Systematic Review and Meta-Analysis

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A comparison between perpendicular and parallel plating methods for distal humerus fractures

A meta-analysis of randomized controlled trials

Xiaohan Wang, MD[a], Guoyan Liu, PhD[b,*]

Abstract

Objective: To compare the clinical outcomes of perpendicular and parallel plating for the treatment of distal humerus fractures.

Methods: Two investigators independently searched PubMed, OVID, and ScienceDirect databases prior to April 2019, without any limitations on language or publication status. The outcomes were union time, range of motion of elbow, Mayo Elbow Performance Score, and postoperative complications. Two authors independently performed a methodological quality and risk of bias assessment using Cochrane collaboration's tool. Data analysis was performed with STATA version 13.0.

Results: Six randomized controlled trials with 305 participants were included. The present meta-analysis indicated that orthogonal plating was associated with a longer union time compared with parallel plating. There were no significant differences between the 2 groups regarding Elbow function, Mayo Elbow Performance Score, operation time, reduction quality, or postoperative complications.

Conclusion: Both parallel plating and orthogonal plating are considered to be effective methods when treating distal humerus fractures. The results of this study found that parallel plating is superior to orthogonal plating in humerus fracture healing.

Abbreviations: MEPS = Mayo Elbow Performance Score, ROM = range of motion, RCT = randomized controlled trial.

Keywords: distal humerus fractures, meta-analysis, orthogonal plating, parallel plating

1. Introduction

Distal humerus fractures are common and they are usually caused by high velocity injuries. These fractures account for about 4% of all adult fractures and for approximately 30% of all elbow fractures.[1] It is reported that there was a twofold increase in the incidence of distal humerus fractures between 1970 (12/100,000) and 1995 (28/100,000), and predicted an additional threefold increased by 2030.[2] In younger people, these fractures are commonly caused by high energy injuries. For elderly female patients, these fractures are considered to be a low energy injury, and are often caused by fall from a standing height. With the aging population and higher demand of life expectancy, health care expenditures would increase sharply. Palvanen et al[3] showed a significant increase in the risk of distal humerus fractures in an ageing population and there was a five-fold increase in the annual number of distal humeral fractures in women older than 60 years. Distal humerus fractures remain some of the most challenging injuries to medically manage. They are commonly multifragmented, occur in the osteopenic bone, and are anatomically complex with limited options for successful treatment.[4] To achieve early mobilization, an anatomical reduction of the complex geometry of the distal humerus is necessary. However, this may be extremely difficult especially in the presence of substantial osteoporosis or comminution.

Open reduction and internal fixations have resulted in improved outcomes for the treatment of distal humerus fractures.[5,6] Among the various types of treatment techniques, a double plate fixation has been reported to stabilize reduction and articular reconstruction compared to other internal fixation methods.[7,8] Published biomechanical trials have also indicated that a double-plate fixation resulted in adequate stability for the patient.[9,10] However, the optimal position of the plating remains controversial. A dual plate fixation with one on the medial supracondylar ridge and the other placed posterolaterally is the most commonly used method.[11] This approach is considered to achieve rigidity and fatigue resistance. However, recent studies have reported that plates that are placed along each supracondylar ridge at approximately 180° to each other, is stronger and stiffer than an orthogonal plating system.

Currently, there have been no systematic, quantitative evaluations conducted that have compared orthogonal and parallel plating methods. In this article, we have explored the relevant studies to compare the clinical outcomes of these 2 techniques for the treatment of distal humerus fractures, in order to provide reliable evidence for clinical decision making.

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The authors declare that they have no competing interests.

[a] Department of Orthopedics, Beijing University of Chinese Medicine Third Affiliated Hospital, Beijing, [b] Department of Orthopedics, Affiliated Hospital of Shandong University of Traditional Chinese Medicine, Shandong, China.

[*] Correspondence: Guoyan Liu, Department of Orthopedics, Affiliated Hospital of Shandong University of Traditional Chinese Medicine, Shandong 250014, China (e-mail: 3115170475@qq.com).

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2. Materials and methods

This work has been reported in line with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). Ethical approval is not necessary because it is a meta-analysis.

2.1. Search methodology

Two investigators independently searched PubMed, OVID, and ScienceDirect databases prior to April 2019, without any limitations on language or publication status. The following search terms were used: "distal humerus fractures", "humeral intercondylar fracture", "humeral supracondylar fracture", "orthogonal plating method", and "parallel plating method". In addition, references that were cited in articles found in the course of the search, were subsequently searched for additional relevant articles.

2.2. Study selection criteria

Studies were included in this meta-analysis if they met the following criteria: Population: Adult patients with AO type C distal humerus fractures; Intervention: orthogonal plating method; and Comparator: parallel plating method; Outcomes: union time, range of motion (ROM) of elbow, Mayo Elbow Performance Score (MEPS) and postoperative complications. Study design: randomized controlled trial (RCTs). Studies were excluded if they were:

1. fundamental research or studies on animals;
2. review articles, case report;
3. reports published as conference proceedings;
4. reports in books.

A total of 210 relevant studies were identified, with no additional records being identified during a manual search of the references. Screening using NoteExpress software consequently removed 185 duplicates, and 17 records were excluded as irrelevant after reading titles and abstracts. A further 2 articles failed to meet the inclusion criteria and were removed. Finally, 6 RCTs[12–16] were included. The characteristics of all the included studies are presented in Figure 1.

2.3. Data extraction

Two independent reviewers extracted the data, and a third reviewer checked the consistency using the Kappa test (Kappa = 0.64). The relevant data that was extracted included the first author, year of publication, study design, sample size, average age, gender ratio, outcome measures, and the follow-up time. Corresponding authors of the included studies were consulted for the missing data and any additional information was requested.

