Research Article

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Comparison between minimally invasive plate osteosynthesis and open plating for proximal humeral fractures: a meta-analysis

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Aim: We conducted this meta-analysis for comparing the efficacy and safety in proximal humeral fractures by treatment minimally invasive plate osteosynthesis and open plating. **Methods:** The potential academic literature were identified from the Cochrane Library, Springer, PubMed, Embase and ScienceDirect. Pooled data were analyzed by RevMan 5.1. **Results:** Seven studies marched with the inclusion criteria. Meta-analysis showed the significant differences in terms of blood loss, operative time, length of hospital stays and constant score between two groups. No significant differences were found in time to union, the union rate and complications. **Conclusion:** Minimally invasive plate osteosynthesis in proximal humeral fractures provided significantly shorter operative times, length of hospital stays, less blood loss and better clinical outcomes without increasing complications.

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Keywords: minimally invasive • plate • proximal humeral fracture

The proximal humeral fracture (PHF) is a common fracture in the extremities and account for approximately 4–5% of all adult fractures [1]. The morbidity and severity of PHF is increasing year by year due to an increased number of older patients with osteoporotic fractures [2]. Nonsurgical treatment and surgical treatment are used to treat these fractures [3]. Surgical treatment, including external fixation, plating, intramedullary fixation and shoulder arthroplasty, has been reported to be associated with earlier resumption of daily activity and good clinical outcomes [4–6]. Of these, open reduction and internal fixation (ORIF) is the most commonly used technique for the majority of fractures and has been considered to be the gold standard surgical treatment [7,8]. However, ORIF inevitably exposes the fracture region and strip periosteum [9,10] and reveals complications such as postoperative infection, nonunion, nerve injury and hardware removal.

Minimally invasive plate osteosynthesis (MIPO) is popular for its advantages of reserving and avoiding extensive soft tissue dissection [11–13]. Thus, MIPO provides more favorable conditions for fracture healing by preserving local fracture biology. To date, several researches had been reported that compared MIPO with ORIF in the treatment of PHF. The methodological flaws in the published literature include poor study designs, small sample sizes and variable outcomes, although a meta-analyses has been published to discuss comparisons of MIPO with ORIF in the treatment of PHF [14]. However, this literature had a few limitations, such as language bias, lacking updated studies published in recent years and some errors in counting the characteristics of included studies. Therefore, it is necessary to conduct a large sample meta-analysis from randomized controlled trials (RCTs) and non-RCT studies to compare the efficacy and safety of MIPO with ORIF in the treatment with PHF.

Methods

Search strategy

The literature searches were performed in Cochrane Library, Springer, PubMed, Embase and ScienceDirect from 1966 to March 2018. Secondary sources were identified from studies cited in the references of retrieved articles.

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No studies were excluded based on language. The key search terms applied were 'humeral fracture', 'plate', 'open' and 'minimally invasive' in combination with the Boolean operators AND or OR.

Inclusion criteria

The following criteria were considered eligible as including studies: patients with proximal humeral fractures; intervention: treated with MIPO; control: treated with ORIF; outcome measures, one or more of the following outcomes were reported: operative time, blood loss, union time, function score, perioperative outcomes and complications and study design: RCT and non-RCT.

Exclusion criteria

We excluded studies that were: studies without controlled groups; unavailable full-text versions; unavailable outcomes data and pathological fractures or multiple fractures.

Selection criteria

Data were extracted from the included studies by two independent researchers. We contacted the corresponding author for additional information in case of the study with an incomplete data. The following information was extracted: the first author's name, publication year, interventions, outcome measures, sample size and comparable baselines. Other relevant parameters were also extracted from the individual studies.

Quality assessment

The methodological index for non-randomized studies form was used to assess non-RCT [15]. Quality assessment for the RCTs was conducted according to a modification of the generic evaluation tool described in the Cochrane Handbook for systematic review of interventions [16]. A third reviewer resolved disagreements.

Data extraction

The data were extracted from the included trials by two independently researchers. In cases of incomplete data, the corresponding author of the study was contacted for additional information. The following information was extracted: the first author's name, publication year, interventions, outcome measures, sample size and comparable baselines.

