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Antegrade intramedullary nail versus plate fixation in the treatment of humeral shaft fractures

An update meta-analysis

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Abstract

Background: There is no consensus regarding the surgical treatment of humeral shaft fracture. The present meta-analysis was performed to compare the efficacy and safety between antegrade intramedullary nailing (IMN) and plating for humeral shaft fracture.

Methods: PubMed, MEDLINE, Cochrane Library, EMBASE, Clinical Trails, Ovid, ISI Web of Science, and Chinese databases including WanFang Data, China National Knowledge Infrastructure were searched through March 10, 2019. The Review Manager software was adapted to perform statistical analysis and relative risk (RR) were used for the binary variables, and weighted mean difference and standardized mean difference (SMD) were used to measure the continuous variables. Each variable included its 95% confidence interval (CI).

Results: A total of 15 trials with 839 patients were included in the analysis. There was significant difference between IMN group and plate group in blood loss (SMD=3.49, 95% CI: 1.19, 5.79, P=.003) and postoperative infections (RR=3.04, 95% CI: 1.49, 6.24, P=.002). Additionally, significant difference was observed between minimally invasive plate osteosynthesis (MIPO) group and IMN group in nonunion rate (RR=3.20, 95% CI: 0.12, 0.84, P=.02). Statistical significance was also observed between the open reduction plate fixation group and IMN group in restriction of shoulder and elbow joints results (RR=0.49, 95% CI: 0.26, 0.96, $P<.05$). No significant difference was observed for the operation time, American Shoulder and Elbow Surgeons score, nerve injury, delayed union, reoperation in either group.

Conclusion: IMN may be superior to plate in reducing blood loss and postoperative infections for the treatment of humeral shaft fracture. However, MIPO was superior to IMN group in nonunion and equal to IMN in other parameters. Further research is required and future studies should include analysis of assessments at different stages and follow-up after removal of the implants.

Abbreviations: 95% CI = 95% confidence interval, ASES = American Shoulder and Elbow Surgeons, CCTs = clinical controlled trials, CNKI = China National Knowledge Infrastructure, COP = conventional open plating, DCP = dynamic compression plate, HSS = Hospital for special surgery, IMN = intramedullary nailing, LCP = locking compression plate, MIPO = minimally invasive plate osteosynthesis, NA = not available, NOS = Newcastle–Ottawa scale, ORPF = open reduction plate fixation, RCTs = randomized controlled trials, RR = relative risk, SMD = standardized mean difference, WMD = weighted mean difference.

Keywords: humeral shaft fractures, meta-analysis, nail, plate

1. Introduction

Humeral shaft fracture is one of the most common fractures in adults, accounting for approximately 3% of all fracture types.[1] Whether or not surgical intervention is required for humeral shaft fractures remains controversial, but for comminuted fractures, multiple fractures, severely displaced fractures, or fractures associated with vascular and nerve injuries, surgical treatment is still required. However, the failure of traditional plate and screw internal fixation is relatively high.[2] With the continuous improvement of internal fixation technology and implants, recent reports suggest that intramedullary nailing (IMN) or locking plate internal fixation have a good clinical effect in the treatment of humeral shaft fractures.[3–5] There is no consensus in

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the literature on which method is better and the advantages and disadvantages of the two ways. Although several studies have compared the clinical outcomes of plating versus IMN in the treatment of humeral shaft fractures, the optimal surgical treatment of these fractures remains controversial.[6,7]

At present, there are numerous comparative studies on these two algorithms. However, a handful of high-quality comparative studies are reported, and the quantity and quality of trials included in previous meta-analysis are limited. In addition, the conclusions are inconsistent. The present meta-analysis included 15 high-quality studies published before March 2019. Different from the previous meta-analysis, the function results were evaluated from American Shoulder and Elbow Surgeons (ASES) score and the excellent and good function rate. The plate group was divided into subgroups to reach more accurate conclusion. The aim of the present study was to systematically evaluate the efficacy of the two treatment methods and provide a theoretical basis for clinical decision.

2. Materials and methods

2.1. Meta-analyses principles

We performed all the analyses based on previously published studies, thus no ethical approval was required. The meta-analysis followed the principles of "Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)" statement (S1, http://links.lww.com/MD/D367 Checklist).[8]

2.2. Search strategy

Three individual investigators (WHJ, LCZ, and ZSY) searched the selective databases according to the principles of the Cochrane collaboration. The following databases were searched: PubMed, MEDLINE, Cochrane Library, EMBASE, Clinical Trails, Ovid, ISI Web of Science, and Chinese databases including WanFang Data, China National Knowledge Infrastructure (CNKI), and Chinese Biomedical Literature databases. All the databases were searched up to March 2019, with no limitation of language. We performed the literature search by using the keywords of "humeral shaft," "humeral diaphyseal," "humeral diaphysis," "intramedullary nail," and "plate." Any differences are resolved through consensus and discussion.

2.3. Study selection

The inclusion criteria were as follows:

(i) closed humeral shaft fracture treated with plate or intramedullary nail;
(ii) the modified Jadad scale (S3, http://links.lww.com/MD/D369, S4, http://links.lww.com/MD/D370) of randomized controlled trials (RCTs) ≥4 or Newcastle-Ottawa scale (NOS) (S2, http://links.lww.com/MD/D368) of case-controlled study, prospective, or retrospective trail > 7;
(iii) age ≥ 18 yeas old;
(iv) treatment protocols were either plating or IMN, and the patient's clinical data was complete.

Exclusion criteria were as follows:

(i) Reviews, meta-analyses, case reports, letters, and editorial articles;
(ii) duplicates of previous published papers; and
(iii) studies which children included (<18 years old).

2.4. Data extraction

In order to extract the data, a standardized selective protocol was designed. The outcome parameters were as follows: ASES score, functional results, complications, operation time, blood loss, and bone union time. The following characteristics of each eligible study were recorded: the first author, publication year, country, intervention, case number, average age, gender, follow-up, fracture type, and modified Jadad scale.

2.5. Quality assessment

Modified Jadad scale, NOS, and Cochrane's risk of bias tool were adapted to evaluate bias and risk of each eligible study.[9] All the investigators evaluated each included trial, and the modified Jadad scale and NOS scores are illustrated in Table 1. In addition, the risk of bias graph and summary were make up (Fig. 2).