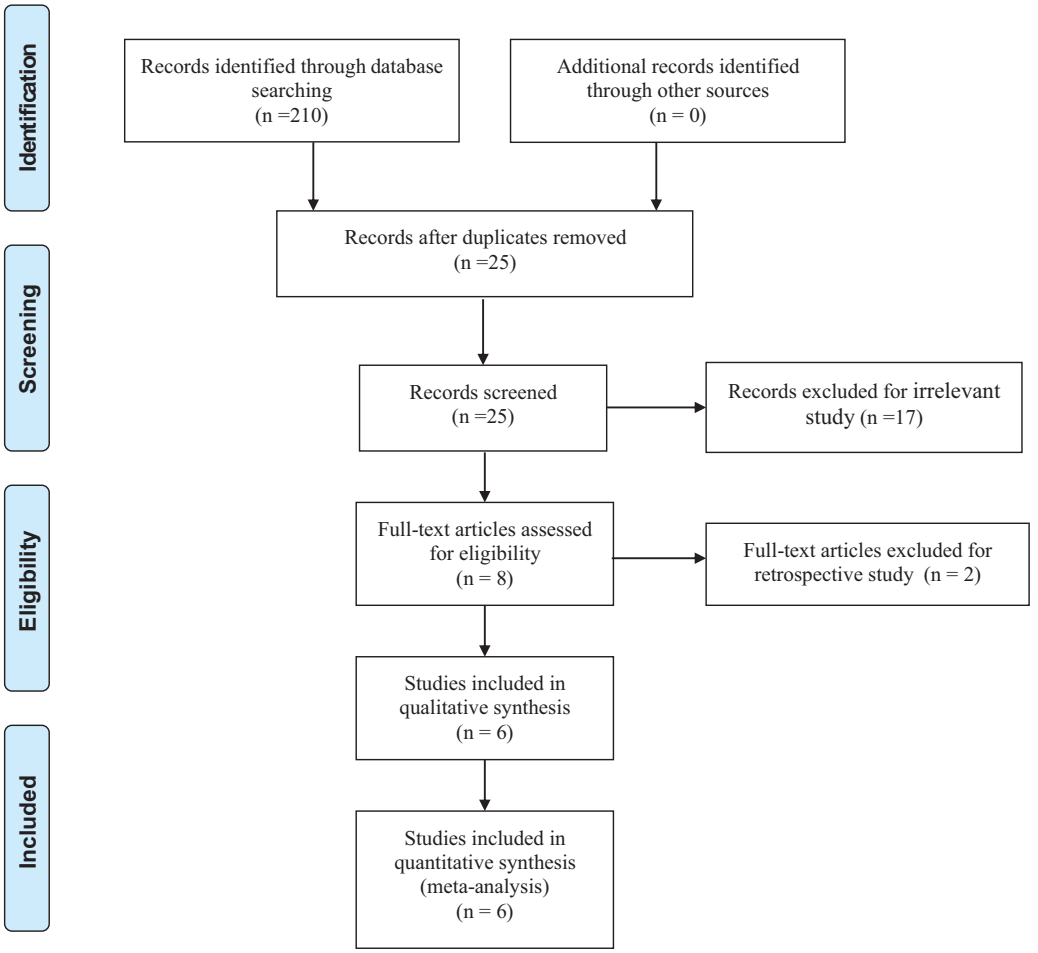


Figure 1. PRISMA flow diagram for search strategy and study selection.

Table 1

Characteristics of the included RCTs.

Study	Year	Design	Participants	No. of patients		Age		Gender (Female %)		Follow up
				OP	PP	OP	PP	OP	PP	
Shin et al	2010	RCT	Distal humerus fracture	17	18	52	56	65%	67%	40 months
Lan et al	2013	RCT	Distal humerus fracture	24	21	38	39	58%	62%	16 months
Lee et al	2013	RCT	Distal humerus fracture	32	35	58	55	65%	67%	24 months
Guo et al	2013	RCT	Distal humerus fracture	27	26	52	53	41%	35%	24 months
Li et al	2013	RCT	Distal humerus fracture	26	19	35	45	46%	42%	24 months
Yan et al	2017	RCT	Distal humerus fracture	30	30	33	36	47%	40%	24 months

RCT = randomized controlled trial, OP = orthogonal plating, PP = parallel plating.

Any disagreement arising between the reviewers was resolved by discussions with the third author.

2.4. Quality assessment

Two authors independently performed a methodological quality and risk of bias assessment, which included RCTs using Cochrane collaborations tool.[17] 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 low, unclear, and high risk of bias. The evidence grade was assessed using the guidelines of the Recommendations Assessment, Development and Evaluation (GRADE) system.[18] The evidence grades are divided into the following categories:

1. high, which indicates that further research is unlikely to alter confidence in the effect estimate;
2. moderate, which indicates that further research is likely to significantly alter confidence in the effect estimate and may change the estimate;
3. low, which indicates that further research is likely to significantly alter confidence in the effect estimate and to change the estimate; and
4. very low, which indicate that any effect estimate is uncertain.

2.5. Statistical analysis

A data analysis was performed with STATA version 13.0 (Statacorp, college station, Tex). We used a 95% confidence interval (CI), with a weighted mean difference (WMD) and risk difference (RD) to present the results of the meta-analysis. Heterogeneity between our studies was evaluated using the Cochran Q test and I^2 statistics. If the analysis of the data yielded $P > .05$ and $I^2 < 50\%$, the level of heterogeneity was considered low, and a fixed-effects model was adopted. Otherwise a random model was adopted. Publication bias was evaluated using a funnel plot by Review Manager 5.3 (The Cochrane Collaboration, Oxford, UK).

3. Results

3.1. Characteristics of included studies

The characteristics of the included studies are shown in Table 1. All of characteristics were RCTs that were published between 2010 and 2017. There were 156 participants in the orthogonal plating group and 149 in the parallel plating group. The follow up period ranged from 16 to 40 months.

3.2. Methodological quality assessment

The risk of bias assessment of RCTs was presented in Table 2. All articles reported randomization and adopted computer-generated random sequence. Four RCTs described that allocation concealment was accomplished by an opaque sealed

Table 2

Risk of bias assessment of the RCTs.

