ORIGINAL ARTICLE

Open reduction and internal fixation versus external fixation for unstable distal radial fractures: A meta-analysis

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Summary

Purpose: To compare the clinical outcomes of open reduction and internal fixation (ORIF) versus the ones of closed reduction and external fixation (EF) in the treatment of distal radial fractures. Methods: We performed a meta-analysis of randomized controlled trials that compared the clinical results of ORIF to EF in the treatment of distal radial fractures. A systemic retrieve from PubMed, EMBASE, OVID and Cochrane Collaboration CENTRAL database resulted in 11 studies with 824 patients. We thus performed data synthesis using RevMan (version 5.1). Results: Superior statistical differences were observed for DASH scores (at 3, 6 and 12 months follow-up) grip strength (at 3 months follow-up), volar tilt (at 12 months follow-up), flexion and supination (at 3 months follow-up), and extension (at 3 and 6 months follow-up) in ORIF patients group, compared with those in EF group. We also found a significantly higher risk of infection associated with EF. There was no significant difference in the incidence of malunion and median nerve dysfunction. Conclusion: Regarding surgical fixation of unstable distal radius fractures, ORIF yields significantly better subjective outcome (DASH scores) the first year after operation, restoration of anatomic volar tilt, and forearm flexion and extension at the end of the follow-up period. However, EF results in higher incidence of infection compared to ORIF. ORIF is equal to EF for either grip strength, or range of motion of the injured wrist, or incidence of malunion or median nerve dysfunction at the end of the follow-up period. Level of Evidence: Level II. Therapeutic study.

KEYWORDS
Distal radial fractures; External fixation; Meta-analysis; Plate fixation; Systemic review

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Introduction

Distal radial fractures are among the most common fractures of the upper extremity [1] and account for almost one sixth of all fractures seen in the emergency room, with an annual incidence of 26 per 10,000 people [2]. While, unstable displaced distal radial fractures which are common in old people with osteopenic or osteoporotic condition are often caused by a simple fall or low energy injury. Many different treatment methods have been recommended: external fixation, open reduction and internal fixation with volar or dorsal plate. Multiple studies have demonstrated good clinical results with various plates, including dorsal, volar, column and fragment-specific devices [3–5]. In the past, open reduction and internal fixation in the management of unstable fractures of distal radial fractures has been the popular trend, but there have been many complications reported with the use of locked plating through various approaches, including rupture of tendons, carpal tunnel syndrome and complex regional pain syndrome [6,7]. Closed reduction and external fixation has been used for unstable distal radius fractures for several decades, while some complications have also been reported in many literatures, including pin-track infection, loss of reduction, stiffness of the fingers [8,9]. Currently, the importance of anatomic reduction and restoration of the articular surface has been stressed. Several studies have revealed a direct correlation between posttraumatic arthritis and intra-articular step deformities of 2 mm or greater [10]. Both of the two surgical management could lead to this complication [11]. However, both of the two surgical managements are still superior to other treatment. Other treatments, such as pin and plaster fixation and percutaneous pinning, have been described, but these methods are not suitable for the unstable distal radial fractures and these methods usually lead to a poor outcome [12].

To the best of our knowledge, in unstable and non-reducible distal radial fractures, surgical treatment is recommended but can be complex. And some observational or retrospective studies support the use of plate [13,14]. While, external fixation is also used commonly in distal radial fractures. Both of the two methods are suitable for unstable distal radial fractures. The best choice of treatment remains a topic of controversy for many years. Which is the most appropriate treatment for distal radial fractures needs more high quality studies to be proved. Our aim was to compare the radiological, complication rate, clinical and functional outcomes of the two groups of patients treated either by open reduction and internal fixation or external fixation for unstable distal radial fractures. Our hypothesis was that open reduction and internal fixation was superior to external fixation in the surgical treatment of unstable distal radial fractures.

