast, distal humeral fractures in elderly people are predominantly low velocity injuries complicated by poor bone quality [2]. Anatomical restitution of the complex geometry of the distal humerus allowing early mobilization is the goal of distal humerus fracture treatment [3–5]. Although this goal is necessary for regaining a functional range of elbow motion, stable fracture fixation may be technically difficult, especially in the presence of substantial osteoporosis or comminution. Because the distal humerus offers the unique shapes of articular surfaces, limited space for

instrumentation, and lies close enough to neurovascular structures, this may present substantial difficulties during surgery. Furthermore, the elbow joint is intolerant of immobilization, and the rigid fixation of displaced fragments to allow early rehabilitation and successful outcomes is emphasized for distal humerus fractures.

Open reduction and internal fixation using plates have demonstrated satisfactory clinical outcomes for the treatment of distal humerus fractures, and various ways of plating methods have been described to achieve firm stabilization [6,7]. Among them, several mechanical studies have proved that double plate fixation provides more stable fixation than other methods [8,9]. However, controversy still exists concerning plate positions in terms of providing optimal stability for distal humerus fractures. The most widely used dual plate fixation method involves placing plates perpendicular to each other,

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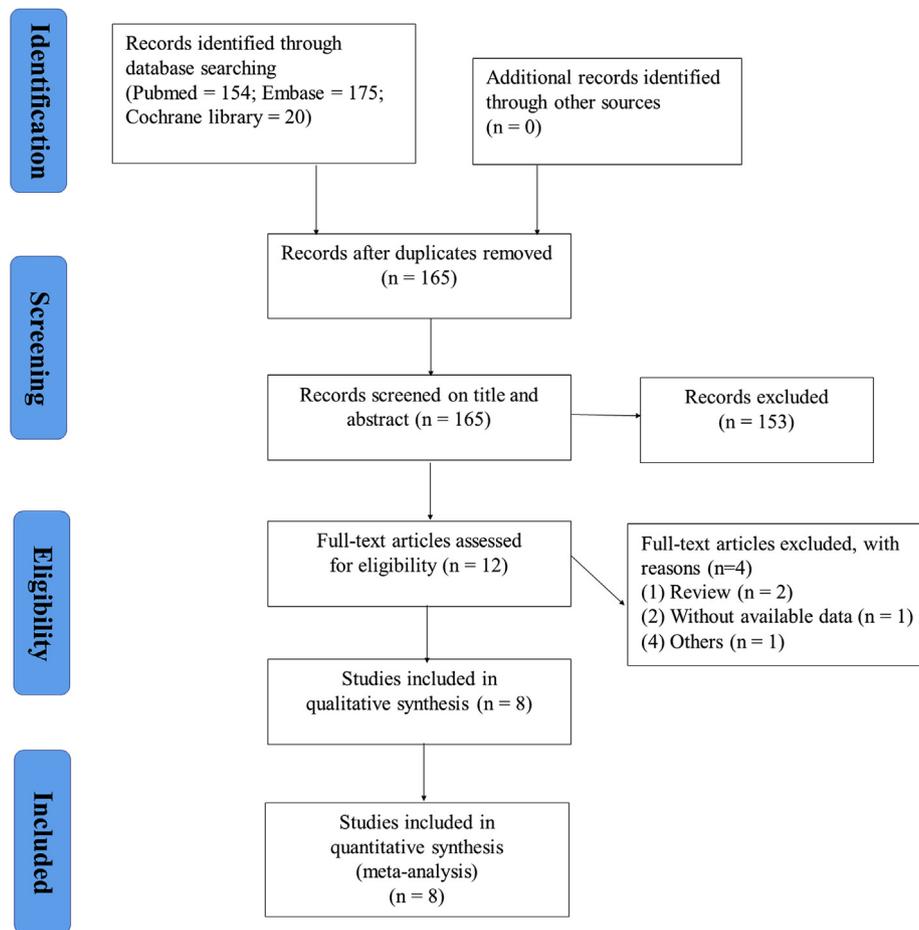


Fig. 1. Flowchart of study selection.

**Table 1**  
The characteristics of the included studies.

Author	Publication year	Study design	Cases (OP/PP)	Age (years)	Gender (M:F)	Follow-up term (months)
Shin et al. [16]	2010	RCT	17/18	52/56	6:11/6:12	40.3
Lan et al. [2]	2013	RCT	24/21	38.0/39.3	10:14/8:13	16.0 months in OP group 15.5 months in PP group
Lee et al. [17]	2013	RCT	32/35	58.2/55.3	8:24/9:26	24
Yan et al. [18]	2017	RCT	30/30	33.1/36.0	16:14/18:12	24
Guo et al. [19]	2013	RCT	27/26	51.8/52.9	16:11/17:9	24
Li et al. [20]	2013	RCT	26/19	35/44.5	14:12/11:8	24
Tao et al. [21]	2013	Cohort study	34/11	48/56	16:18/5:6	28
Ditsios et al. [22]	2017	Cohort study	10/14	53.5/56.5	8:7/6:5	48.8 months in OP group 33 months in PP group

OP: orthogonal plating; PP: parallel plating; M/F: male/female; RCT: randomized controlled trial.

**Table 2**  
Risk of bias assessment of the RCTs.

Study	Randomization	Allocation concealment	Blinding of participants	Blinding of outcome assessment	Incomplete outcome data	Selective reporting	Other bias
Shin et al. [16]	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Lan et al. [2]	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Lee et al. [17]	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Unclear risk
Yan et al. [18]	Low risk	Unclear risk	Low risk	Low risk	Low risk	Low risk	Unclear risk
Guo et al. [19]	Low risk	Low risk	Low risk	Low risk	Unclear risk	Low risk	Low risk
Li et al. [20]	Low risk	Low risk	High risk	Unclear risk	Unclear risk	Low risk	Low risk

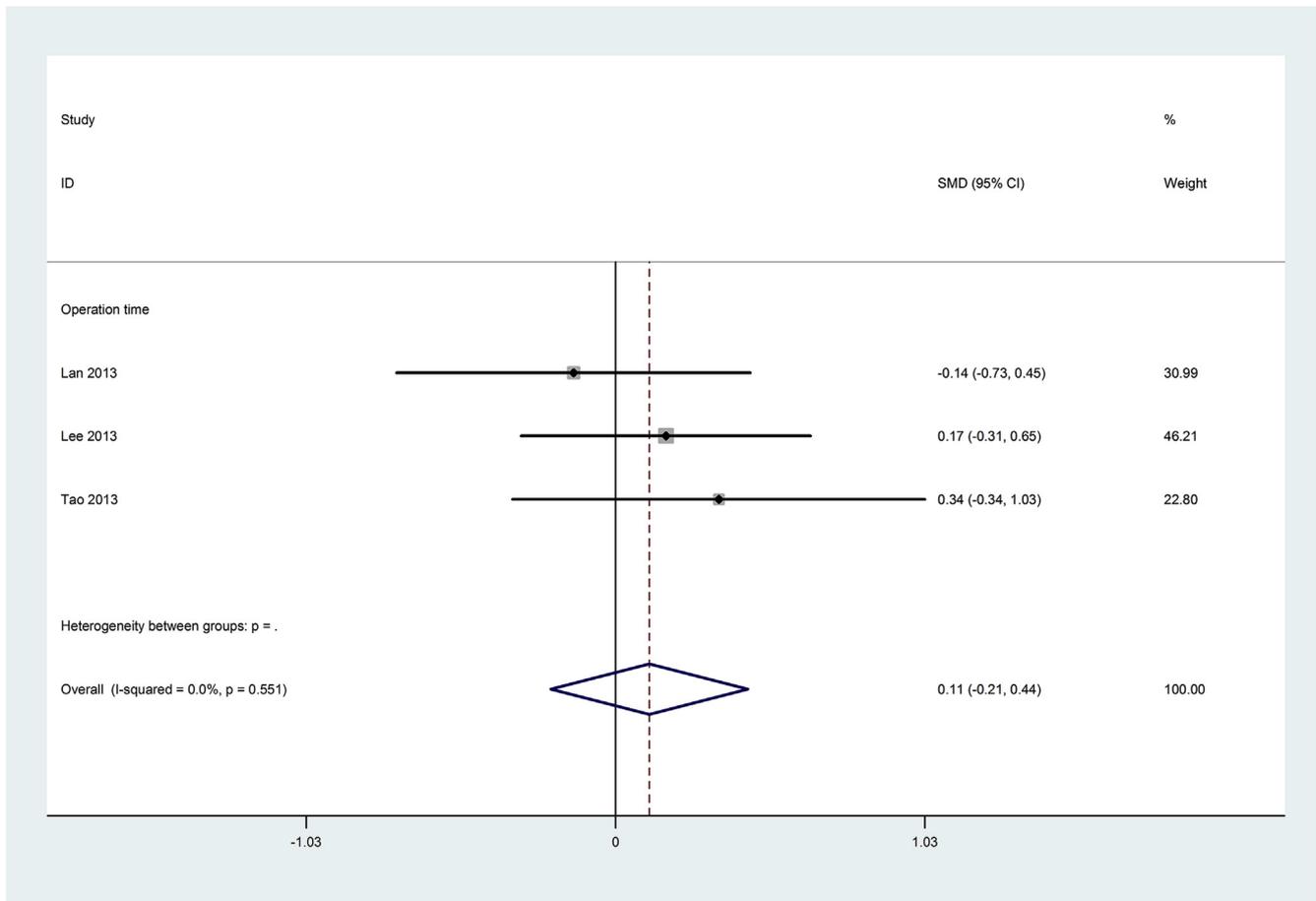
with 1 on the medial supracondylar ridge and the other placed posterolaterally. This orthogonal plating system was reported to provide greater rigidity and fatigue resistance than the single Y plate in a