Table 1

Characteristics of included studies.

			Intervention		Mean age (yr)		Number		Gender female (%)					Fracture type (AO)			
Studies	Year	Country	Plate	IMN	Plate	IMN	Plate	IMN	Plate	IMN	Follow-up (mo)	Rate of follow-up (%)	Type of study	A	B	C	Studies assessment scale
Chapman JR[12]	2000	USA	ORPF	Anterograde	34 (18–83)	33 (18–70)	46	38	45.7	31.6	13 (4–48)	100	RCT	NR	5†		
McCormack[13]	2000	Canada	ORPF	Anterograde	49 (20–81)	40 (19–82)	23	21	78.3	38.1	14.3 (6–33)	93.2	RCT	18	19	7	4†
Benegas E[10]	2007	NR	ORPF	Anterograde	42.2 ± 17.6	36.4 ± 18	14	11	35.7	9.1	21 (12–42)	100	RCT	50	35	14	4†
Changulani M[11]	2007	India	ORPF	Anterograde	35 ± 11.5	39 ± 12	24	23	20.8	13	14.3 (6–33)	95.7	RCT	26	13	8	5†
Putti[14]	2009	India	ORPF	Anterograde	39	36	18	16	6.3		>24	100	RCT	19	25	0	4†
Singisetti[15]	2010	England	ORPF	Anterograde	18–70		25	20	23		12 (10–24)	91.1	RCT		NR		5†
Li D[19]	2011	China	ORPF	Anterograde	34.3 (18–61)	34.6 (19–60)	14	21	NR		13 (10–25)	80	RCT		NR		4†
Li Y[20]	2011	China	ORPF	Anterograde	35.7 ± 10.9	39.9 ± 11.3	23	22	30.4	27.3	12	95.6	RCT	15	21	9	5†
Chaudhary P[21]	2011	Indonesia	ORPF	Anterograde	36.5	34.5	30	30	75	25	6	100	RCT		NR		6†
Benegas[17]	2014	Brazil	MIPO	Anterograde	44.8 ± 17.1	38.4 ± 19.1	21	19	42.9	27.8	24	90%	RCT	21	11	8	7†
Wali[22]	2014	India	ORPF	Anterograde	37.72 ± 12.7	37.28 ± 12.26	25	25	20	16	17.3	100	RCT		NR		4†
Fan[18]	2015	China	ORPF	Anterograde	39.2 ± 10.3	39.3 ± 10.8	30	30	36.7	40	12	100	RCT	23	29	8	4†
Zhang[16]	2015	China	ORPF	Anterograde	49.62 ± 2.95		50	50	39		NR	NR	RCT	61	26	13	4†
Kulkarni[24]	2017	India	MIPO	Anterograde	39.55 (18–70)		44	68	25.9		>6	100	CCT	73	28	11	8*
Bisaccia[23]	2017	Italy	ORPF	Anterograde	52.5	58.9	32	26	53.1	57.7	11.5 (9–16)	100	CCT	39	11	8	8*

Values are shown as n, mean, mean standard deviation or mean range.
* NOS = Newcastle-Ottawa scale.
† Modified Jadad scale.
CCT = clinical controlled trial, IMN = intramedullary nail, MIPO = minimally invasive plate osteosynthesis, NR = never report, ORPF = open reduction and plate fixation, RCT = randomized controlled trial.

2.6. Statistical analyses

The Review Manager software (version 5.3; The Nordic Cochrane Centre, Copenhagen, Denmark) was adapted to perform statistical analysis and establish forest plots. Relative risk (RR) estimation was used for the binary variables, and weighted mean difference (WMD) and standardized mean difference (SMD) were used to measure continuous variables. Each variable is presented with its 95% confidence interval (CI). Meta analysis was performed on the data included in the study, and the studies with clinical homogeneity were divided into a subgroup, and then statistical homogeneity was analyzed ($I^2 < 50\%$, $P > .01$ is the test standard of homogeneity). When the homogeneity between subgroups was low ($I^2 < 50\%$, $P > .05$), the fixed effect model was used; otherwise, the random effect model was applied. When the I^2 value was inconsistent with the P value, the P value was used as the standard to select the processing model. When $P < .05$, the difference was considered statistically significant.

2.7. Patient and public involvement

No patients and public were involved in the present study. The results of the present research will be communicated to the relevant patient community.