Methods

Literature search

Systematic literature review and meta-analysis of randomized controlled trials comparing between the open reduction and internal fixation (ORIF) and closed or minimize invasive reduction and external fixation (EF) in treatment of distal radial fractures, as well as those reporting patient outcome were selected. The following electronic databases were used for the search: PubMed (1966–2012), Cochrane Collaboration CENTRAL database, EMBASE (1980–2012), and OVID (1966–2012). The following terms were adopted for each database search: “distal radial fractures”, “wrist injury”, “plate fixation”, “external fixation” and “randomized controlled trial”. Different search strategies were used for different databases. We placed no restrictions on the language of publication.

A manual search was also carried out using the references from the articles obtained by the method above, as well as other journals (the journal of bone and joint surgery, American or British volume and the journal of hand surgery, American or European volume) that published on the referred subject.

Eligibility criteria

Inclusion criteria

The inclusion criteria are:

- randomized controlled trials;
- adult patients aged more than 16 years;
- displaced unstable fracture impossible to retain in an acceptable position in cast after closed reduction;
- axial shortening of > 2 mm or a dorsal angulation > 10°;
- follow-up period > 6 months.

Exclusion criteria

The exclusion criteria are:

- patients with previous ipsilateral fracture, a history of premature osteoporosis, drug abuse, or alcohol abuse;
- open fracture (Gustilo and Anderson [15] type-II or III fractures) and patients who presented more than eight hours after the injury;
- pathological fracture;
- patients with mental disorders or were unable to answer a written questionnaire in English.

Outcomes

Primary outcomes

Disabilities of the Arm, Shoulder and Hand score (DASH): the DASH score is a validated self-reported thirty-item metric of upper extremity function based on a 100-point scale, with 0 points indicating no disability and 100 points indicating maximum disability [16].

Secondary outcomes

The secondary outcomes are:

- radiographic parameters: volar tilt, radial inclination, ulnar variance and radial length at 12 months;
- the grip strength at 3, 6 and 12 months follow-up;
- range of motion (ROM) of injured wrist (the values represent the percentage of the value on the uninjured wrist): flexion, extension, radial deviation, ulnar
deviation, pronation and supination at 3, 6 and 12 months follow-up;
- complications: incidence of infection, malunion rate and median nerve dysfunction rate. Malunion defined as follow [17]:
  - radial inclination: less than 15° on posteroanterior view,
  - radial length: more than 5 mm shortening on posteroanterior view,
  - radial tilt: more than 15° dorsal or 20° volar tilt on lateral view,
  - articular incongruity: more than to 2 mm of step-off.

Study selection

All the clinical trials identified were reviewed independently by two reviewers for selection by screening the titles and abstracts based on the eligibility criteria. The intensive reading of the full texts was performed when those studies met the inclusion criteria. In those cases where the original selection was discordant, the authors reviewed the articles together until a consensus was reached.

Data extraction

Two reviewers extracted the following data from the included studies independently, using the standardized data extraction method. The data extracted from the studies included the title, published year, authors, country, study design, sample size, population, age and sex distribution of subjects, type of interventions, duration of follow-up, and outcomes parameters. The corresponding author of each included study was contacted to obtain more information when it is necessary. The third and fourth authors checked the extracted data for accuracy.

Quality assessment

Two independent reviewers assessed both the quality and risk of bias of the included studies, according to the Cochrane Handbook for Systematic Reviews of Interventions, version 5.0 [18]. The following aspects were assessed: randomization, blinding of assessors, allocation concealment, and incomplete outcome data, if the study did have loss of patients, then check whether the ITT analysis was applied. If the study met all the aspects, the study was A level (low risk of bias); if one or more aspects were unclear, the study was B level (moderate risk of bias); if one or more aspects were inadequate, the study was C level (high risk of bias).

Data synthesis and analysis

Data were analyzed using Review Manager software (RevMan version 5.1; The Nordic Cochrane Center, The Cochrane Collaboration, Copenhagen, Denmark). The results were expressed in terms of risk ratio (RR) and a 95% confidence interval (95%CI) for dichotomous outcomes, and in terms of mean difference (MD) and 95%CI for continuous outcomes. Inverse variance method was used for continuous variables and Mantel-Haenszel analysis method was used for dichotomous variables [19]. The statistical significance was defined as P < 0.05.