cadaveric study [8]. Whereas, some biomechanical studies have demonstrated that the parallel plating system, whereby plates are placed along each supracondylar ridge at approximately 180° to each other, is

**Table 3**  
Quality assessment according to the Newcastle-Ottawa scale.

Study	Selection		Ascertainment of exposure	Outcome of interest	Comparability	Outcome			Total score
	Exposed cohort	Nonexposed cohort				Assessment of outcome	Length of follow-up	Adequacy of follow-up	
Tao et al. [21]	*	*	*	*	**	*	*	*	9
Ditsios et al. [22]	*	*	*	*	*	*	*	*	8

Risk of bias was assessed with use of the Newcastle–Ottawa Scale. “\*” means a score of 1; “\*\*” means a score of 2; the total score of this scale is 9. A higher overall score corresponds to a lower risk of bias; a total score of 5 or less indicates a high risk of bias.



**Fig. 2.** Forest plot showing operation time.

significantly stronger and stiffer than the perpendicular plating system in terms of resisting sagittal bending forces [10,11]. Stoffel et al. [12] also demonstrated that the parallel plate system provides better stability in compression and external rotation than the perpendicular plating system in cadaveric models.

Recently, several clinical trials have evaluated the outcomes of orthogonal plating method versus parallel plating method in surgical treatment of distal humerus fracture. However, the results in these studies are inconsistent and there was no meta-analysis conducted to test which fixation method is better in surgical treatment of distal humerus fracture. Therefore, we conducted a meta-analysis of some published randomized controlled trials (RCTs) and cohort studies to explore the outcomes of orthogonal plating method versus parallel plating method for distal humerus fracture by comparing their clinical results. The outcomes included clinical outcomes (operation time and union time), functional outcomes, complications (heterotopic ossification, transient ulnar nerve neuropathy and ankylosis).

## 2. Methods

This systematic review and meta-analysis has been reported in line with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) [13] and AMSTAR (Assessing the methodological quality of systematic reviews) Guidelines. No primary personal data will be collected; therefore no additional ethical approval needs to be obtained.

### 2.1. Search strategy

The electronic databases of PubMed, Embase and Cochrane library were searched from the inception of the database to November 2018, without language restriction. Two independent researchers conducted literature searches using the search strategy of (“distal humerus fracture” or “humeral intercondylar fracture” or “humeral supracondylar fracture”) and (“orthogonal plating method” or “perpendicular plating

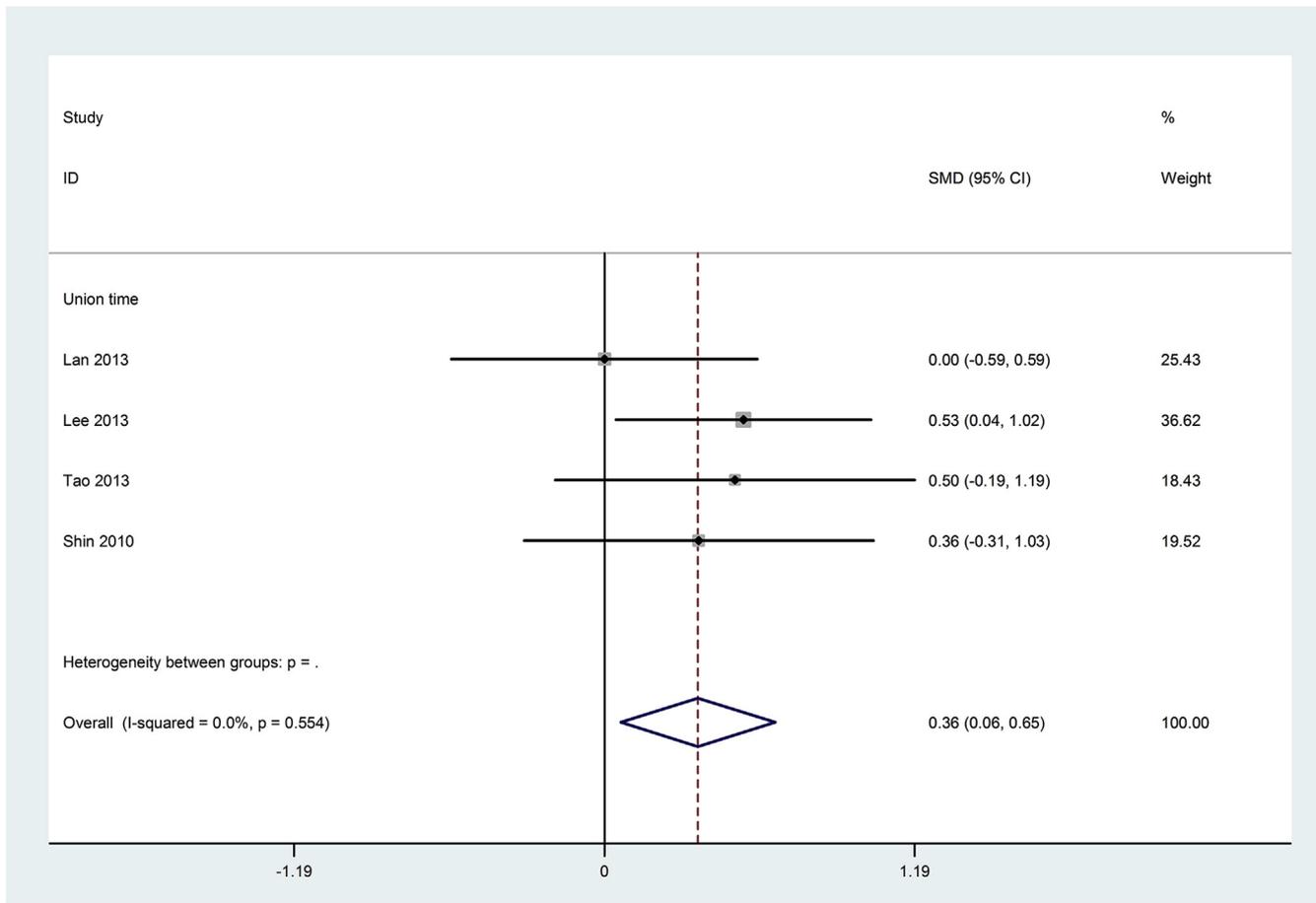


Fig. 3. Forest plot showing union time.

method”) and (“parallel plating method”). In addition, the reference lists of previously published randomized trials, review articles, and meta-analyses were manually searched for additional eligible studies. Related articles and reference lists were searched to avoid original miss.