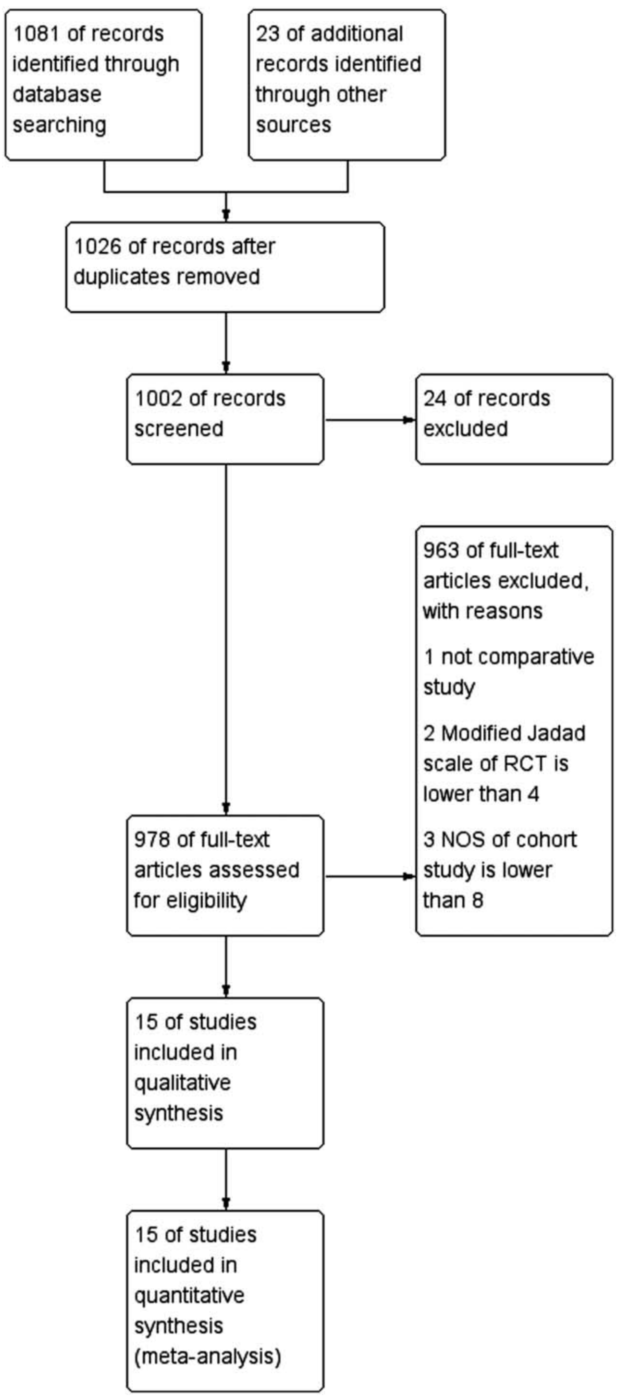

Figure 1. The study selection and inclusion process.

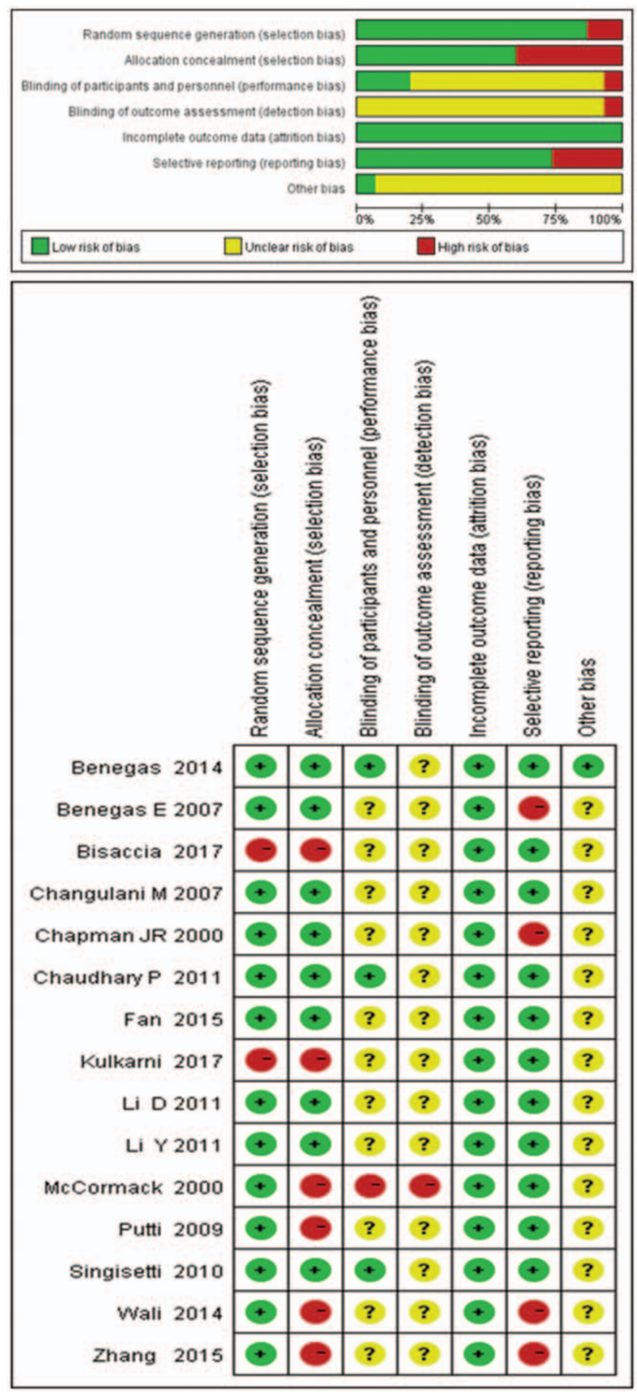

Figure 2. Methodological quality of the included studies and risk of bias.

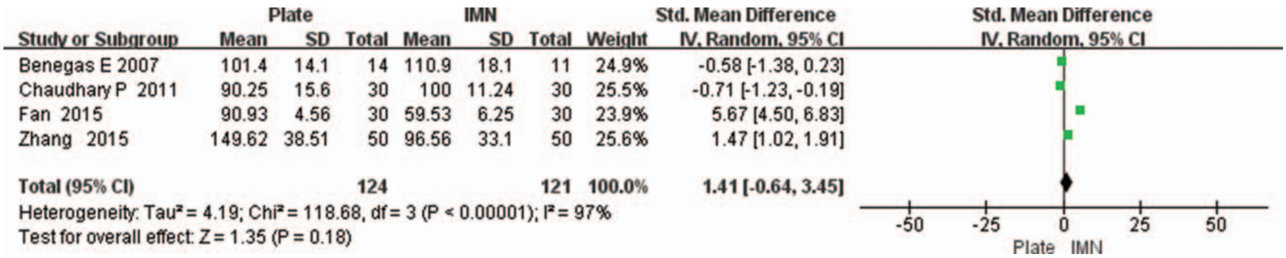

Figure 3. Forest plot for meta-analysis of operation time between the plate and IMN groups.

3. Results

3.1. Study characteristics

The search procedure is shown in Figure 1. Initially, 1104 related studies were searched, and 216 trials were excluded according to the title and abstract. Then, according to the inclusion criteria, 973 studies were excluded from the 988 studies which might be relevant. Finally, 15 studies[10–24] were included in the meta-analysis, including a total of 839 patients. To avoid heterogeneity, studies which only applied plate or intramedullary nail were excluded. In this paper, intervention of plate fixation was set as the study group, and in contrary, intramedullary nail fixation as the control group. Baseline characteristics of the studied article and patients are shown in Table 1.