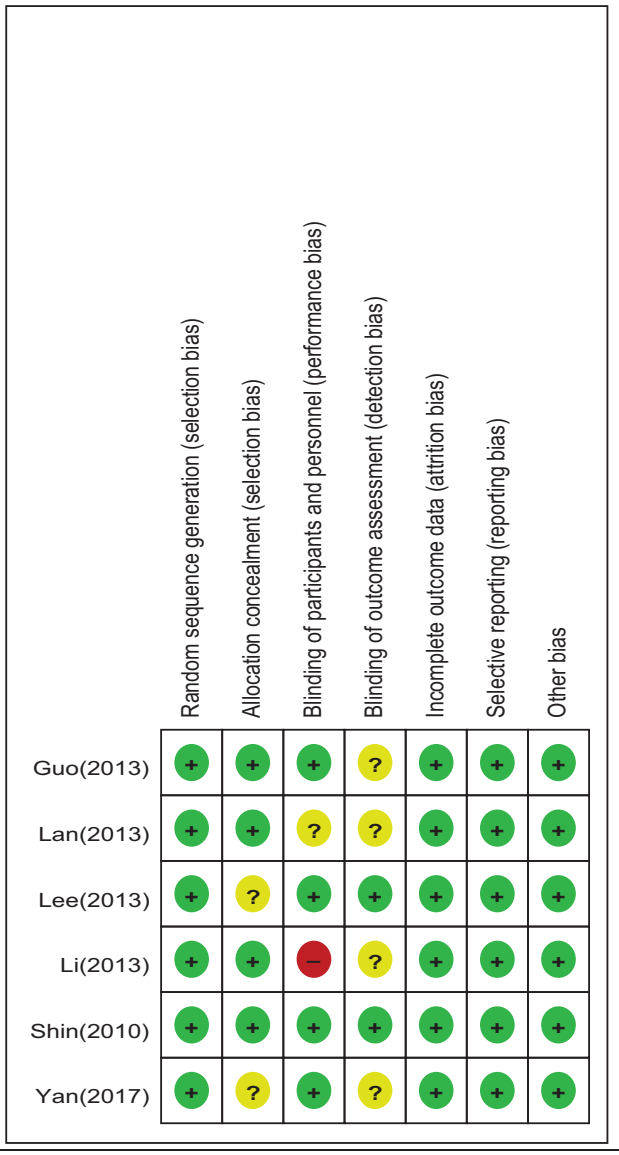
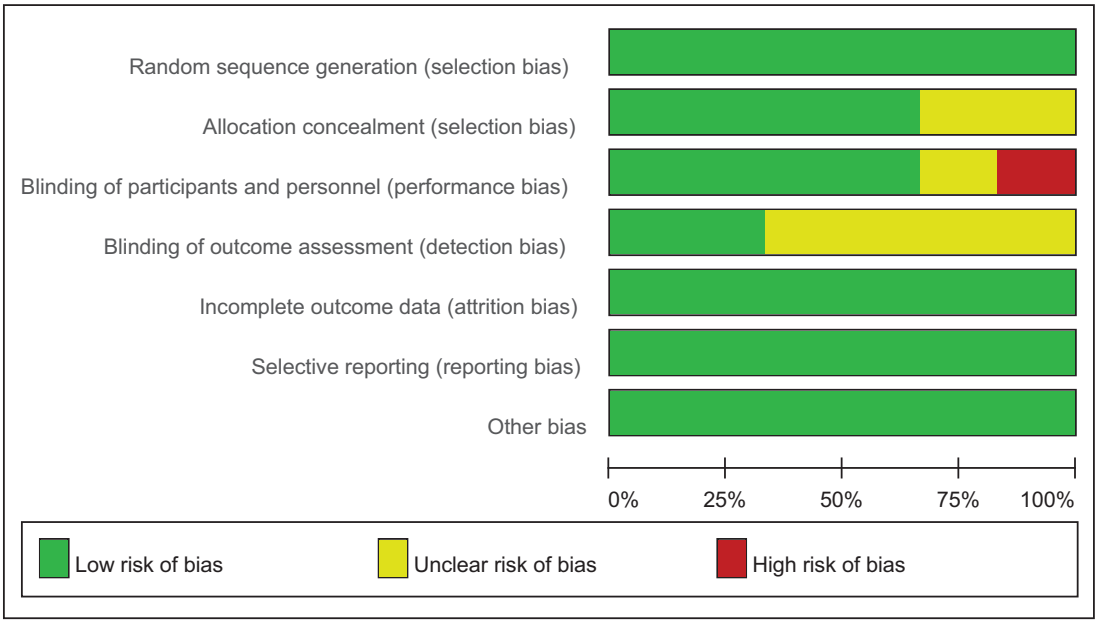


Table 3

Risk of bias summary.



envelope. Four studies showed double blinding and 2 of them attempted to blind the assessors. All RCTs provided complete outcome data. Each risk of the bias item was expressed in terms of the percentage across all the included studies, which indicated the proportion of risk levels for each item bias (Table 3).

3.3. Outcomes assessments

3.3.1. Union time. Four RCTs reported the union time after surgical treatment. Since there was significant heterogeneity (I^2 = 73.9%, P = .009), a random effect model was used. The pooled data indicated that orthogonal plating was associated with a longer union time compared with parallel plating (WMD = 0.236; 95% CI = 0.029–0.444; P = .026, Fig. 2).

3.3.2. Elbow flexion. Five studies provided data on the elbow flexion at the final follow up. Heterogeneity among the 5 studies was low (I^2 = 0%, P = .746). The meta-analysis showed that there was no significant difference between the 2 groups regarding the elbow flexion (WMD = −2.293; 95% CI = −5.806 to 1.221; P = .201, Fig. 3).

3.3.3. Elbow extension. A total of 4 RCTs reported the outcome of elbow flexion at the final follow up. A random effect model was adopted (I^2 = 78.7%, P = .003). The present meta-analysis indicated that there was no significant difference in terms of elbow extension (WMD = −0.276; 95% CI = −2.981 to 2.429; P = .841, Fig. 4).

3.3.4. Mayo Elbow Performance Score (MEPS). Four RCTs reported the outcome of MEPS after surgical procedures. Since there was no significant heterogeneity among studies (I^2 = 0%, P = .971), a fixed effect model was used. No significant difference was identified for the MEPS between the groups (WMD = −2.127; 95% CI = −10.234 to 5.979; P = .607, Fig. 5).

3.3.5. Operation time. Three studies indicated operation time. Since there was significant heterogeneity, a random effect model was used (I^2 = 78.0%, P = .011). The pooled results showed that there were no significant differences between the 2 groups (WMD = 2.700; 95% CI = −16.486 to 21.886; P = .783, Fig. 6).

3.3.6. Anatomical reduction. All RCTs reported the reduction in quality after an operation was conducted. There was no significant heterogeneity (I^2 = 0%, P = .971), and a fixed effect model was used. The pooled data demonstrated that there was no significant difference between the groups (WMD = −0.017; 95% CI = −0.064 to 0.029; P = .467, Fig. 7).

3.3.7. Postoperative complications. Four RCTs reported the postoperative complications, including heterotopic ossification and ulnar nerve neuropathy. No statistically significant differences were found between the 2 groups (RD = 0.020; 95% CI = −0.022 to 0.062; P = .359, Fig. 8), with an absence of statistical heterogeneity (I^2 = 0%, P = .960).

3.3.8. Sensitivity analysis and publication bias. A sensitivity analysis was performed by omitting 1 study at a time and then calculating the pooled outcomes for the remaining studies. The result of the sensitivity analysis about the union time and elbow extension indicated that no significant effects were observed after we had excluded any single study (Fig. 9). However, considering the potential confounding factors, it was concluded that further high-quality research was required. The symmetrical shape of the funnel plots indicated that there was a low risk of publication bias for the outcome of anatomical reduction (Fig. 10).