## 2.2. Inclusion and exclusion criteria

Included studies were considered eligible if they met the following population, intervention, comparison, outcome and study design (PICOS) criteria:

Population: Skeletally mature patients (older than 18 years) with distal humerus fracture;

Intervention: Dual plating method fixation;

Comparator: Orthogonal plating method or parallel plating method;

Outcomes: The primary outcome was range of motion (ROM) of elbow, arc of elbow flexion, arc of elbow extension, Mayo Elbow Performance Score (MEPS) and the rate of excellent and good results. The secondary outcomes included operation time, union time and postoperative complications;

Study design: RCTs and cohort studies.

## 2.3. Selection of literature

We used the PRISMA flow diagram to select the included studies. The results of literature search were imported into the software Endnote X7. Two authors independently assessed the potentially eligible studies. Firstly, the titles and abstracts were screened to exclude the duplicated and apparently irrelevant ones or those that do not meet our inclusion criteria. After then, the remaining potential studies were full-text downloaded and reviewed. Any disagreement between two above

authors was sent and discussed with the third independent author.

## 2.4. Data extraction

Two reviewers independently extracted data, and the third reviewer checked the consistency between them. A standard form was used; the extracted items included the following: (1) the general study information, for example, the authors, publishing date, study design, case number, age, gender and follow-up term. (2) clinical outcomes, including operation time and union time. (3) Functional outcomes including range of motion (ROM) of elbow, arc of elbow flexion, arc of elbow extension, Mayo Elbow Performance Score (MEPS) and the rate of excellent and good results. (4) complications, including heterotopic ossification, transient ulnar nerve neuropathy and ankylosis. For continuous outcomes, we extracted the mean and standard deviation (SD) and participant number will be extracted. For dichotomous outcomes, we extracted the total numbers and the numbers of events of both groups. The data in other forms was recalculated when possible to enable pooled analysis. Disagreements between two researchers were resolved by discussion. Whenever necessary, we contacted the authors of the studies for the missing data and additional information.

## 2.5. Quality assessment of included studies

Two authors independently performed methodological quality and risk of bias assessment of the included RCTs using Cochrane collaboration's tool [14]. The Cochrane tool assesses following items: randomization, allocation concealment, blinding of participants, blinding of outcome assessment, incomplete outcome data, selective outcome reporting and other bias, for each individual item, classifies studies into

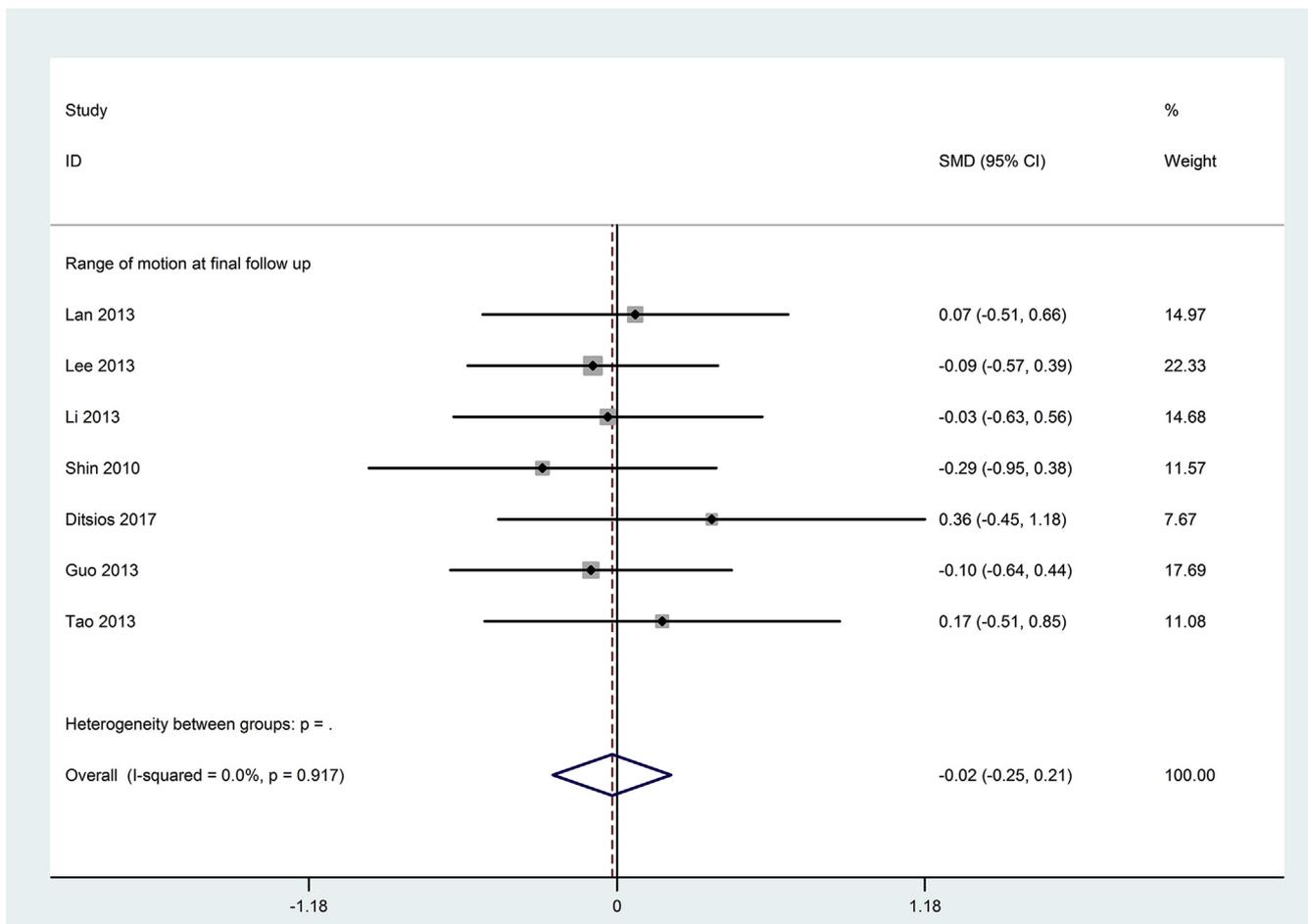


Fig. 4. Forest plot showing ROM of elbow at final follow-up.

low, unclear, and high risk of bias. The methodological quality of included cohort studies was assessed according to the Newcastle–Ottawa Scale (NOS) [15]. The NOS uses a star system ranges from zero to nine stars. We determined studies that received the score more than 6 stars to be high-quality.

## 2.6. Statistical analysis

The data was collected and input into the STATA software (version 12.0; StataCorp, College Station, TX) for meta-analysis. A random-effects model was applied when heterogeneity was detected or the statistical heterogeneity was high ( $P < 0.05$  or  $I^2 > 50\%$ ) and then further subgroup study and meta-regression analysis were performed to detect the origin of heterogeneity. Otherwise, a fixed-effects model was used ( $P \geq 0.05$  or  $I^2 \leq 50\%$ ). To test the strength and stability of the pooled results, we performed a sensitivity analysis by omitting the individual studies one by one. Moreover, the effect of publication bias was investigated by Begg's test and Egger's test. Relative risk (RR) was calculated for dichotomous outcomes, standard mean difference (SMD) was calculated for continuous outcomes.