Overall, 13 RCTs and 2 clinical controlled trials (CCTs) were included in this study. Modified Jadad scale of all the eligible RCTs[10–22] was greater than or equal to 4 and NOS of the CCTs[23,24] was greater than 7 (the highest was 10). Only 3[15,17,21] applied blinding methods, which may lead to observation bias; in addition, there was one article[16] that did not report the loss of follow-up. The main problem in the included trials lies in the implementation of randomization and the improper use of the blinding methods, which may lead to a moderate degree of bias. The specific quality evaluation of the 15 studies is shown in Figure 2.

3.2. Operation time

Overall, 4 studies[10,16,18,21] reported operation time, and significant heterogeneity was found ($P<.01$, $I^2=97\%$). Random effect model was used and the results showed that there was no significant difference between the two groups (SMD=1.41, 95% CI: –0.64, 3.45, $P=.18$), indicating no difference in operation time between the study group and the control group (Fig. 3).

3.3. Blood loss

Blood loss were described in 3 studies,[16,18,21] and significant heterogeneity was found ($P<.01$, $I^2=97\%$). Random effect model was used and the results showed that there was significant difference between the two groups (SMD=3.49, 95% CI: 1.19, 5.79, $P=.003$). The blood loss for IMN group was lower than plate group (Fig. 4).

3.4. ASES score

In total, 5 studies[10,13,14,18,20] compared the ASES score, and no significant heterogeneity was found ($P=.55$, $I^2=0\%$). Fixed effect model was used and the results showed that there was no significant difference between the two groups (SMD=0.15, 95% CI: –0.10, 0.41, $P<.24$), indicating there was no significant difference in ASES score between the plate group and the IMN group (Fig. 5).

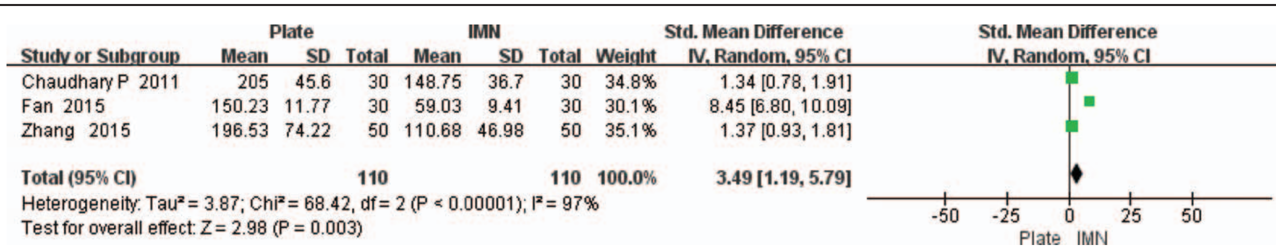

Figure 4. Forest plot for meta-analysis of blood loss between the plate and IMN groups.

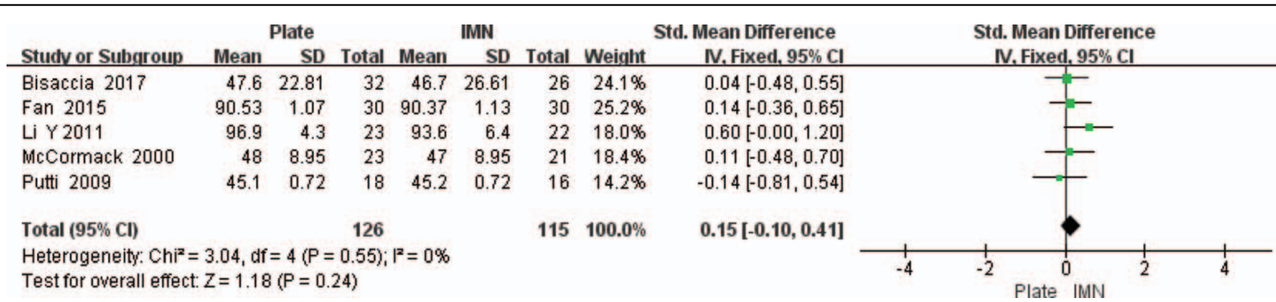

Figure 5. Forest plot for meta-analysis of ASES score between the plate and IMN groups.