Statistical heterogeneity was quantified using the chi-square and I-square tests. The P value < 0.10 was considered statistically significant. An I-square value less than 25% was considered homogeneous, an I-square value between 25% and 50% as low heterogeneity, an I-square value between 50% and 75% as moderate heterogeneity, and an I-square value above 75% as high heterogeneity [20]. A fixed effect model was applied when the studies were homogeneous or the statistical heterogeneity was low. However, when the statistical heterogeneity was moderate or high, we used the random effect model [21].

In this meta-analysis, subgroup analysis based on follow-up period was performed to assess DASH scores, grip strength and ROM, and we also check the included studies in each outcome to find the studies only used volar plates and performed a subgroup analysis based on volar plates.

Results

Search results

A total of relevant articles and abstracts were reviewed, of which eleven randomized controlled trials met the eligibility criteria. Other comparative studies were excluded were all retrospective.

Quality assessment

Seven studies [6,7,11,22–25] had comparable baseline in demographic characteristics, they had comparable the baseline of sample, patient’s age and sex distribution. One study [26] had uncomparable baseline, because it had uncomparable baseline of sample and sex distribution. Three studies [27–29] were unclear, of which two [27,28] had unclear baseline of age and sex distribution, and one [29] had unclear baseline of age distribution. Seven studies [6,7,11,24,26–28] mentioned exact randomization methods, while eight studies [6,7,11,22,24,26–28] documented concealment of randomization. But only one study [26] blinded to assessors, and none of the included studies mentioned blinding in orthopedic surgery trial. The methodological quality of one [26] of the total eleven studies was Level A, eight [6,7,11,23–25,27,29] were Level B and two [22,28] were Level C (Table 1). In addition, three studies documented conflict of interest, either directly or indirectly, with third parties [6,24,26].

Demographic characteristics

A total of 824 patients, consisting of 388 men and 436 women, were included, of whom 407 patients underwent ORIF and 417 patients underwent EF. For the ORIF group, there were a variety of plates, including volar, dorsal and volar combining dorsal plate. Volar plate was used in four studies [6,22,24,26], dorsal plate was used in one study [25]. There was one study [29] did not mention the style of plate in ORIF group, and one study used TriMed plate in ORIF group [27]. The rest of the studies used volar or
Table 1  Methodological quality of included studies.

<table>
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<th>Baseline</th>
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<th>Blinding of outcome assessment</th>
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### Table 2  Demographic characteristics of the included studies.

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<th>Study center</th>
<th>Sample size</th>
<th>Mean age (years)</th>
<th>Gender (f/m)</th>
<th>Intervention type</th>
<th>Follow-up (months)</th>
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<td>39</td>
<td>64.7 ± 3.5</td>
<td>64.6 ± 3.7</td>
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<td>RCT</td>
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<td>2011</td>
<td>One</td>
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<td>26</td>
<td>58 ± 9.9</td>
<td>53.8 ± 11.7</td>
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<td>Wilcke et al. [22]</td>
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<td>Sweden</td>
<td>2011</td>
<td>One</td>
<td>33</td>
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<td>2009</td>
<td>One</td>
<td>26</td>
<td>24</td>
<td>48 (20–65)</td>
<td>36/14</td>
<td>TriMed plate</td>
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<td>RCT</td>
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<td>One</td>
<td>12</td>
<td>22</td>
<td>61 ± 18</td>
<td>55 ± 16</td>
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<td>54 (17–60)</td>
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<td>2005</td>
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<td>45 ± 2.7</td>
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RCT: randomized controlled trial; ORIF: open reduction and internal fixation; EF: external fixation; V: volar plate; D: dorsal plate; R: radial plate; bridging: bridging external fixator; f: female; m: male.
dorsal or volar combining dorsal plate [7,11,23,28]. Seven studies [7,22,24,26–29] applied bridging external fixator, others [6,11,23,25] did not reported (Table 2).