## 3. Results

### 3.1. Included studies

A total 349 potential records were identified through Pubmed ( $n = 154$ ), Embase ( $n = 175$ ), and Cochrane library ( $n = 20$ ). After removal of duplicates, 165 articles were screened for relevance on the basis of the title and abstract. Of the 12 articles that were possibly

eligible for inclusion, 4 were excluded for reasons of “the papers were review or without available data” and some other reasons (details were showed in Fig. 1). The remaining 8 studies (6 RCTs [2,16–20] and 2 cohort studies [21,22]) were included in this meta-analysis.

### 3.2. Characteristics and quality assessment of the eligible studies

The characteristics of all the 8 included studies were summarized and shown in Table 1. All of them were published between 2010 and 2017. A total of 200 participants in orthogonal plating (OP) group and 174 in parallel plating (PP) group were included in this meta-analysis. Risk of bias assessment of RCTs was presented in Table 2. The methodological quality of cohort studies assessed with the NOS are illustrated in Table 3. 1 study scored 8 stars whereas 1 study scored 9 stars, indicating that all the two included cohort studies were of high quality.

### 3.3. Clinical outcomes

#### 3.3.1. Operation time

Three studies reported operation time [2,17,21]. No significant heterogeneity was found in the pooled outcomes, so a fixed-effects model was utilized in our study ( $\chi^2 = 1.19$ ,  $df = 2$ ,  $I^2 = 0\%$ ,  $P = 0.55$ ). As shown in Fig. 2, the pooled results showed no significant difference between the two groups (SMD = 0.11; 95% CI = -0.22 to 0.44;  $P = 0.50$ ).

#### 3.3.2. Union time

Four studies stated union time [2,16,17,21]. Based on the four studies providing available data, the pooled results showed no

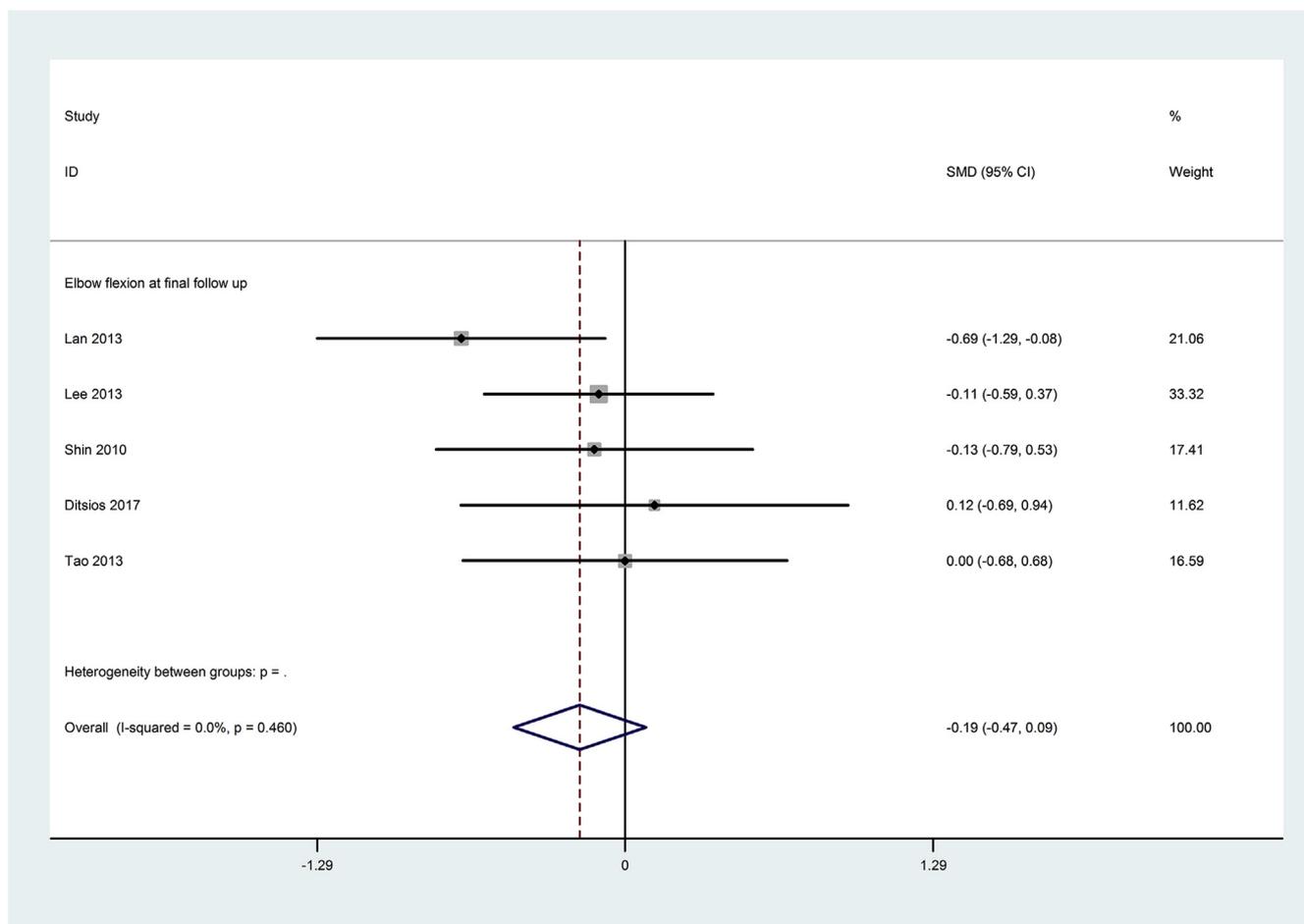


Fig. 5. Forest plot showing elbow flexion at final follow-up.

significant heterogeneity ( $\chi^2 = 2.09$ ,  $df = 3$ ,  $I^2 = 0\%$ ,  $P = 0.55$ ), and therefore, a fixed-effects model was used. The available data demonstrated that union time in orthogonal plating group was significantly longer than parallel plating group (SMD = 0.36; 95% CI = 0.06 to 0.65;  $P = 0.018$ , Fig. 3).

### 3.4. Functional outcomes

#### 3.4.1. ROM of elbow at final follow-up

There were seven studies reporting ROM of elbow at final follow-up [2,16,17,19–22]. A fixed-effects model was applied because no significant heterogeneity was found between the studies ( $\chi^2 = 2.03$ ,  $df = 6$ ,  $I^2 = 0\%$ ,  $P = 0.92$ ). The results indicated that there was no statistically significant difference regarding the ROM of elbow at final follow-up between the two groups (SMD = -0.02; 95% CI = -0.25 to 0.21;  $P = 0.87$ , Fig. 4).

#### 3.4.2. Elbow flexion at final follow-up

Five studies [2,16,17,21,22] described elbow flexion at final follow-up. The pooled results showed no significant heterogeneity ( $\chi^2 = 3.62$ ,  $df = 4$ ,  $I^2 = 0\%$ ,  $P = 0.46$ ), and therefore, a fixed-effects model was used. The available data demonstrated that elbow flexion at final follow-up was not significantly different between the two groups (SMD = -0.19; 95% CI = -0.47 to 0.09;  $P = 0.18$ , Fig. 5).

#### 3.4.3. Elbow extension at final follow-up

The results of a pooled statistical analysis of four studies [2,16,17,21] are shown in Fig. 6 and indicate that there was no statistically significantly heterogeneity ( $\chi^2 = 1.99$ ,  $df = 3$ ,  $I^2 = 0\%$ ,

$P = 0.58$ ). The results revealed that elbow extension at final follow-up was not significantly different between the two groups (SMD = 0.08; 95% CI = -0.21 to 0.38;  $P = 0.58$ , Fig. 6).