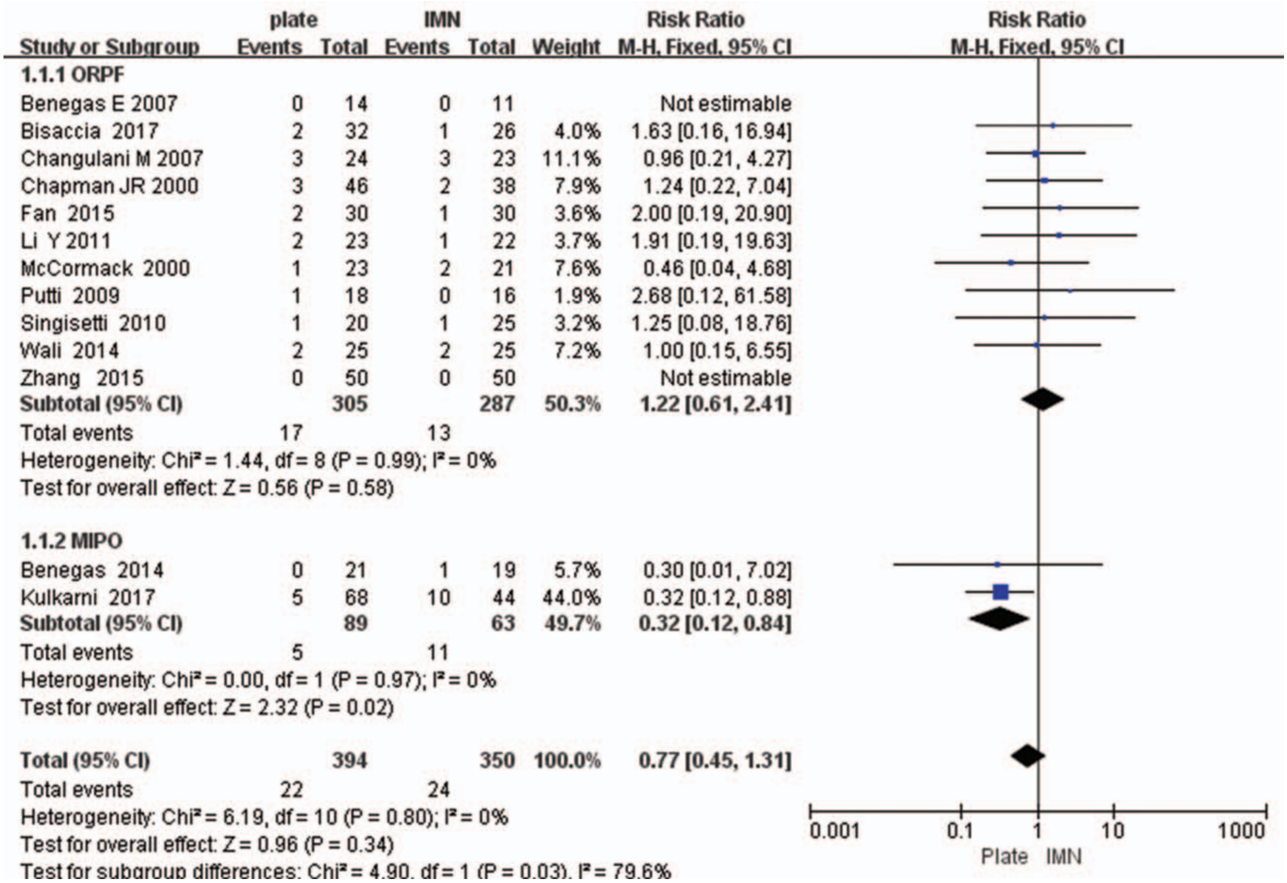

Figure 6. Forest plot for meta-analysis of nonunion rate between the plate and IMN groups.

3.5. Nonunion rate

In total, 13 studies[10–18,20,22–24] compared the nonunion results, and no significant heterogeneity was found ($P=.80$, $I^2=0\%$). Fixed effect model was applied and the results showed that there was no significant difference between the two groups (RR=.77, 95% CI: 0.45, 1.31, $P=.34$). However, when plate group was divided into open reduction plate fixation (ORPF) group and minimally invasive plate osteosynthesis (MIPO) group, there was significant difference between MIPO group and IMN group (RR=3.20, 95% CI: 0.12, 0.84, $P=.02$). Therefore, the results indicated no difference in nonunion rate between the ORPF group and the IMN group, but MIPO group was superior to IMN group (Fig. 6).

3.6. Nerve injury

Nerve injury results were reported in 12 studies,[10–20,22] and no significant heterogeneity was found ($P=.34$, $I^2=12\%$). Fixed effect model was applied and the results showed that there was no significant difference between the two groups (RR=1.07, 95% CI: 0.49, 2.34, $P=.86$), indicating no difference in rate of nerves injury between the plate group and the IMN group (Fig. 7).

3.7. Postoperative infections

Rate of infections after operation were mentioned in 13 studies,[10–20,22,24] which showed no significant heterogeneity ($P=.93$, $I^2=0\%$). Fixed effect model was applied and the results showed that there was significant difference between the two groups (RR=3.04, 95% CI: 1.49, 6.24, $P=.002$). However, when plate group was divided into ORPF group and MIPO group, there was no significant difference between MIPO group and IMN group (RR=3.20, 95% CI: 0.52, 19.68, $P=.21$). Therefore, the results for postoperative infection rate for IMN group was lower than for ORPF group ($P=.006$) (Fig. 8).

3.8. Reoperation

Reoperation results were described in 12 studies,[10–20,22] and no significant heterogeneity was found ($P=.19$, $I^2=39\%$). Fixed effect model was applied and the results showed that there was no significant difference between the two groups (RR=0.40, 95% CI: 0.12, 1.31, $P=.13$), indicating no difference in reoperation between the plate group and the IMN group (Fig. 9).

3.9. Delayed union

A total of 11 studies[10–17,19,20,22] described the reoperation results, and no significant heterogeneity was found ($P=.81$, $I^2=0\%$). Fixed effect model was applied and the results showed that there was no significant difference between the two groups (RR=.58, 95% CI: 0.31, 1.06, $P=.08$), indicating no difference in delayed union between the plate group and the IMN group (Fig. 10).

Study or Subgroup	plate Events	plate Total	IMN Events	IMN Total	Weight	Risk Ratio M-H, Fixed, 95% CI
Benegas 2014	0	21	0	19		Not estimable
Benegas E 2007	0	14	0	11		Not estimable
Changulani M 2007	1	24	1	23	9.0%	0.96 [0.06, 14.43]
Chapman JR 2000	1	46	2	38	19.3%	0.41 [0.04, 4.38]
Fan 2015	0	30	0	30		Not estimable
Li D 2011	1	14	0	21	3.6%	4.40 [0.19, 100.91]
Li Y 2011	3	23	0	22	4.5%	6.71 [0.37, 122.83]
McCormack 2000	0	23	3	21	32.1%	0.13 [0.01, 2.39]
Putti 2009	0	18	2	16	23.2%	0.18 [0.01, 3.47]
Singisetti 2010	1	20	0	25	3.9%	3.71 [0.16, 86.55]
Wali 2014	2	25	0	25	4.4%	5.00 [0.25, 99.16]
Zhang 2015	0	50	0	50		Not estimable
Total (95% CI)		**308**		**301**	**100.0%**	**1.07 [0.49, 2.34]**
Total events	9		8			

Heterogeneity: Chi² = 7.97, df = 7 (P = 0.34); I² = 12%
Test for overall effect: Z = 0.18 (P = 0.86)

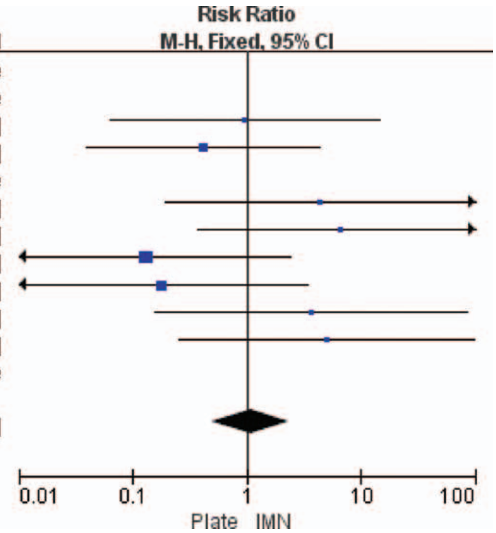

Figure 7. Forest plot for meta-analysis of nerve injury between the plate and IMN groups.