3.4. Quality of the evidence and recommendation strengths

All outcomes were evaluated using the GRADE system. The quality of the evidence for each outcome is moderate. This

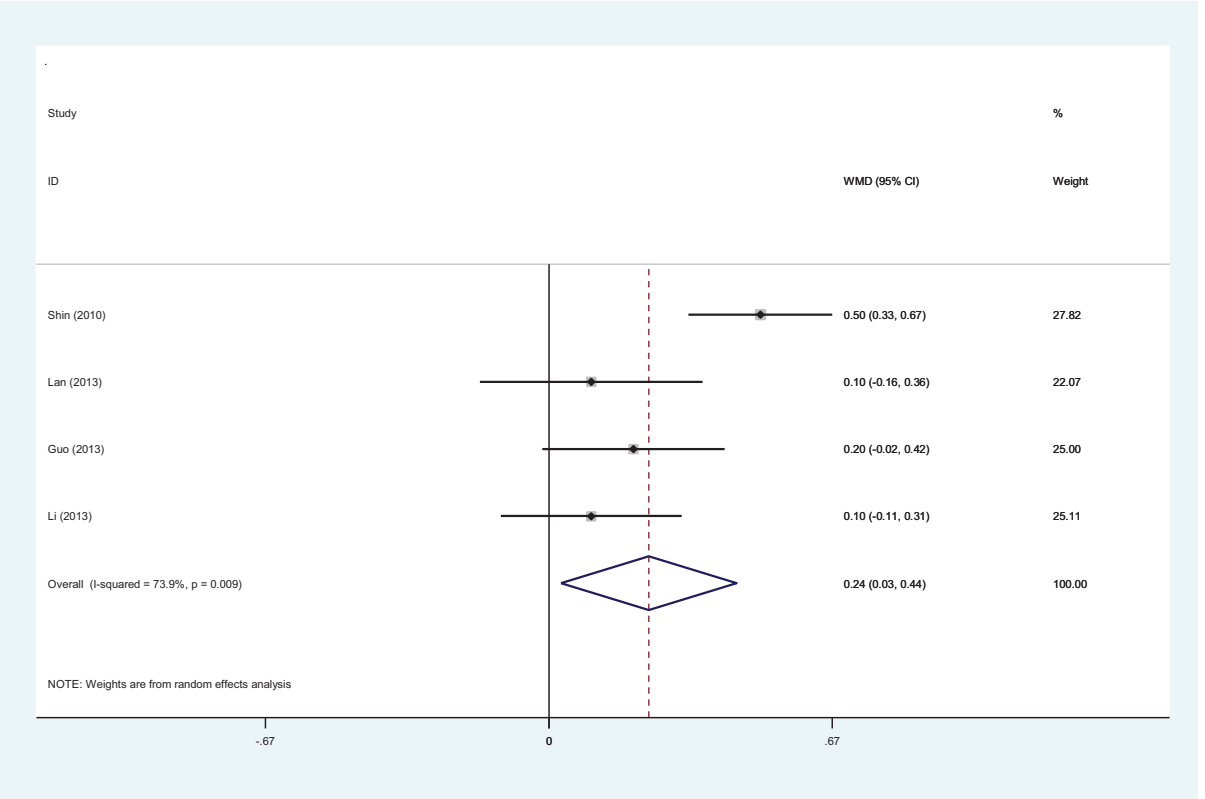


Figure 2. Meta-analysis for union time between orthogonal groups and parallel groups.

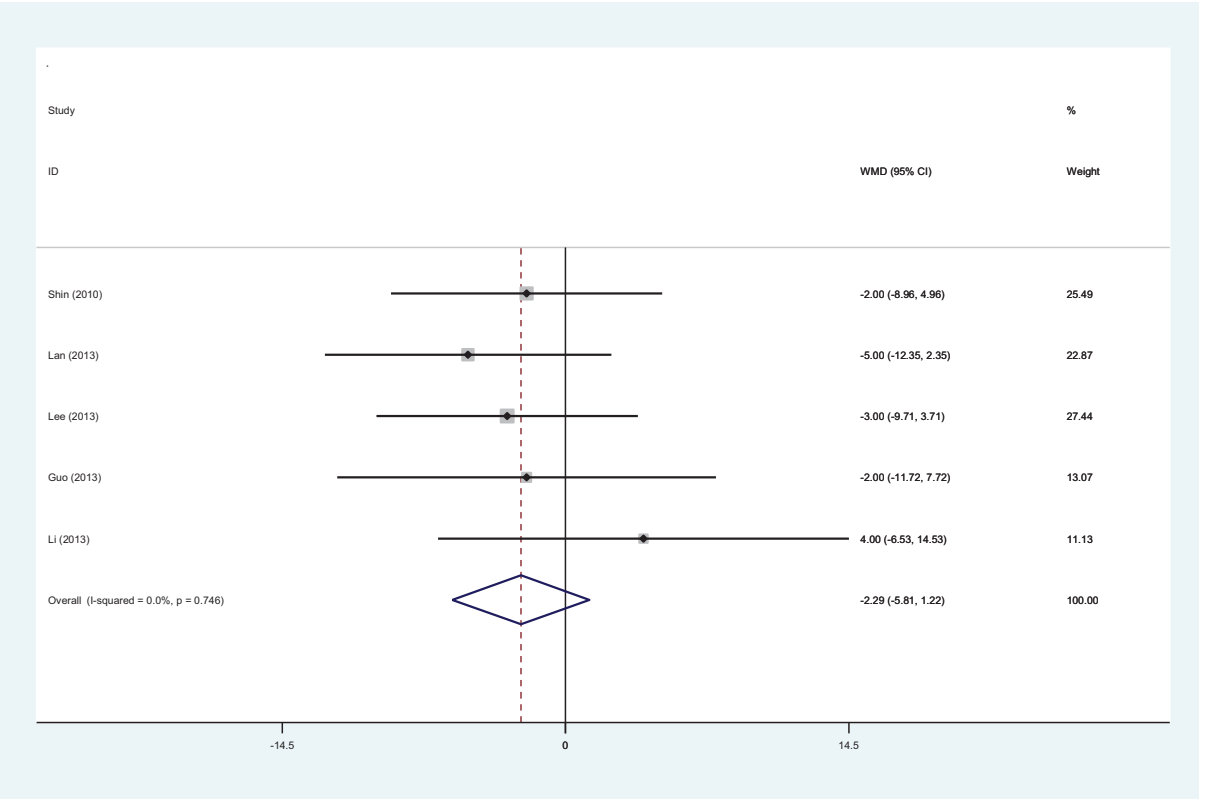


Figure 3. Meta-analysis for elbow flexion between orthogonal groups and parallel groups.