#### 3.4.4. MEPS at final follow-up

Five studies reported MEPS at final follow-up [2,16,17,20,22]. No significant heterogeneity was found in the pooled outcomes, so a fixed-effects model was utilized in our study ( $\chi^2 = 0.86$ ,  $df = 4$ ,  $I^2 = 0\%$ ,  $P = 0.93$ ). As shown in Fig. 7, the pooled results showed that MEPS at final follow-up was not significantly different between the two groups (SMD = -0.12; 95% CI = -0.39 to 0.15;  $P = 0.39$ ).

#### 3.4.5. Rate of excellent and good results at final follow-up

There were eight studies reporting rate of excellent and good results at final follow-up [2,16–22]. A fixed-effects model was applied because no significant heterogeneity was found between the studies ( $\chi^2 = 3.35$ ,  $df = 7$ ,  $I^2 = 0\%$ ,  $P = 0.85$ ). There was no significant difference regarding the rate of excellent and good results at final follow-up between the two groups (RR = 0.98; 95% CI = 0.93 to 1.04;  $P = 0.59$ , Fig. 8). The results of subgroup analysis of rate of excellent and good results were shown in Table 4.

### 3.5. Complications

Complications including heterotopic ossification, transient ulnar nerve neuropathy and ankylosis were reported. The meta-analysis showed that there was no significant difference between the two groups (RR = 0.77, 95% CI = 0.47 to 1.25,  $P = 0.29$ , Fig. 9). While, the heterogeneity among studies was very low ( $\chi^2 = 7.78$ ,  $df = 14$ ,  $I^2 = 0\%$ ,

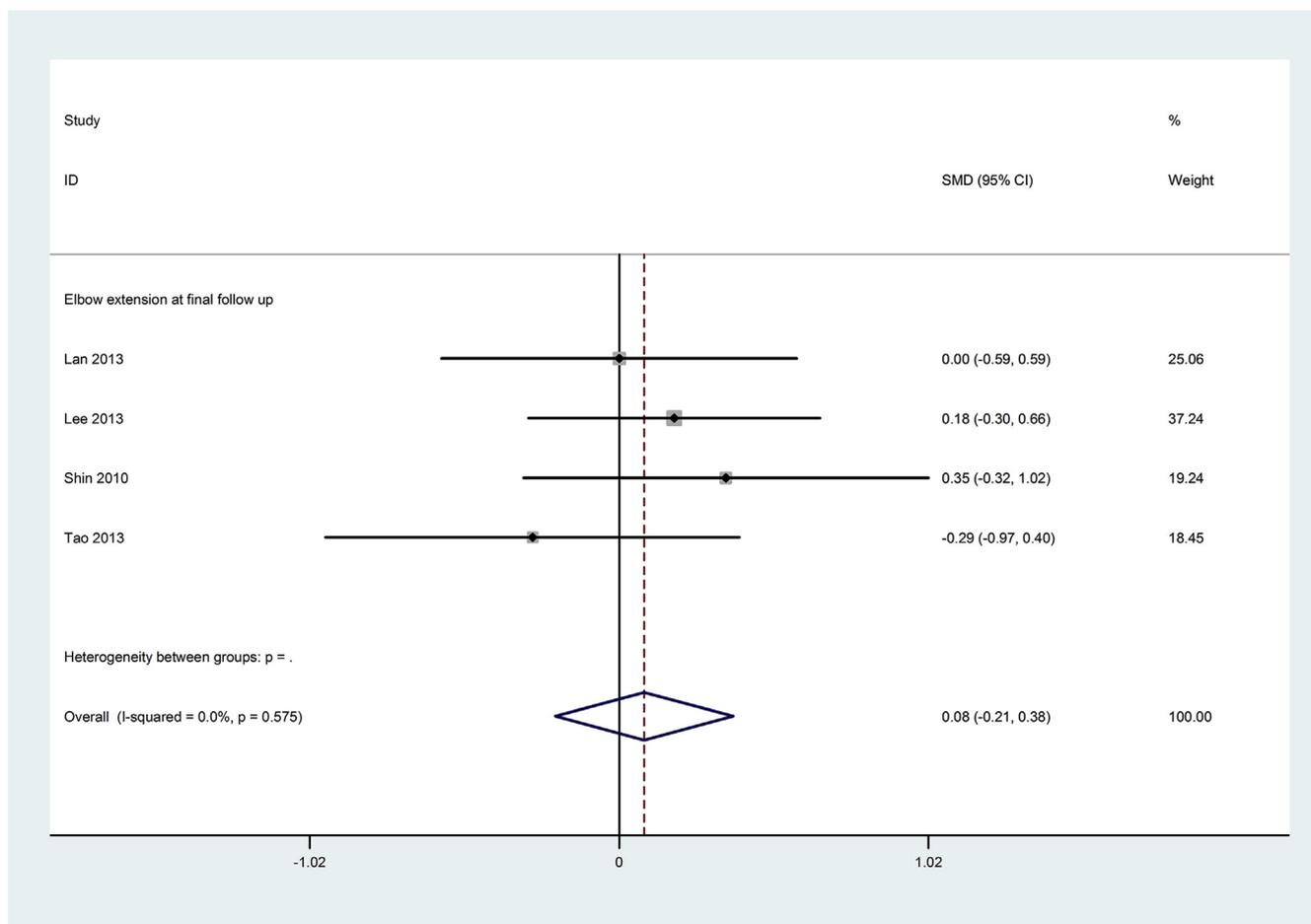


Fig. 6. Forest plot showing elbow extension at final follow-up.

P = 0.90).

### 3.5.1. Heterotopic ossification

Six articles [2,16,17,19,21,22] provided the relevant data. The summarized estimate of effect size did not show a statistically significant difference between the compared groups (RR = 0.82, 95% CI = 0.36 to 1.86, P = 0.63, Fig. 9A). At the same time, no significant statistical heterogeneity was present ( $\chi^2 = 1.68$ , df = 5,  $I^2 = 0\%$ , P = 0.89).

### 3.5.2. Transient ulnar nerve neuropathy

Data extracted from six studies [2,16,17,19–21] substantiated that no statistically significant difference was found between the two groups (RR = 0.52, 95% CI = 0.26 to 1.07 P = 0.08, Fig. 9B), with an absence of statistical heterogeneity ( $\chi^2 = 1.49$ , df = 5,  $I^2 = 0\%$ , P = 0.91).

### 3.5.3. Ankylosis

Three studies [16,20,21] provided data regarding ankylosis. The pooled estimate of information showed that no statistically significant difference was found between the two groups (RR = 2.09, 95% CI = 0.56 to 7.82, P = 0.28, Fig. 9C), and statistical heterogeneity was not present ( $\chi^2 = 2.48$ , df = 2,  $I^2 = 19.4\%$ , P = 0.29).

### 3.6. Publication bias and sensitivity analysis

Begg's funnel plot and Egger's test (Fig. 10) were used to assess the potential publication bias of the ROM of elbow, elbow flexion and elbow extension at final follow-up studies included in this meta-analysis. The symmetrical shape of the funnel plots and the P values from

Begg's and Egger's tests indicated that there was no significant publication bias for ROM of elbow, elbow flexion and elbow extension at final follow-up (P = 0.13 and P = 0.18, P = 0.308 and P = 0.22, P = 0.73 and P = 0.65, respectively).

To determine the influence of each study on the pooled SMDs for ROM of elbow, elbow flexion and elbow extension at final follow-up and to verify the robustness of our results, sensitivity analysis was performed by omitting one study at a time and calculating the pooled SMDs for the remaining studies. The results of the sensitivity analysis indicated that no significant effect on pooled SMDs was observed after excluding any single study, suggesting that the results of this meta-analysis were relatively robust (Fig. 11).