3.10. Restriction of shoulder and elbow joints

Restriction of shoulder and elbow joints results were reported in 12 studies,[10–17,19,21,22,24] and no significant heterogeneity was found ($P=.20$, $I^2=28\%$). Fixed effect model was applied and the results showed that there was a statistically significant difference between the ORPF group and IMN group (Fig. 12) (RR=.49, 95% CI: 0.26, 0.96, $P<.05$). The restriction of shoulder and elbow joints result for the ORPF group were superior to IMN group. There was no significant difference between the MIPO group and IMN group (Fig. 12) (RR=3.16, 95% CI: 0.37, 26.6, $P=.29$), indicating no difference in restriction of shoulder and

Study or Subgroup	plate Events	plate Total	IMN Events	IMN Total	Weight	Risk Ratio M-H, Fixed, 95% CI
1.3.1 ORPF						
Benegas E 2007	0	14	0	11		Not estimable
Changulani M 2007	5	24	1	23	10.6%	4.79 [0.60, 37.95]
Chapman JR 2000	3	46	0	38	5.7%	5.81 [0.31, 109.06]
Fan 2015	0	30	0	30		Not estimable
Li D 2011	1	14	0	21	4.2%	4.40 [0.19, 100.91]
Li Y 2011	0	23	0	22		Not estimable
McCormack 2000	0	23	1	21	16.3%	0.31 [0.01, 7.12]
Putti 2009	1	18	0	16	5.5%	2.68 [0.12, 61.58]
Singisetti 2010	2	20	1	25	9.2%	2.50 [0.24, 25.63]
Wali 2014	3	25	1	25	10.4%	3.00 [0.33, 26.92]
Zhang 2015	7	50	2	50	20.8%	3.50 [0.76, 16.03]
Subtotal (95% CI)		**287**		**282**	**82.8%**	**3.01 [1.38, 6.57]**
Total events	22		6			
Heterogeneity: Chi² = 2.54, df = 7 (P = 0.92); I² = 0%						
Test for overall effect: Z = 2.77 (P = 0.006)						
1.3.2 MIPO						
Benegas 2014	1	21	1	19	10.9%	0.90 [0.06, 13.48]
Kulkarni 2017	5	68	0	44	6.3%	7.17 [0.41, 126.60]
Subtotal (95% CI)		**89**		**63**	**17.2%**	**3.20 [0.52, 19.68]**
Total events	6		1			
Heterogeneity: Chi² = 1.14, df = 1 (P = 0.28); I² = 13%						
Test for overall effect: Z = 1.25 (P = 0.21)						
Total (95% CI)		**376**		**345**	**100.0%**	**3.04 [1.49, 6.24]**
Total events	28		7			

Heterogeneity: Chi² = 3.66, df = 9 (P = 0.93); I² = 0%
Test for overall effect: Z = 3.04 (P = 0.002)
Test for subgroup differences: Chi² = 0.00, df = 1 (P = 0.95), I² = 0%

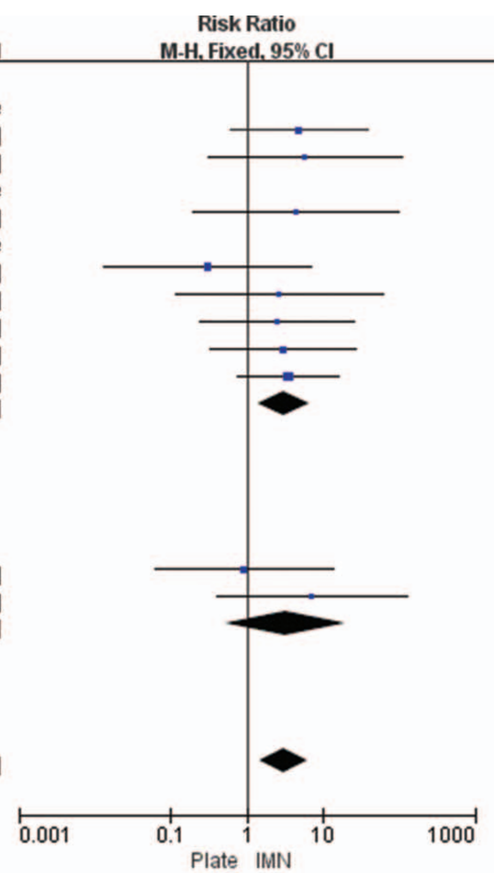

Figure 8. Forest plot for meta-analysis of postoperative infections between the plate and IMN groups.