Data analysis & statistical methods

The RevMan 5.1 (The Cochrane Collaboration, Oxford, UK) were used for data analysis. The mean difference (MD) and 95% confidence intervals (CIs) were determined for continuing outcomes. The dichotomous data were calculated by the risk difference and 95% CIs. The heterogeneity was estimated by I^2 based on the standard chi-square test. When $I^2 < 50\%$ and $p > 0.1$, no significant heterogeneity existed, and a fixed-effects model was used for the data analyzing while a random-effects model was used when $I^2 > 50\%$ and $p < 0.1$. Subgroup analysis was performed to investigate the sources of heterogeneity.

Results

Search results

The search strategy identified 158 citations as potentially relevant literature reports. By screening titles and abstracts, 151 references were excluded due to the eligibility criteria. No additional studies were obtained after the reference review. Ultimately, one RCT and six non-RCTs were eligible for data extraction and meta-analysis [9,10,17–21]. A flow chart of the studies recruited in our review was shown in Figure 1.

Risk of bias assessment

A summary of the methodological assessment results is presented in Figure 2. All the seven parameters showed low risks of bias of RCT. The methodological index for non-randomized studies scores of non-RCTs were 16–20. A summary of the methodological assessment results is presented in Table 2.

Study characteristics

The characteristics of the included studies are shown in Table 1. There was no significant difference between demographic variables in the study. The studies' sample sizes ranged from 28 to 107 shoulders.