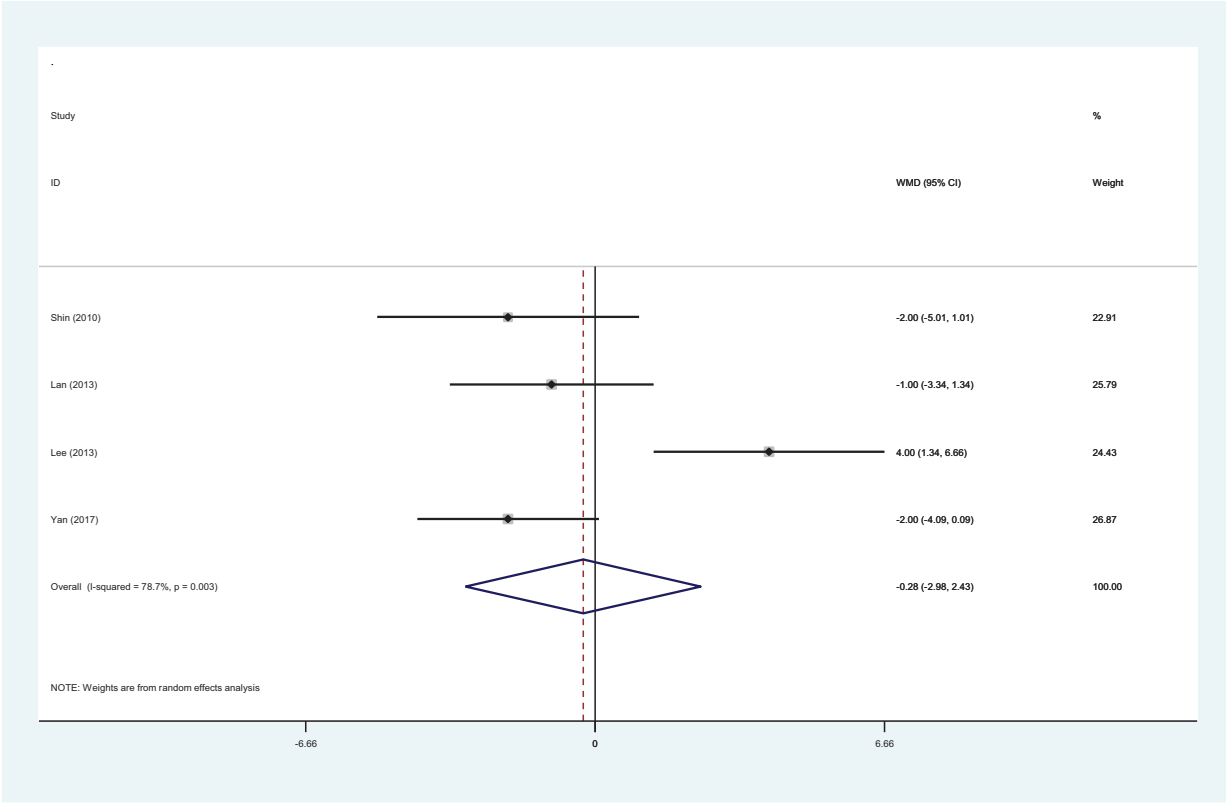


Figure 4. Meta-analysis for elbow extension between orthogonal groups and parallel groups.

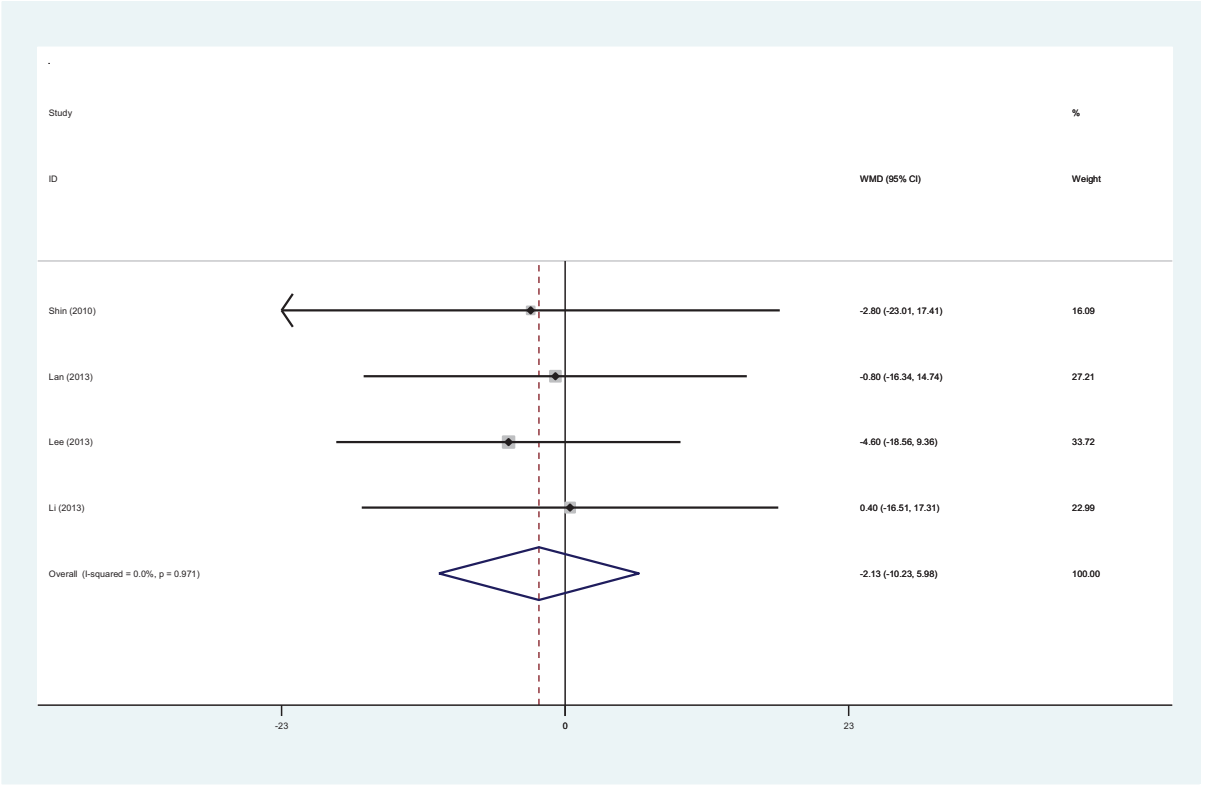


Figure 5. Meta-analysis for MEPS between orthogonal groups and parallel groups.