Outcome analysis

Disabilities of the Arm, Shoulder and Hand scores
Four studies [22,24,26,27] reported the DASH scores, of which three studies [22,24,26] reported that at 3, 6 and 12 months follow-up, and one study [27] reported that at 3 and 12 months follow-up. We performed subgroup analysis according to the follow-up period. And we found significantly lower DASH scores at 3, 6 and 12 months follow-up for ORIF compared to EF, respectively (Figure 1). The mean difference of DASH scores at 3, 6 and 12 months follow-up through the random effect model were −12.28 (95%CI, −21.42 to −3.15; P = 0.008), −6.41 (95%CI, −9.82 to −2.99; P = 0.0002), −7.27 (95%CI, −12.40 to −2.15; P = 0.005) with the statistical heterogeneity (I² = 82%, P = 0.0008; I² = 0%, P = 0.70; I² = 49%; P = 0.12). Furthermore, we found that three studies [22,24,26] used volar plate and one [27] used TrMed plate among the four studies. By removing the latter one, we performed meta-analysis again, and found that there was also significant lower DASH scores at 3 (MD, −15.64; 95%CI, −24.31 to −6.96; P = 0.0004; I² = 72%), 6 (MD, −6.41; 95%CI, −9.82 to −2.99; P = 0.0002; I² = 0%) and 12 months (MD, −8.00; 95%CI, −15.55 to −0.45; P = 0.04; I² = 62%) follow-up for ORIF compared to EF, respectively.

Radiographic parameters
Four studies [7,24–26] reported the radiographic parameters at 12 months follow-up. There was a significantly greater loss of volar tilt in patients receiving EF, compared with those receiving ORIF (MD = −2.93; 95%CI, 1.33 to 4.53; P = 0.0003) (Fig. 2). However, no significant difference was found for for either radial inclination (MD = −0.88; 95%CI, −2.92 to 1.16; P = 0.40; I² = 81%), ulnar variance (MD = −0.54; 95%CI, −1.16 to 0.07; P = 0.08; I² = 27%) and radial length (MD = −0.09; 95%CI, −1.22 to 1.04; P = 0.87; I² = 37%) between the two groups. Volar plates were used in only two studies, subgroup analysis based on the type of plate fixation showed that volar plates also lead to significantly better restoration of volar tilt (MD, 4.66; 95%CI, 1.95 to 7.38; P = 0.0008; I² = 0%), whereas no statistical difference was found for either radial inclination, ulnar variance or radial length.

Grip strength
Five studies [6,7,22,24,26] reported the grip strength of participants, of which four studies [7,22,24,26] reported it at 3, 6 and 12 months follow-up and one study [6] reported it at 6 and 12 months follow-up. We found significant superior grip strength at 3 months follow-up with ORIF group. However, no significant differences were found for grip strength at 6 and 12 months follow-up between the two groups. The statistical heterogeneities were high within the three follow-up periods, and the random effect models were used (Fig. 3). Furthermore, among the five studies, volar plates were used in three studies, dorsal plates were used in one study and volar or dorsal plates were used in one study. By removing the latter two studies, we detected that volar plates were significantly better compared with EF at 3 months follow-up (MD, 13.95; 95%CI, 3.34 to 24.56; P = 0.010; I² = 73%). However, there was no significant difference between volar plates and EF at 6 (MD, 0.01; 95%CI, −14.36 to 14.38; P = 0.81; I² = 90%) and 12 months (MD, 1.72; 95%CI −12.31 to 15.75; P = 0.81; I² = 56%) follow-up.

Range of motion
ROM at 3, 6 and 12 months follow-up was reported by four studies [22,24–26], which included flexion, extension, radial deviation, ulnar deviation, pronation and supination. One study [25] only reported ROM at 3 months, and dorsal plates were used in this study. We detected significantly greater rehabilitation of flexion at 12 months follow-up (MD, 7.60; 95%CI, 2.94 to 12.26; P = 0.001; I² = 12%) (Fig. 4), extension at 6 (MD, 14.81; 95%CI, 5.49 to 24.13; P = 0.002; I² = 61%) and 12 (MD, 16.03; 95%CI, 4.28 to 27.77; P = 0.007; I² = 74%) months follow-up (Fig 5) and supination at 6 months follow-up among patients of ORIF group, compared with those in EF group. The rest of the ROM parameters were not significantly different between the two groups at any follow-up period. When removed the study using the dorsal plates, the analysis results did not change and this showed that it was volar plates lead to better rehabilitation of flexion at 6 months follow-up, extension at 3 and 6 months follow-up and supination at 3 months follow-up.