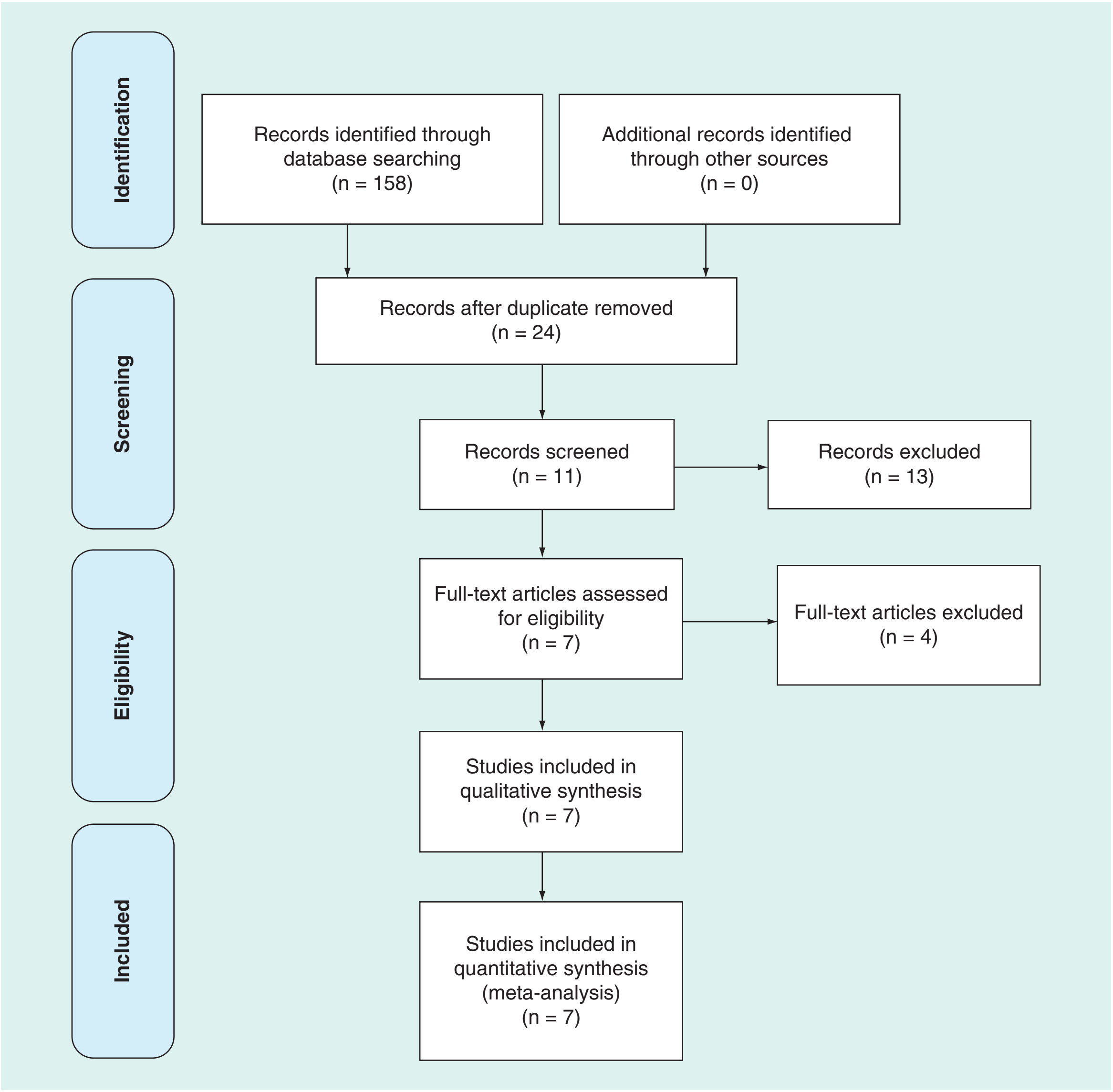

Figure 1. Flowchart of the study selection and inclusion process.

Outcomes of meta-analysis

Operative time

Operative time was shown in seven articles [9,10,17–21]. A random-effects model was performed with obvious heterogeneity (I^2 = 88%; $p < 0.00001$). Operative time in the MIPO group was significantly lower than in the ORIF group (MD = -15.58; 95% CI: -23.44 to -7.73; p = 0.0001; Table 3).

Blood loss

Blood loss was mentioned in six articles [9,17–21]. A random-effects model was performed with obvious heterogeneity (I^2 = 98%; $p < 0.00001$). Blood loss in the MIPO group was significantly lower than that in the ORIF group (MD = -77.95; 95% CI: -151.01 to -4.89; p = 0.04; Table 3).

Time to union

Time to union was shown in three studies [10,17,21]. A random-effects model was performed with obvious heterogeneity (I^2 = 91%; $p < 0.0001$). There was no significance between the two groups regarding time to union (MD = -0.94; 95% CI: -5.58 to 3.70; p = 0.69; Table 3).

Figure 2. The summary of bias risk of randomized controlled trials.

Table 1. Characteristics of included studies.

Study (year)	Group	Simple size	Age (Y)	Gender (M/F)	Fracture classification (two/three/four)	Follow-up months	Refs.
Chiewchantanakit (2015)	MIPO ORIF	12 16	51.9 62.2	4/8 8/8	8/4/0 6/10/0	NS NS	[17]
Lin (2014)	MIPO ORIF	43 43	63 61	16/27 12/31	10/24/9 9/22/12	12 12	[18]
Liu (2015)	MIPO ORIF	39 52	60.2 61.7	17/22 25/27	15/18/6 18/25/9	24 24	[9]
Liu (2016)	MIPO ORIF	33 42	50.3 52.1	12/21 16/26	22/11/0 25/17/0	14.2 14.2	[19]
Röderer (2011)	MIPO ORIF	46 61	67.6 65	13/33 19/42	NS NS	12 12	[20]
Sohn (2017)	MIPO ORIF	45 45	61 62.6	NS NS	17/21/7 18/23/4	14.3 15	[10]
Zhao (2017)	MIPO ORIF	17 19	64.0 64.3	9/8 12/7	8/9/0 7/12/0	10 10	[21]

F: Female; M: Male; MIPO: Minimally invasive plate osteosynthesis; NS: Not stated; ORIF: Open reduction and internal fixation; Y: Year.

Union rate

Union rate was provided in four articles [9,18,19,21]. A fixed-effects model was performed without heterogeneity (I^2 = 12%; p = 0.33). There was no significance between the two groups regarding the union rate (risk difference = 0.00; 95% CI: -0.04 to 0.50; p = 0.83; Table 3).

Length of hospital stay

Length of hospital stay was reported in three studies [17,18,20]. A fixed-effects model was performed without heterogeneity (I^2 = 6%; p = 0.35). Length of hospital stay in the MIPO group was significantly lower than that in the ORIF group (MD = -1.05; 95% CI: -1.71 to -0.39; p = 0.002; Table 3).