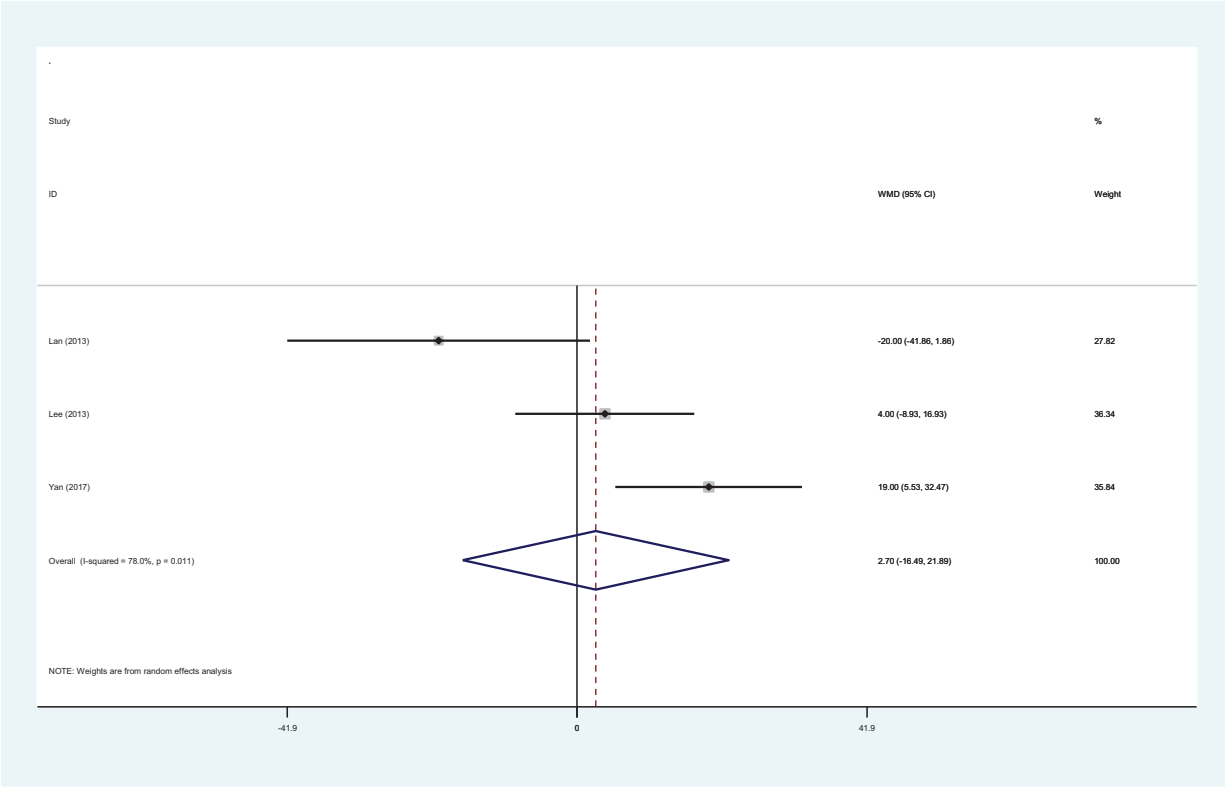


Figure 6. Meta-analysis for operation time between orthogonal groups and parallel groups.

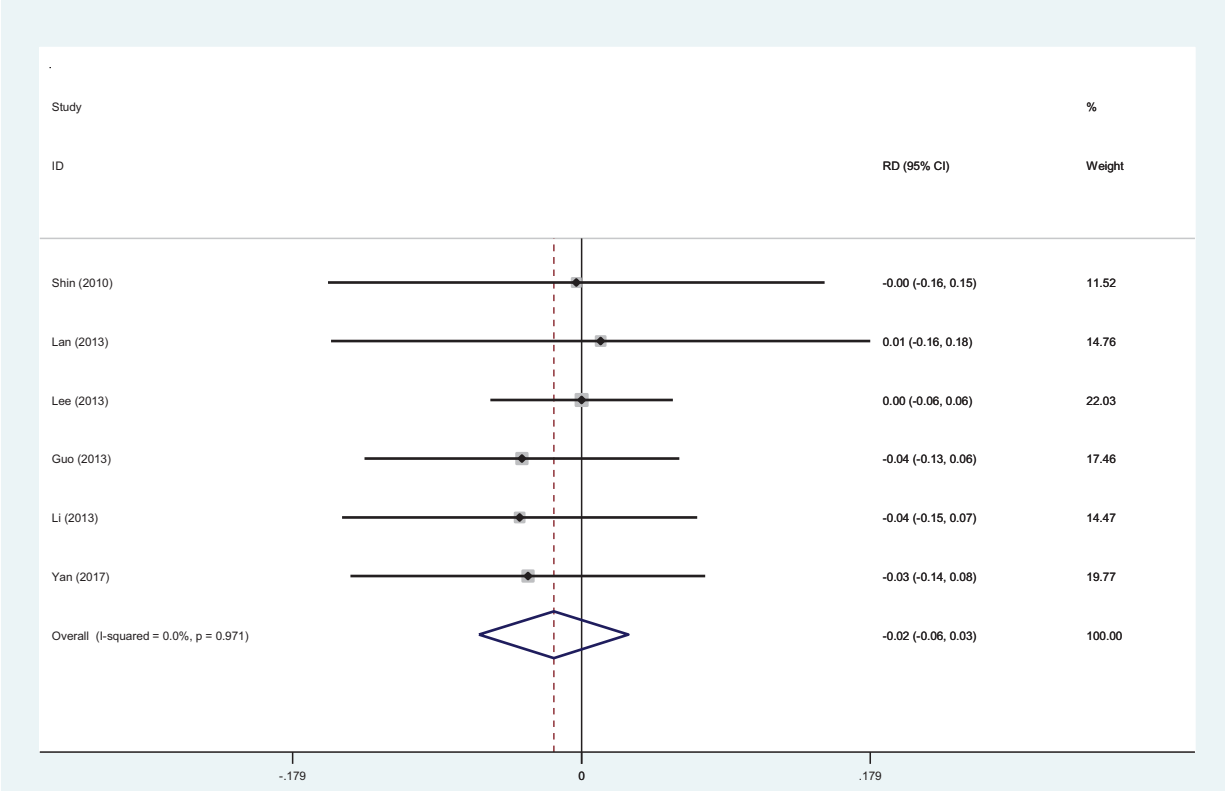


Figure 7. Meta-analysis for anatomical reduction between orthogonal groups and parallel groups.