## 4. Discussion

Distal humerus fractures are often both comminuted and intra-articular. This condition in combination with the complex anatomy of the elbow and the limited amount of available subchondral bone makes it difficult to manage such fractures [17]. Despite some controversies concerning the appropriate treatment of distal humerus fractures, double plating fixation has been widely reported to produce satisfactory clinical outcomes even in patients with complex intra-articular fractures [23]. The two most popular plating techniques for distal humeral fractures are perpendicular and parallel plating. To our knowledge, no high-quality meta-analysis has been reported to analyse the high level clinical evidence in orthogonal plating method versus parallel plating method for distal humerus fractures. The present study summed up high-quality studies after strict screening in order to find more reliable outcomes.

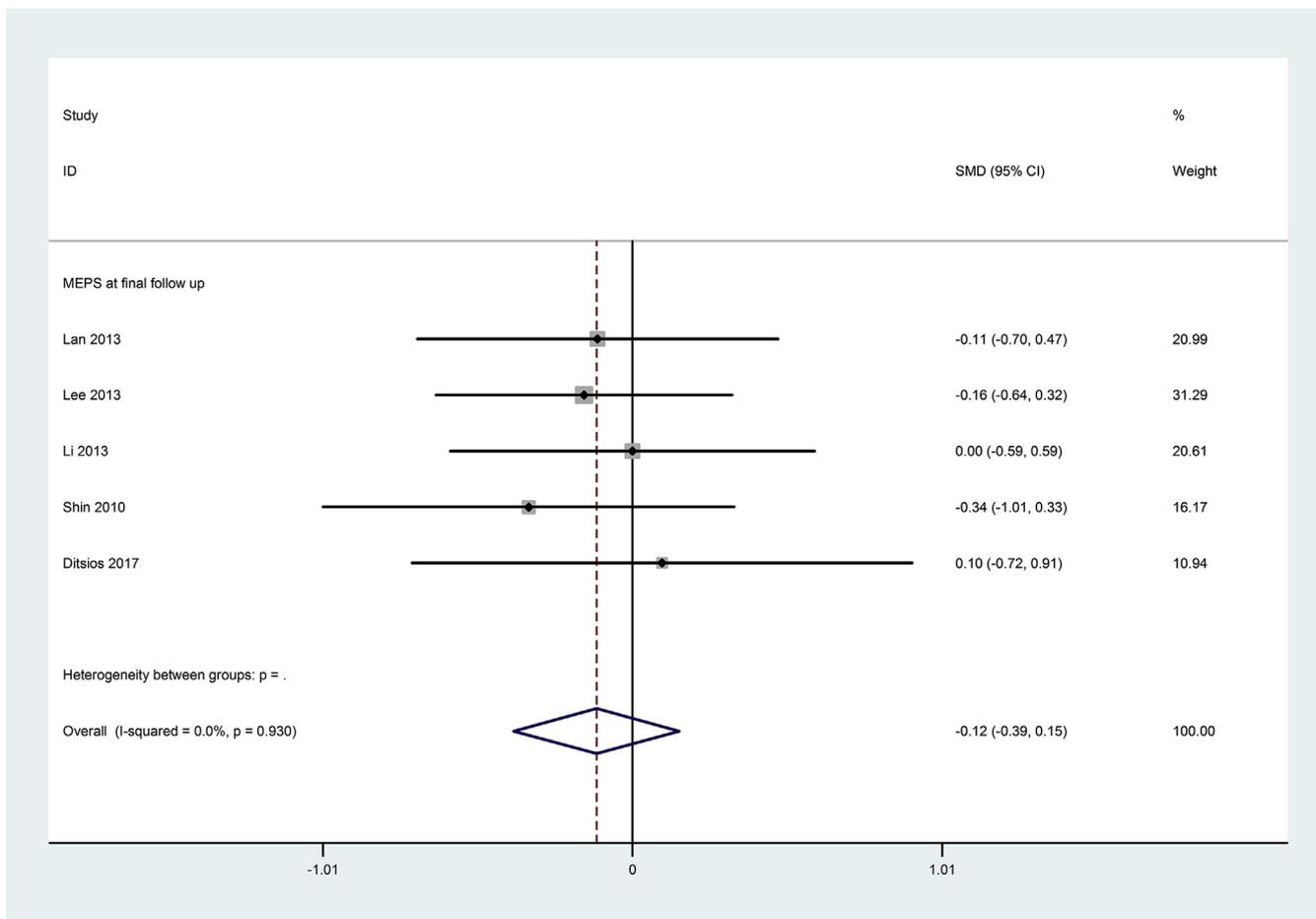


Fig. 7. Forest plot showing MEPS at final follow-up.

Many biomechanical studies have compared the mechanical properties of parallel and perpendicular plating systems for distal humerus fractures [10,11,24,25]. Schemitsch et al. [11] found that in the presence of a metaphyseal defect, the parallel plating method was biomechanically superior to orthogonal plating method. Zalavras et al. [18] reported that the parallel plating method was biomechanically superior to the orthogonal plating method in a varus-loading test. Arnanter et al. [10] tested a simple transverse distal humerus osteotomy without articular involvement in an epoxy resin humerus. They examined sagittal plane bending forces and noted that the parallel system had superior strength and stiffness. However, Jacobson et al. [26] found that the orthogonal plating method was superior with respect to stiffness in the sagittal plane and Schwartz et al. [25] found no significant differences between the two methods regarding stability and fixation security. Furthermore, the geometry of parallel plating offers greater fixation stability in rotation and compression, as the load is shared over a large area, which reduces stress at the boneplate interface.

On the other hand, a large number of studies have reported the functional outcomes of parallel and perpendicular plating systems for distal humerus fractures [3,4,7,21,22]. Huang et al. [27] documented that Type C distal humeral fractures were treated with two perpendicular AO reconstruction plates. They showed that good to excellent results were achieved in 100%. Aslam and Willett [3] reported the functional outcome of AO orthogonal plating in 26 patients aged older than 60 years treated for Type C fractures. Good to excellent results were achieved in 70% of patients who had a mean flexion arc of 112° and a grip strength of 82% compared to the uninjured side. Gofton et al. [4] studied 23 patients with Type C distal humeral fractures treated by orthogonal plating. The flexion arc was 122°, with 17% loss of flexion

torque and 22% loss of extension torque, and 93% were satisfied by the overall outcome. Sanchez-Sotelo et al. [7] in the Mayo Clinic introduced a principle-based parallel-plate technique. They showed that the mean flexion-extension arc was 99° and the mean MEPS was 85 points. The rate of excellent and good results was 79.4%. Athwal et al. [28] studied 37 patients with Type C distal humeral fractures treated by the bicolour parallel plating system. They found that the mean arc of elbow flexion-extension motion was 97° and the mean MEPS was 82 points. In this meta-analysis, we found that there was no statistically significant difference regarding the ROM of elbow, arc of elbow flexion and extension, MEPS and the rate of excellent and good results at final follow-up between the two groups ( $P = 0.87$ ,  $P = 0.18$ ,  $P = 0.58$ ,  $P = 0.39$  and  $P = 0.59$  respectively), which indicated that both parallel and perpendicular plating methods for distal humerus fractures can provide anatomical reconstruction and stable fixation and achieve satisfactory results.