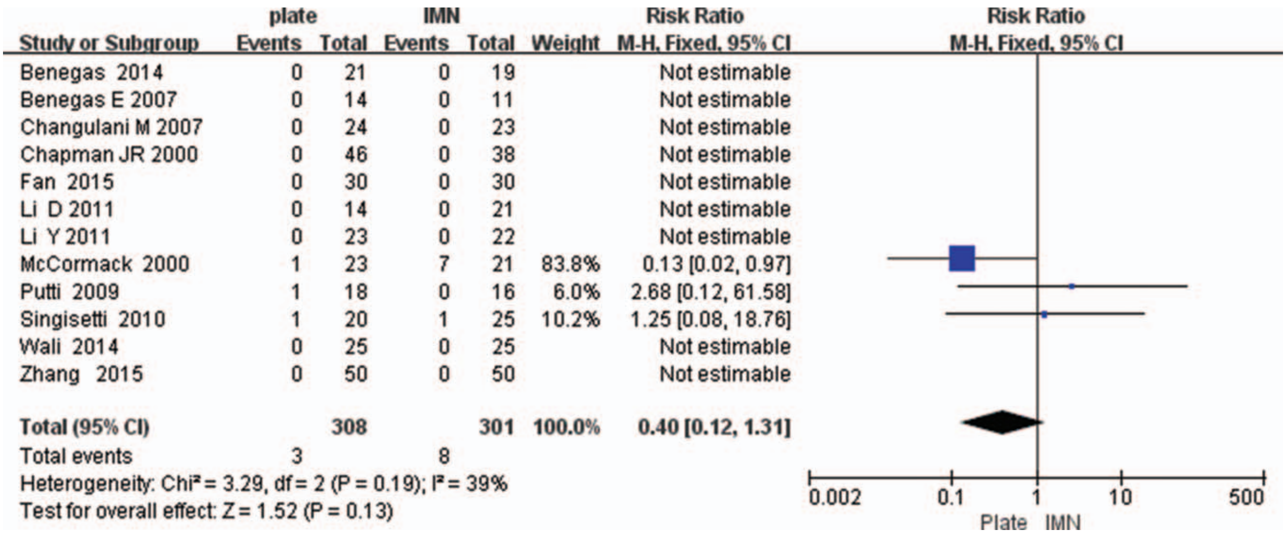

Figure 9. Forest plot for meta-analysis of reoperation between the plate and IMN groups.

elbow joints between the MIPO group and the IMN group (Fig. 11).

3.11. Publication bias test

A funnel plot of bone results was used to analyze whether there was publication bias. As can be seen from the funnel plot, the two sides of the funnel plot are symmetrical, indicating low publication bias (Fig. 12).

4. Discussion

Surgical treatment of humeral shaft fractures is usually recommended for patients with associated neurovascular injury, open fractures, associated elbow and forearm fractures, and polytrauma.[5,25] At present, there is no agreement and powerful guidance on surgical protocol of humeral shaft fracture. The main surgical methods include ORPF, intramedullary nail fixation, and MIPO and each algorithm has its own advantages and disadvantages. In recent years, there have been lots of comparative studies and certain meta-analysis[6,7,26–28] on the treatment of humeral shaft fractures with plate and intramedullary nail. Davies et al performed a retrospective study. They suggested that humeral MIPO results in a significantly lower pooled major complication rate than that of IMN.[29] Another prospective case-control study indicated that the MIPO technique in treating the mid-distal humeral shaft fracture is superior to IMN in union time, complication rate, and functional and clinical results.[30] On the contrary, Ozan et al described that inflatable intramedullary nails seem to be applicable, safe, and effective for humeral AO/OTA type A midshaft fractures.[31] Besides, Heineman et al performed a meta-analysis in 2010, they did not find a statistically significant difference between implants in the rate of total complications, nonunion, infection, nerve-palsy, or the need for reoperation.[32]

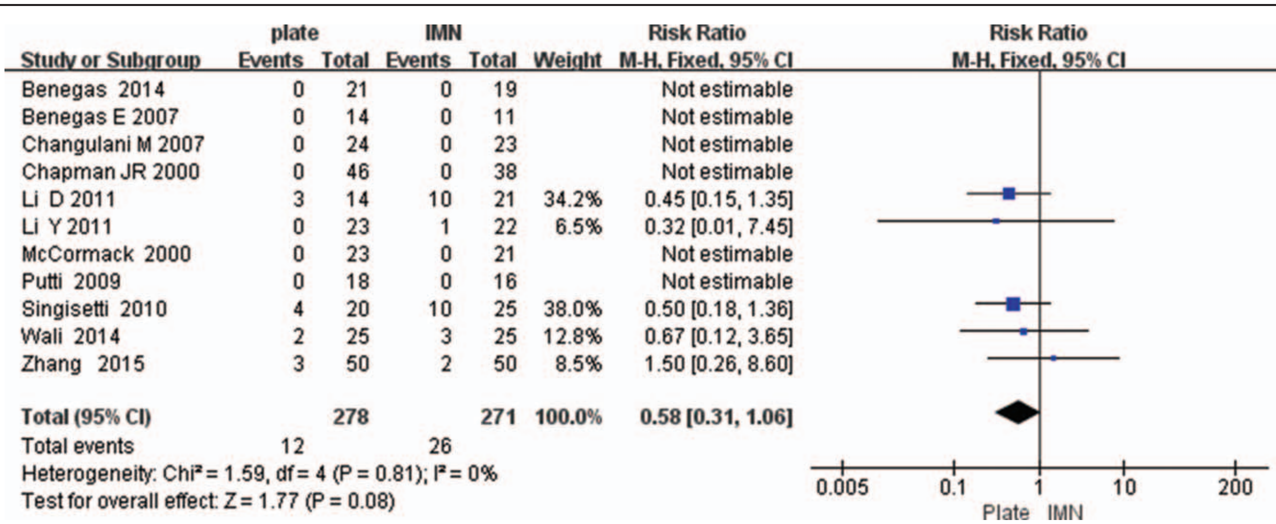

Figure 10. Forest plot for meta-analysis of delayed union between the plate and IMN groups.