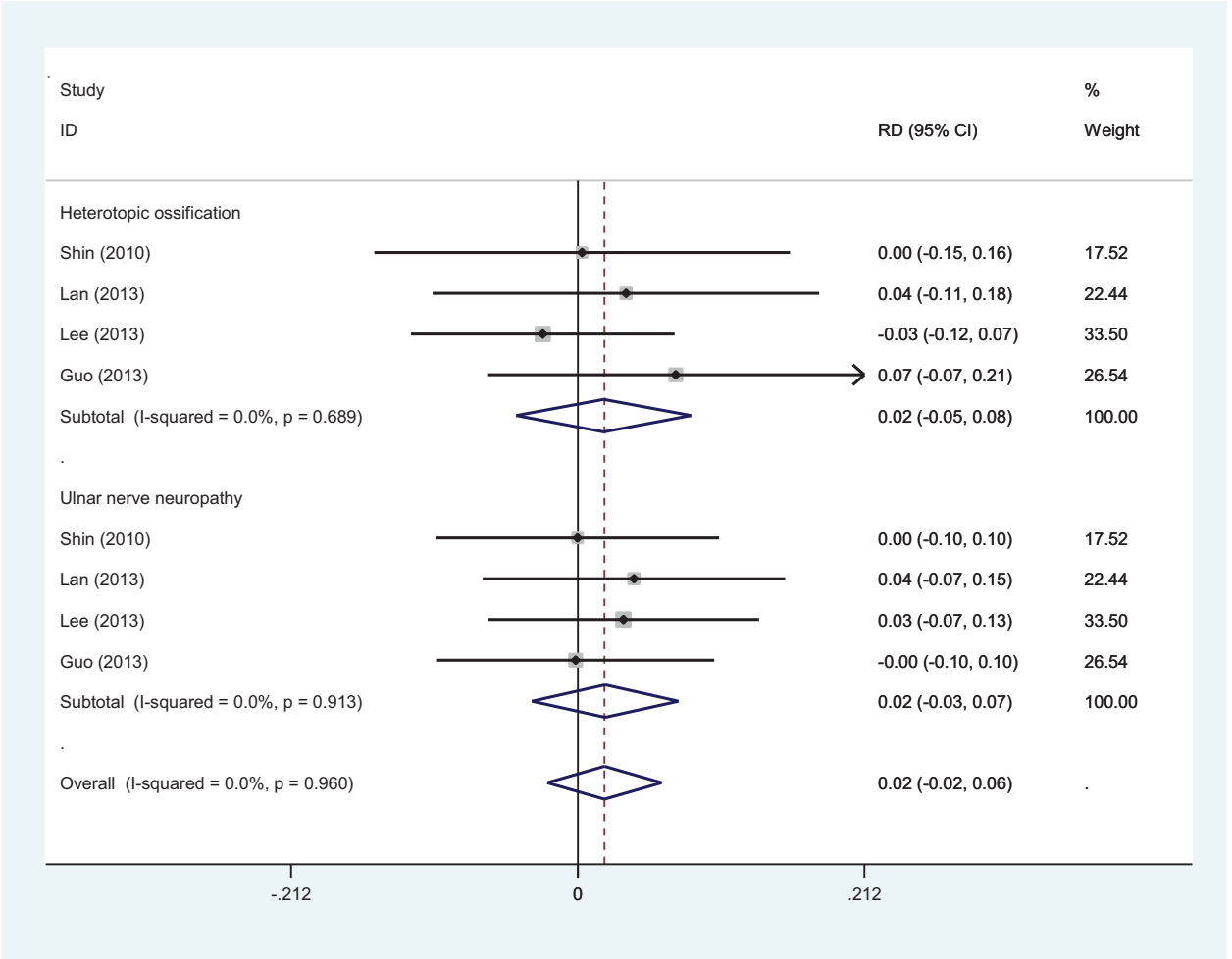


Figure 8. Meta-analysis for postoperative complications orthogonal groups and parallel groups.

indicates that further research is likely to significantly alter confidence in the effect estimate and may even change the estimate (Table 4).

4. Discussion

To the best of our knowledge, this is the first meta-analysis that has compared orthogonal and parallel plating methods for the treatment of distal humerus fractures. Our review indicated that orthogonal plating was associated with a longer union time compared with parallel plating.

Distal humerus fractures are often intraarticular comminuted fractures. This condition in combination with the complex anatomy of the elbow makes it quite difficult to medically manage. Published studies have reported that a double plating fixation was effective in treating distal humerus fractures.[19] Orthogonal and parallel plating are the most popular techniques. A nonunion is a common complication, which is associated with biomechanical properties of implants. Biomechanical trials have compared the mechanical properties between orthogonal and parallel plating systems for distal humerus fractures. Schwartz et al showed no significant differences in the stiffness of the 2 plate constructs when loading in any direction. Both systems demonstrated similar mechanical stiffness theoretically providing similar fracture stabilization. However, Stoffel et al[20] reported that the parallel locking system demonstrated improved stability compare with perpendicular locking system. Besides, Zalavras et al[21] indicated that the parallel plating method was biomechanically superior to the orthogonal plating method in a varus-loading test. Union time is the most important outcome to assess the efficacy between the various surgical treatments. As far as we are aware, the fixation methods that are based on pre-contoured plates were only compared in biomechanical studies. In our study, 4 RCTs with 200 participants reported the outcome of the union time between targeted groups. The present meta-analysis indicated that orthogonal plating was associated with a longer union time compared with the union time of parallel plating.

Functional outcomes are a major concern after surgical treatments and numerous articles have demonstrated the functional outcomes of parallel and perpendicular plating systems for distal humerus fractures. Huang et al[22] reported that perpendicular plates systems could achieve better satisfactory rate as high as 100%. Gofton et al[23] reviewed the functional outcome of AO type C distal humerus fractures managed with dual orthogonal plate fixation. The result revealed that patients