Postoperative functional assessment

Constant score at postoperative 3 months were provided in two studies [9,18]. A fixed-effects model was performed without heterogeneity (I^2 = 0%; p = 0.68). Constant score at postoperative 3 months in the MIPO group was significantly higher than that in the ORIF group (MD = 4.47; 95% CI: 1.95–7.00; p = 0.005; Table 3). Constant

Table 2. Quality assessment for non-randomized trials.

Quality assessment for nonrandomized trials	Chiewchantanakit (2015) [17]	Lin (2014) [18]	Liu (2015) [9]	Liu (2016) [19]	Röderer (2011) [20]	Zhao (2017) [21]
A clearly stated aim	2	2	2	2	2	2
Inclusion of consecutive patients	2	2	2	2	2	2
Prospective data collection	0	0	0	0	0	0
End points appropriate to the aim of the study	2	2	2	2	2	2
Unbiased assessment of the study end point	2	2	2	2	2	2
A follow-up period appropriate to the aims of study	2	2	2	2	2	2
Less than 5 % loss to follow-up	2	0	2	2	2	2
Prospective calculation of the sample size	0	0	0	0	0	0
An adequate control group	2	2	2	2	2	2
Contemporary groups	2	0	2	2	2	2
Baseline equivalence of groups	2	2	2	2	2	2
Adequate statistical analyses	2	2	2	2	2	2
Total score	20	16	20	20	20	20

Table 3. Meta-analysis results.

Outcome	Studies	Groups (MIPO/ORIF)	Overall effect			Heterogeneity	
			Effect estimate	95% CI	p-value	I^2(%)	p-value
Operative time	7	235/278	-15.58	-23.44; -7.73	0.0001	88	<0.00001
Blood loss	6	190/233	-77.95	-151.01; -4.89	0.04	98	<0.00001
Time to union	3	74/80	-0.94	-5.58; 3.70	0.69	91	<0.0001
Union rate	4	132/156	0.00	-0.04; 0.05	0.83	12	0.33
Length of hospital stay	3	101/120	-1.05	-1.71; -0.39	0.002	6	0.35
Constant score							
3 months	2	82/95	4.47	1.95; 7.00	0.005	0	0.68
6 months	2	82/95	4.07	1.52; 6.63	0.002	0	0.55
12 months	4	132/156	2.14	1.20; 3.08	0.00001	0	0.54
Complications							
Avascular necrosis	4	163/200	-0.01	-0.05; 0.03	048	32	0.22
Impingement	3	134/149	-0.01	-0.05; 0.04	0.82	0	0.83
Screw perforation	3	134/149	0.01	-0.05; 0.08	0.72	0	0.51
Implant loosening	3	130/158	0.01	-0.06; 0.07	0.83	0	0.71
Nerve injury	4	111/130	0.01	-0.03; 0.04	0.65	0	0.94
Delayed union	2	85/113	-0.01	-0.04; 0.03	0.76	0	0.53
Infection	3	96/122	-0.01	-0.06; 0.04	0.69	0	0.73
Stiff shoulder	2	91/106	-0.01	-0.08; 0.06	0.87	57	0.13
Varus collapse	2	88/88	0.00	-0.06; 0.06	1.00	0	0.39

CI: Confidence interval; MIPO: Minimally invasive plate osteosynthesis; ORIF: Open reduction and internal fixation.

score at postoperative 6 months was provided in two studies [9,18]. A fixed-effects model was performed without heterogeneity (I^2 = 0%; p = 0.55). Constant score at postoperative 6 months in the MIPO group was significantly higher than that in the ORIF group (MD = 4.07; 95% CI: 1.52–6.63; p = 0.002; Table 3). Constant scores at postoperative 12 months were reported in four included studies [9,18,19,21]. A fixed-effects model was performed without heterogeneity (I^2 = 0%; p = 0.54). Constant score at postoperative 12 months in the MIPO group was significantly higher than in the ORIF group (MD = 2.14; 95% CI: 1.20–3.08; p = 0.00001; Table 3).

Complications

Complications were reported in all six included studies. A fixed-effects model was performed without heterogeneity. No significant difference between the two groups regarding all complications, such as avascular necrosis of humerus

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head, impingement, screw perforation, implant loosening, nerve injury, delayed union, infection, stiff shoulder and varus collapse (Table 3).