Complications
Eight studies [7,11,22,24,25,27–29] reported the incidence of infection. A significant difference in incidence of infection was found favoring plate fixation (RR, 0.37; 95%CI, 0.19 to 0.71; P = 0.003; I² = 0%) (Fig. 6). Malunion rate was reported by eight studies [6,11,22,23,26–29]. There was a non significant trend toward a lower malunion rate following ORIF compared with EF (RR, 0.67; 95%CI, 0.43 to 1.02; P = 0.06; I² = 0%). Four studies reported the incidence of median nerve dysfunction [6,22,23,28]. We found no significant difference in the incidence of median nerve dysfunction (RR, 0.85; 95%CI, 0.28 to 2.62; P = 0.78; I² = 20%).

Publication bias
To investigate the potential for publication bias, resulting from analysis comparing the incidence of infection between the ORIF group and the EF group were assessed using a funnel plot. Our funnel plot indicated limited evidence of small publication bias with a slightly asymmetrical plot with few studies plotted on the left tip of the funnel.

Discussion
DASH scores as the primary outcome revealed that, compared with EF, distal radial fractures with treatment of ORIF led to a superior performance in subjective outcome. This advantage over EF was evident at 3, 6 and 12 months follow-up periods, in which the volar plates lead to the same analysis results. Two of the included studies favored external fixation did not factor into this analysis, because they both did not used the DASH scores to assess the subjective outcome. And ORIF in one of the two studies included the Kirschner-wires, small T plates or both, and EF in the other study included supplementary K-wires, cannulated or
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1.1.4 3 months follow-up

<table>
<thead>
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<th>Study or Subgroup</th>
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<td>Heterogeneity: Tau² = 71.9; Chi² = 36.03; df = 3 (P = 0.0008); P = 82%</td>
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<td>Test for overall effect: Z = 3.64 (P = 0.0000)</td>
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1.1.5 6 months follow-up

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<th>EF</th>
<th>Mean Difference</th>
<th>Mean Difference</th>
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<td>Heterogeneity: Tau² = 0.09; Chi² = 0.70; df = 2 (P = 0.70); P = 6%</td>
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1.1.6 12 months follow-up

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<td>Heterogeneity: Tau² = 1.28; Chi² = 0.87; df = 2 (P = 0.12); P = 49%</td>
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<td>Test for overall effect: Z = 2.78 (P = 0.0056)</td>
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Figure 1 Forest plot to illustrate mean difference in Disabilities of the Arm, Shoulder and Hand scores at 3, 6 and 12 months follow-up between open reduction and internal fixation and external fixation.

Figure 2 Forest plot to illustrate mean difference in volar tilt at 12 months follow-up between open reduction and internal fixation and external fixation.

Figure 3 Forest plot to illustrate mean difference in grip strength at 3, 6 and 12 months follow-up between open reduction and internal fixation and external fixation.
Figure 4  Forest plot to illustrate mean difference in flexion at 12 months follow-up between open reduction and internal fixation and external fixation.

Figure 5  Forest plot to illustrate mean difference in extension at 6 and 12 months follow-up between open reduction and internal fixation and external fixation.

Figure 6  Forest plot to illustrate risk ratio in incidence of infection between open reduction and internal fixation and external fixation.
regular small- or mini-fragment screws. Hence, the data of the two studies was not fit for the analysis of subjective outcome. Many cohort studies [30,31] had reported the DASH scores of the distal radial fractures, which had the same conclusion, and one study [32] reported the similar DASH scores between the two groups at 17 months follow-up period, but other randomized controlled trials [22,26,33] reported that the plated patients had better DASH scores only in the first 3 months, or at 6 and 12 months. However, these cohort studies were all retrospective and the mentioned RCTs included a small number of patients and their methodological qualities were low, as a consequence, were unlikely to demonstrate very strong evidence to support one treatment option over another. One most possible explanation for the difference of DASH scores of our meta-analysis could be that plate osteosynthesis could restore the bony anatomy as a stable internal fixation, which could allow patients to have a more active early mobilization regime. After removing the study that did not use the volar plates, we found that patients fixed with volar plates also achieved better DASH scores, and this was a significant difference. Possible explanation was that the volar cortex of the radius was not often as comminuted as the dorsal cortex and, furthermore, it had a large surface that allowed a stable apposition of the plate [34].