Complications arose regardless of which plating method was used. Postoperative complication rates of up to 48% have been reported for type C distal humerus fractures [5,29]. The main complications reported in the included studies including heterotopic ossification, transient ulnar nerve neuropathy and ankylosis. The most common complication was transient ulnar nerve palsy, followed by heterotopic ossification and arthrofibrosis. Most authors usually performed anterior transposition of ulnar nerve in most patients when the nerve impinged upon the medial plate during elbow motion. However, the incidence of ulnar nerve neuropathy after internal fixation of the distal humerus fractures remains reasonably high. But ulnar nerve symptoms in most patients had subsided completely at 3–12 months postoperatively. The reported incidence of heterotopic ossification in the literature ranges

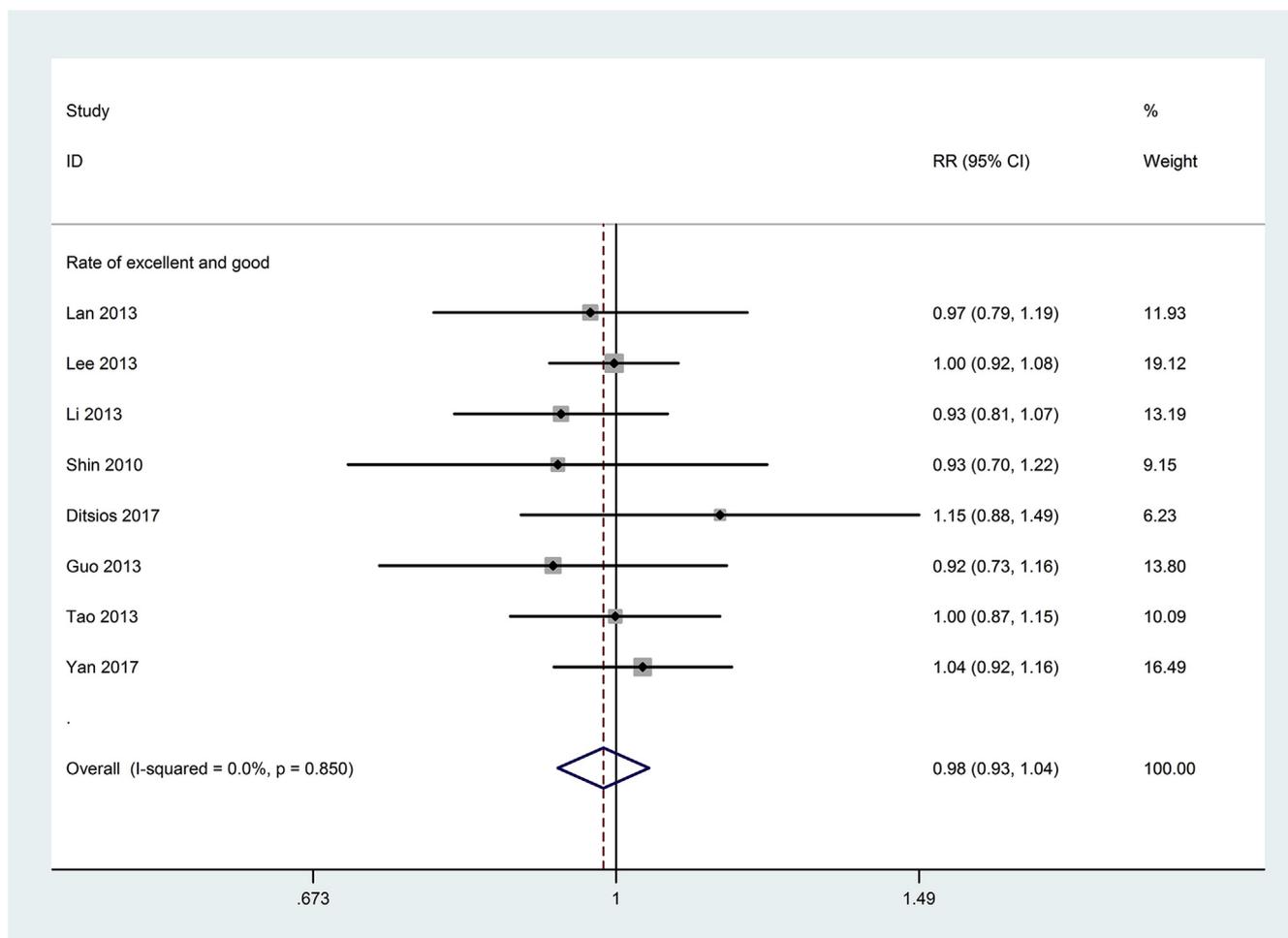


Fig. 8. Forest plot showing rate of excellent and good results at final follow-up.

Table 4

Subgroup analysis for rate of excellent and good results at final follow-up.

Stratified analysis	Number of study	Cases (OP/PP)	I <sup>2</sup> (%)	Heterogeneity (P)	RR	95% CI	Z test (P)
Age (years)							
≥ 50	4	86/93	0	0.580	0.981	0.893 to 1.079	0.694
< 50	4	114/81	0	0.702	0.986	0.915 to 1.062	0.709
Study type							
RCT	6	156/149	0	0.808	0.970	0.907 to 1.037	0.367
Cohort study	2	44/25	0	0.319	1.055	0.924 to 1.204	0.430
Follow-up term (months)							
≤ 24	5	139/131	0	0.739	0.975	0.912 to 1.043	0.461
> 24	3	61/43	0	0.521	1.009	0.887 to 1.147	0.895

OP: orthogonal plating; PP: parallel plating; RCT: randomized controlled trial. All the authors confirm that the data can submit to the journal.

widely, from 4 to 49% [29,30]. This variability may be due to differences in the type of injury, time to treatment, use of heterotopic ossification prophylactics, methods of treatment, rehabilitation and time of reporting. In our meta-analysis, there was no significant difference between the two groups regarding the complication rates (heterotopic ossification, transient ulnar nerve neuropathy and ankylosis, P = 0.89, P = 0.91 and P = 0.29 respectively), which suggested that both parallel and perpendicular plating methods for distal humerus fractures are able to acquire satisfactory outcomes with the similar complications.

The strengths of this meta-analysis include the clear definition of the research question to reduce bias in the selection of the studies, adherence to an explicit research protocol that was developed prior to the analysis, the comprehensive literature search, consensus between the

two reviewers with the entry data elements, and a quality control review of all results. Most of our included studies in this meta-analysis were RCTs, which therefore overcomes the shortcomings of recall or selection bias in non-randomized studies. The methodological quality of included cohort studies was high (1 study scored 8 stars whereas 1 study scored 9 stars) according to the NOS. No publication bias was found in our meta-analysis and sensitivity analysis indicated that the results of this meta-analysis were relatively robust.

Nonetheless, some limitations in the present meta-analysis should be recognized. (1) Only articles with small sample size were included in the study, 2 included studies were cohort studies, which might lower the evidence level. (2) The duration of the follow-up of the included studies was variable. (3) Elbow functional score is an important