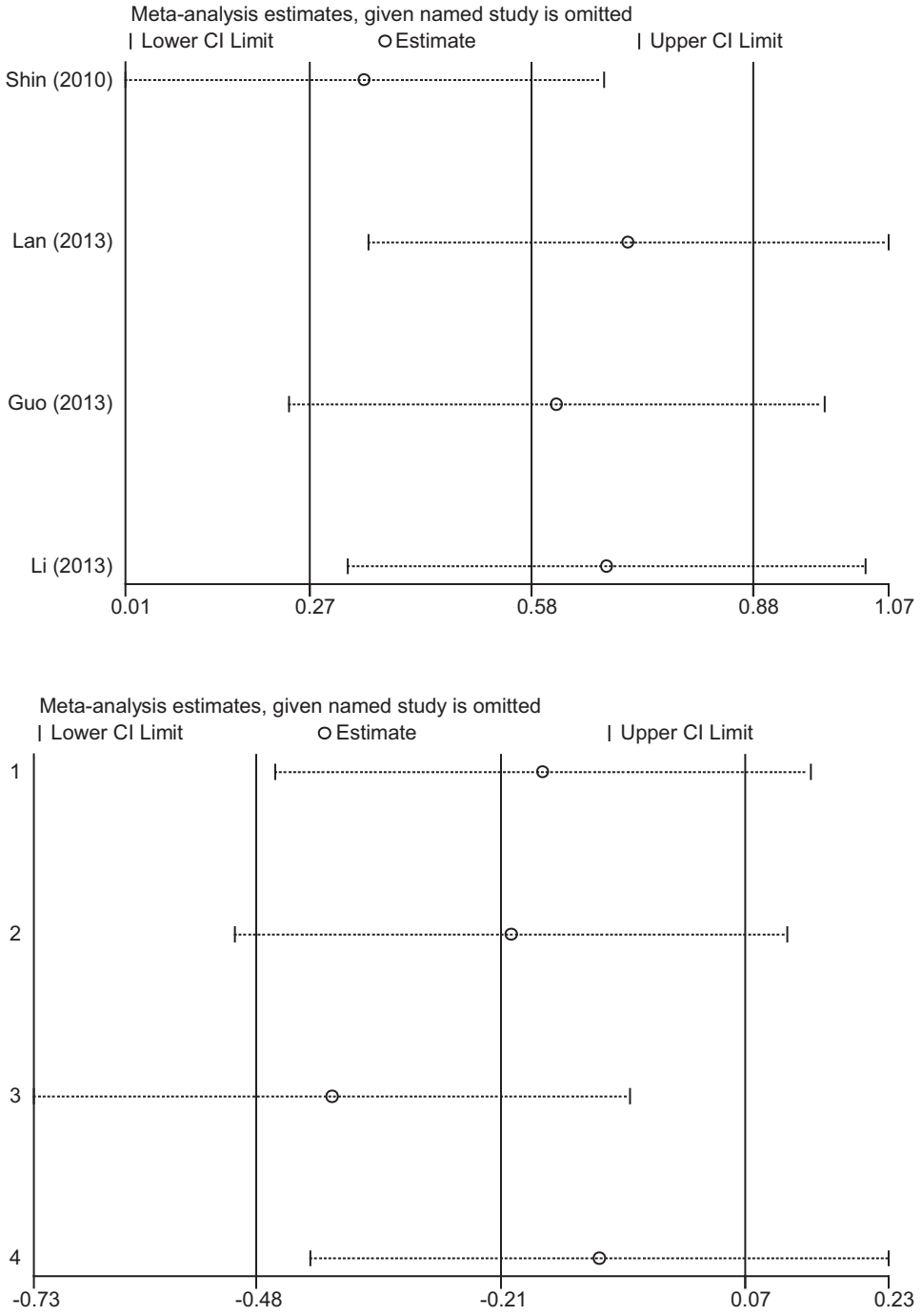


Figure 9. Sensitivity analysis.

identified minimal subjective deficits (10%) with a mean satisfaction of 93%. The mean flexion contracture for the affected arm was 19° ± 12°, which was greater than the unaffected arm at 10° ± 11°. Athwal et al[24] reviewed 37 patients with Type C distal humeral fractures treated by the bicolumn parallel plating system at a 27 months follow-up. The results showed that the mean arc of elbow flexion-extension motion was 97 degrees. The mean Mayo Elbow Performance Score was 82 points. There were no implant failures and all distal humerus fractures healed. The Mayo Elbow Performance score is an instrument used to test the limitations that are caused by pathology, and of the elbow during activities in daily living. It contains pain, range of motion, stability, and daily functions.[25] In our study, 4 RCTs with 192 patients reported the outcome of MEPS after an internal fixation. The present meta-analysis indicated that orthogonal plating showed similar functional recovery compared to parallel plating.

Both groups showed comparable results in operation times. However, complications after surgical treatments remains a major concern. Previous studies have reported that complication rates can be as high as 45% for distal humerus

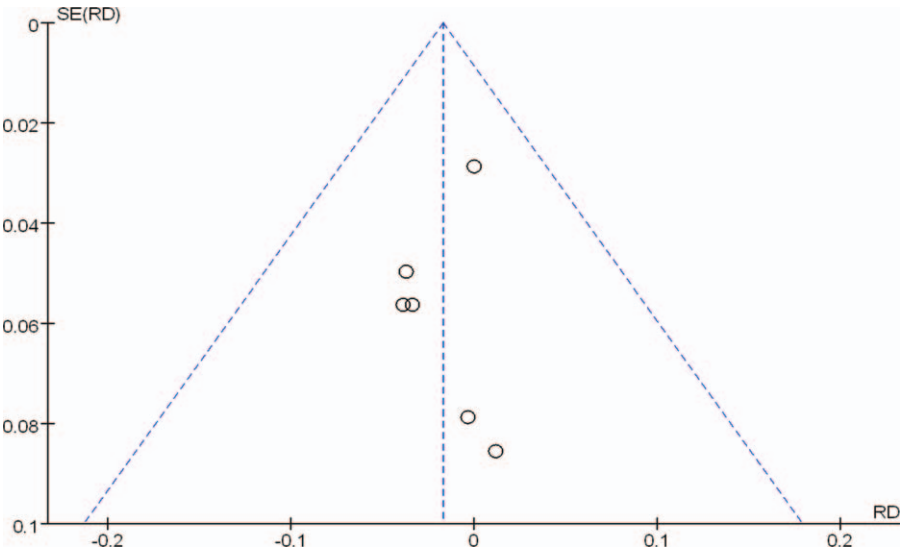


Figure 10. Publication bias.

fractures.[26] Heterotopic ossification and transient ulnar nerve neuropathy is the most common complication.[27,28] The reported prevalence of heterotopic ossification after the surgical treatment of distal humerus fractures ranges from 4% to 49%, although in most cases no functional deficit was involved.[29] The occurrence may be due to differences in the type of injury, time to treatment, methods of treatment, rehabilitation, and time of reporting. In our study, 4 RCTs with 200 patients were included, and the meta-analysis indicated that there were no statistically significant differences between the 2 groups.

There are several potential limitations of this meta-analysis.

1. Only 6 RCTs were included. It was concluded that more RCTs were needed in future studies because the sample size used in this study was considered to be too small for any definitive results.
2. Elbow function is an important parameter, with elbow function scores varying in the results. This may generate heterogeneity.
3. Publication bias was unavoidable because the identified language was restricted to English and;
4. combining clinical outcomes from different follow-up time points can introduce heterogeneities and potential biases.

Table 4

Quality of the evidence and recommendation strengths.

Quality assessment					Sample size				
Number of RCT	Limitations	Inconsistency	Indirectness	Imprecision	OP	PP	Outcome measures	Quality	Importance
Union time									
4	Serious limitations	No serious indirectness	No serious indirectness	No serious imprecision	100	100	WMD = 0.236; 95% CI = 0.029 to 0.444	Moderate	Critical
Elbow flexion									
5	Serious limitations	Serious inconsistency	No serious indirectness	No serious imprecision	126	119	WMD = −2.293; 95% CI = −5.806 to 1.221	Moderate	Critical
Elbow extension									
4	Serious limitations	No serious indirectness	No serious indirectness	No serious imprecision	103	104	WMD = −0.276; 95% CI = −2.981 to 2.429	Moderate	Critical
Mayo Elbow Performance Score									
4	Serious limitations	No serious indirectness	No serious indirectness	No serious imprecision	99	93	WMD = -2.127; 95% CI = −10.234 to 5.979	Moderate	Critical
Operation time									
3	Serious limitations	No serious indirectness	No serious indirectness	No serious imprecision	86	86	WMD = 2.700; 95% CI = −16.486 to 21.886	Moderate	Critical
Reduction quality									
6	Serious limitations	No serious indirectness	No serious indirectness	No serious imprecision	156	149	WMD = -0.017; 95% CI = −0.064 to 0.029	Moderate	Critical
Postoperative complications									
4	Serious limitations	No serious indirectness	No serious indirectness	No serious imprecision	100	100	RD = 0.020; 95% CI = -0.022 to 0.062	Moderate	Critical

OP = orthogonal plating, PP = parallel plating.

5. Conclusion

Both parallel plating and orthogonal plating are considered to be effective methods when treating distal humerus fractures. The results of this study found that parallel plating is superior to orthogonal plating in humerus fracture healing.

Author contributions

Guoyan Liu designs the study, collects the data and calculation. Xiaohan Wang writes the manuscript. All authors read and approved the final manuscript.
Conceptualization: Guoyan Liu.
Data curation: Guoyan Liu.
Formal analysis: Guoyan Liu.
Writing – original draft: Xiaohan Wang.

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