Discussion

Plate fixation has been regarded as an effective treatment for PHF. ORIF and MIPO are two different plate fixation procedures [22]. In the present meta-analysis, we pooled the most recent evidence from both RCTs and non-RCTs and provided the most reliable evidence. This meta-analysis illustrated that, compared with ORIF, MIPO could decrease operative time, blood loss, length of hospital stays and show more effective recovery of shoulder joint function in the treatment of PHF. Based on the results, MIPO is a safe technique with no significant postoperative complications.

Technically, the MIPO technique avoids directly exposing the fracture site to preserve the enveloped soft tissue around the fracture site [23]. Liu *et al.* [19] reported that MIPO in PHF requires a shorter length of incision than ORIF during the surgery (6.74 vs 16.82 cm). In the present meta-analysis, pooled results indicated that MIPO decrease operative time, blood loss and length of hospital stay. The small incision contributed to the significantly reduced operative time and blood loss.

Several surgeons believed that the MIPO technique maintains the periosteal circulation and potentially accelerates the fracture union process [9,10]. Chiewchantanakit *et al.* [17] reported that MIPO offers a shorter time to union than ORIF in PHF (12 vs 20 weeks). Pooled results indicated that no significant differences in time to union ($p = 0.71$) and union rate ($p = 0.82$) were found between the MIPO and ORIF groups. These may be due to the small sample size of included studies, including simple fractures or better protection of blood supply during ORIF.

Shoulder postoperative function is another element in determining the effectiveness of MIPO in PHF. Different scoring systems were used to assess shoulder function. The Constant score is a clinician-assessed score that has been used extensively in the literature to record patient outcomes following shoulder surgery. The pooled result found MIPO provides a better constant score at postoperative 3, 6 and 12 months ($p = 0.005$; $p = 0.002$ and $p = 0.004$, respectively). Liu *et al.* reported that constant score and the disabilities of arm, shoulder and hand questionnaire score at postoperative 24 months were not significantly different. The better postoperative function score indicated good rehabilitation.

Malreduction screw perforation or nerve injury may occur because fracture reduction was indirect in the MIPO technique. Complications with MIPO also lead to orthopedic surgeons' concern. The pooled results showed no significant differences in impingement, screw perforation, implant loosening, nerve injury, infection, stiff shoulder and varus collapse between the two groups. Although the MIPO technique preserves periosteal blood supply without directly exposing the fracture area, pooled result show that MIPO did not decrease the incidence of avascular necrosis of the humeral head in short-term follow-up. The incidence of avascular necrosis of the humeral head may increase in patients with middle- or long-term follow-up.

There are several limitations should be listed: only one RCT was included, which weakened our power to draw a definitively confirming conclusion; the sample sizes were small in most studies; according to the limited number of included studies, the source of heterogeneity could not be determined. We could not perform subgroup analysis in this meta-analysis, and the follow-up period is relatively short and might underestimate the complications.

Conclusion

MIPO in PHF provided significantly shorter operative times, blood loss and length of hospital stay. The MIPO technique had better clinical outcomes compared with ORIF without increasing complications. Further studies that include larger sample sizes, and more detailed clinical data with a longer follow-up time are required to confirm our conclusion.

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Summary points

- Minimally invasive plate osteosynthesis (MIPO) is popular for its advantages of reserving and avoiding extensive soft tissue dissection in fracture healing.
- A meta-analysis was conducted to compare the efficacy and safety of MIPO with open reduction and internal fixation in the treatment with proximal humeral fracture.
- Systematic Cochrane Library, Springer, PubMed, Embase, and ScienceDirect searches (January 1966–March 2018) yielded 158 results; 7 studies were included for review.
- Meta-analyses were conducted using a fixed-effects or random model that reported risk difference or mean differences and 95% credible intervals.
- MIPO had the lower operative time (MD = -17.33; 95% CI: -27.22 to -7.45; p = 0.0006), blood loss (MD = -90.87; 95% CI: -167.24 to -14.49; p = 0.02), and length of hospital stay (MD = -1.05; 95% CI: -1.71 to -0.39; p = 0.002), and higher constant score than open reduction and internal fixation.
- Results for union, union rate and complications were similar across comparators.
- MIPO in proximal humeral fractures provided significantly shorter operative times, length of hospital stay and less blood loss.
- MIPO technique had better clinical outcomes compared with open plating without increasing complications.

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