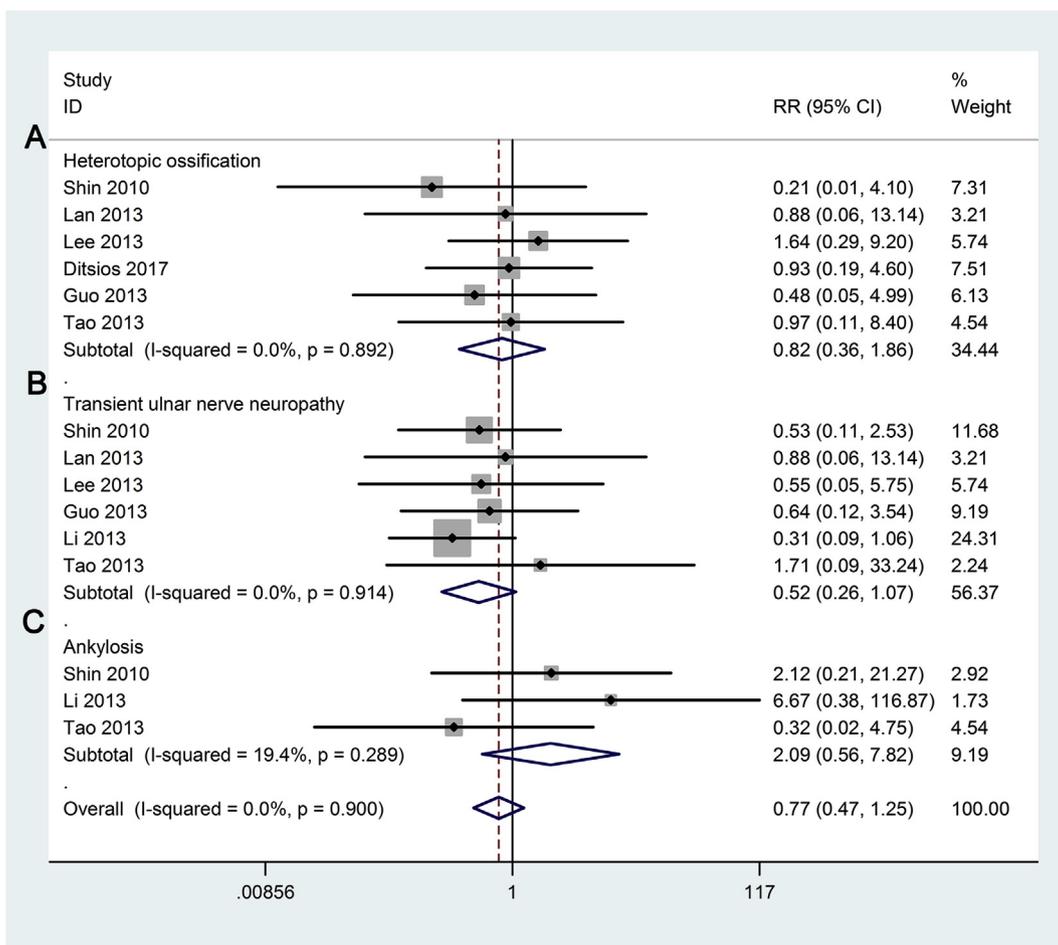


Fig. 9. Forest plot showing complications heterotopic ossification (A), transient ulnar nerve neuropathy (B) and ankylosis (C).

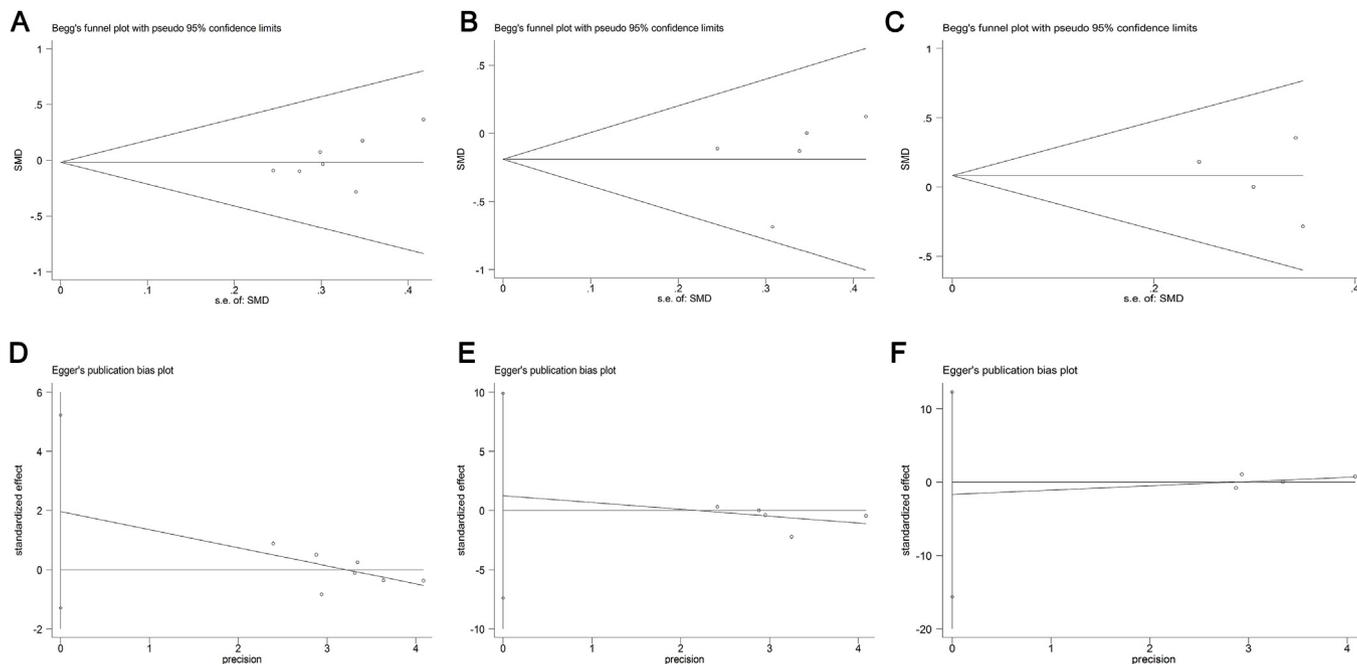


Fig. 10. Begg's funnel plot (A–C) and Egger's test (D–F) of ROM of elbow, elbow flexion and elbow extension at final follow-up.

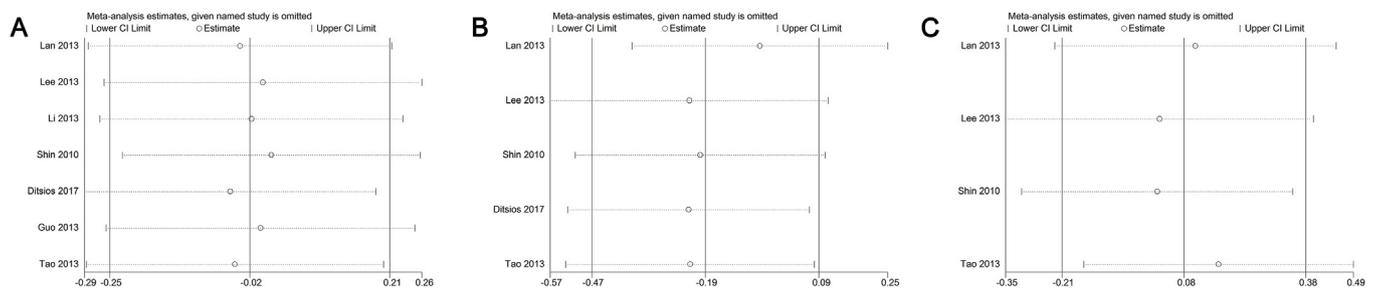


Fig. 11. Sensitivity analysis for ROM of elbow (A), elbow flexion (B) and elbow extension (B) at final follow-up.

parameter. But the type of elbow functional score was various, which may generate heterogeneity. Therefore we suggest that larger sample sizes and multicentric high-quality randomized controlled trials could be carried out to evaluate the outcomes of orthogonal plating method versus parallel plating method for distal humerus fracture in the future. Despite these limitations, this meta-analysis provides evidence that both orthogonal plating and parallel plating method could achieve satisfactory outcomes with the similarly low complications in the treatment of distal humerus fracture.

## 5. Conclusion

In conclusion, both orthogonal plating and parallel plating method could achieve satisfactory outcomes with the similarly low complications in the treatment of distal humerus fracture. Meanwhile, parallel plating group had significantly shorter union time than orthogonal plating group. However, taking the heterogeneity and small sample size into consideration, more high-quality RCTs are required to go a step further in demonstrating the benefits of parallel plating fixation in treatment of distal humerus fracture.

## Provenance and peer review

Not commissioned, externally peer-reviewed.

## Ethical approval

All analyses were based on previous published studies; thus, no ethical approval is required.

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None.

## Author contribution

Wenhao Zheng designed the study and Linzhen Xie wrote this manuscript. Linzhen Xie and Jinwu Wang searched database and reviewed studies. Wenhao Zheng and Chunhui Chen collected and analyzed data. All of the authors have read and approved the final manuscript.

## Conflicts of interest

None.

## Research registry number

The Unique Identifying Number (UIN) from the Research Registry of the study is reviewregistry631.

<https://www.researchregistry.com/browse-the-registry#registryofsystematicreviewsmeta-analyses/registryofsystematicreviewsmeta-analysedetails/>

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## Guarantor

Wenhao Zheng.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ijisu.2019.07.028>.

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