Radiographic parameters have clinical importance in the rehabilitation of distal radial fractures. Our meta-analysis showed no statistical difference in radial inclination, ulnar variance and radial length except the volar tilt, and so did volar plate comparing with EF. However, many other studies [30,31] show that radiographic parameters are significantly better in the patients treated with ORIF. If we study the mentioned studies carefully, we can find that these studies are all retrospective which cannot provide strong evidences.

There may be various explanations for the increased grip strength in the ORIF group at 3 months follow-up. The fractures in the ORIF group might be better aligned at operation and/or a better reduction might be maintained during the healing, leading to a better congruency of the joint. Meanwhile, when external fixator was removed, patients in EF group began to take functional exercises, and grip strength was recovering gradually. Hence, there was no significant difference in grip strength at 6 and 12 months follow-up. Kopylov et al. [39] found that the early difference about grip strength between the two groups was similar to our meta-analysis. By only including the studies using volar plate, this difference remained significant.

The main objective of the treatment of distal radial fractures is to achieve a painless and function wrist with a satisfactory degree of mobility [24]. Following a distal radial fracture, the attainment and maintenance of anatomical reduction of the articular surface is crucial to the preservation of wrist function [28]. In our meta-analysis, although there was no significant difference in radiographic parameters (except the volar tilt), we detected significantly better rehabilitation of flexion, extension and supination in ORIF group, compared with those in EF group. When excluded the study using the dorsal plate, we also found that patients treated with volar plates achieve the same results.

In our meta-analysis, we only analyzed the incidence of infection, malunion and median nerve dysfunction as the representative of complications. Higher incidence of infection has been reported in patients treated with EF [36]. The high incidence of infection of EF group might be explained by that pin tract was tend to be infected because of less or incorrect nursing. Moreover, the deep infection probably correlated with insufficiency of sterilization of the pins and fixator. Malunion rate as an important index for distal radial fractures was evaluated, although no significant difference was found, an obvious trend that ORIF led to a lower malunion rate could be detected. More RCTs are needed to be performed, so as to obtain a more authentic conclusion. Median nerve dysfunction is common complication of distal radial fractures with the incidence estimated at 4% [37]. We detected no significant difference between ORIF and EF. Some authors stated that it occurs with no regard to the fracture type, the amount of initial displacement, the adequacy of reduction or the method of operative treatment [37–41]. Our results confirmed the last one.

Our meta-analysis had several limitations. First, the samples of the included studies were so small, which made the evidence weaker. Second, patients in ORIF group treated with not only the volar plate, but also the dorsal plate or volar combined with dorsal plate. Meanwhile, patients in EF group treated with bridging fixator or non-bridging fixator. Both of the aspects could impact the results of the meta-analysis. The reason why we did not conduct sub-group analysis was that the number of included studies was too small to use this method except the DASH scores, grip strength and ROM. Third, publication bias was detected by funnel plot.

In our meta-analysis of randomized controlled trials on displaced unstable distal radial fractures, we found the following:

- ORIF yields significantly better DASH scores at 3, 6 and 12 months after operation, comparing with EF, and so does the volar plates;
- ORIF is likely to better maintain restoration of anatomical volar tilt;
- ORIF leads to significantly greater recovery of grip strength at 3 months after operation. However, there is no significant difference between ORIF and EF at 6 and 12 months after operation;
- ORIF leads to significantly better flexion at 12 months follow-up, extension at 6 and 12 months follow-up and supination at 6 months follow-up. However, no significant difference was found at 12 months follow-up period.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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