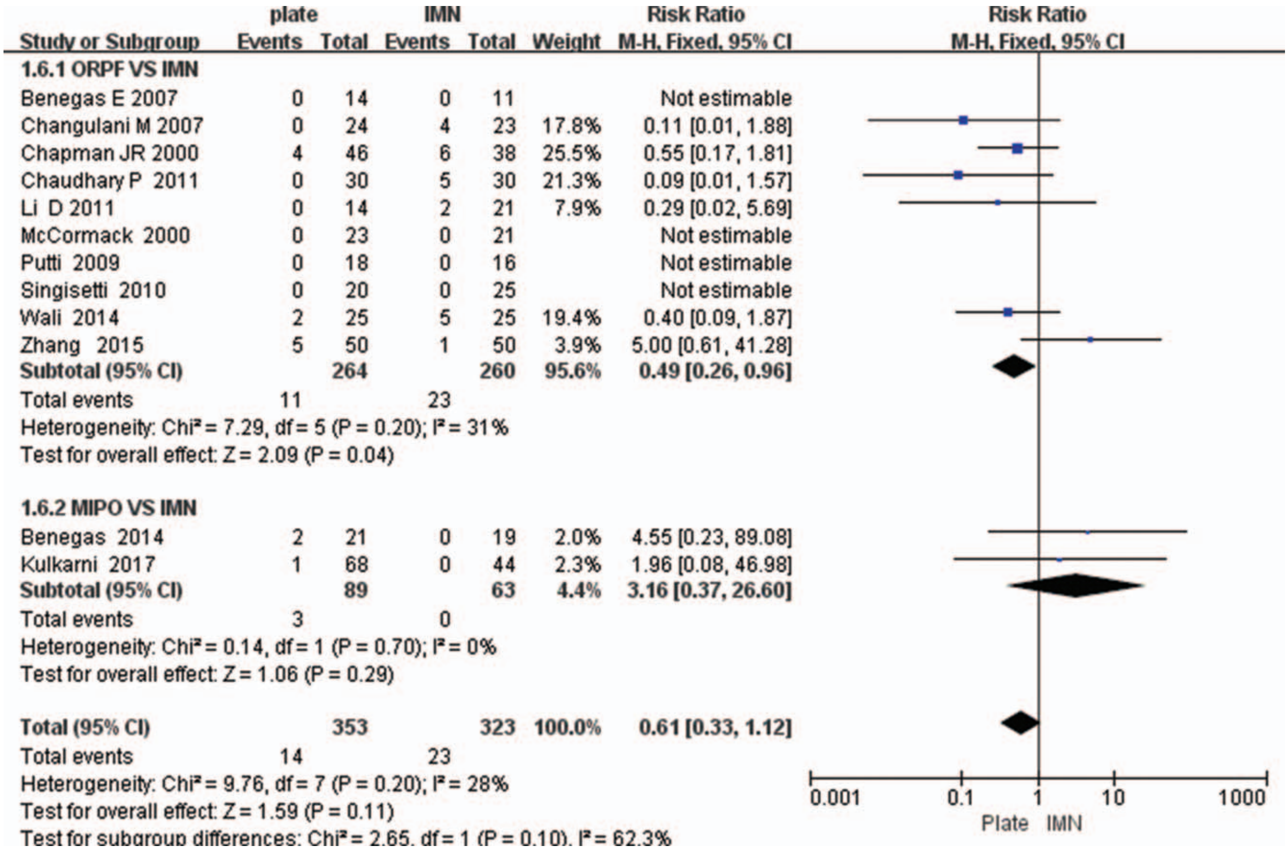

Figure 11. Forest plot for meta-analysis of restriction of shoulder and elbow joints between the plate and IMN groups.

However, suggestions of the literatures and studies are inconsistent.[28] The present study with the largest number of participants only included RCTs with modified Jadad scale ≥ 4 and CCT (clinical controlled trial) with NOS > 7. In addition, plate group was divided into subgroups of ORPF and MIPO to analyze the pooled results.

4.1. Primary outcome

Nonunion, iatrogenic radial nerve injury, and infection were regarded as primary outcome. According to literature reports, the rate of nonunion varies between 3% and 20%.[26,33] Femke analyzed 325 adult patients who underwent operative treatment of a diaphyseal humerus fracture and found that iatrogenic radial nerve palsy occurred in 18 of 259 diaphyseal humeral fractures (7%), and the surgical approach was associated with iatrogenic radial nerve palsy.[34] A network meta-analysis showed a significantly higher rate of occurrence of iatrogenic radial nerve injury in the ORPF group than in the MIPO group, but no significant differences in nonunion and infection.[28] The results of another meta-analysis indicated that both IMN and dynamic compression plate (DCP) can achieve similar fracture union with a similar incidence of radial nerve injury and infection.[6]

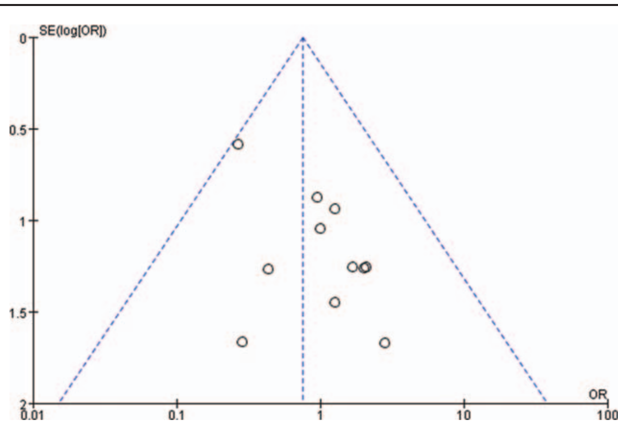

Figure 12. Funnel plot of the nonunion rate between the plate and IMN groups. RR = relative risk, SE = standard error.

However, the present study showed that IMN is superior to plate in reducing postoperative infections, but MIPO is better than IMN for the risk of nonunion. And there was no significant difference regarding the risk of iatrogenic nerve injury. Considering just two trials applying MIPO technology in this study, the credibility of the results was hurt. Intraoperative factors associated with infection include operation time and damage of soft tissue and blood supply.[35] Therefore, the authors suggest that the result may be related to more soft tissue trauma and diminished by plate treatment. However, many previous studies suggest that plate is superior to IMN for infection and union, and the publications are more controversial. Chen, retrospectively evaluated 128 cases with humeral shaft fractures that were treated with MIPO, all fractures healed without infection.[3] Esmailiejah et al suggested that the incidence of nonunion, infection, and iatrogenic radial nerve injury were lower in the MIPO group.[30] Heineman et al concluded that the current literature continues to favor plates over intramedullary nails in humeral shaft fractures in the reduction of complication rates.[36] A prospective randomized study of conventional open plating versus MIPO for noncomminuted humeral shaft fractures confirmed a high overall rate of union and excellent functional outcomes in both MIPO and conventional open plating groups.[37] In addition, a descriptive-cross sectional study suggested that intramedullary nail fixation of humeral shaft fractures may be associated with high rates of non-union.[38] On the contrary, Ozan preformed a study applying inflatable IMN, and found the occurrence of non-union only in one patient (7%).[31] In order to reach reliable conclusions, more high-quality investigations are required and future studies should include detailed evaluation with same criteria in different follow-up stages.

4.2. Secondary outcome

The secondary outcome consisted of operation time, delayed union, re-operation, and blood loss. The present meta-analysis showed that IMN is superior to plate in blood loss, but achieved similar results on operation time, delayed union, and reoperation. Interestingly, the results of operation time, delayed union, and re-operation differ from previous studies. A meta-analysis indicated that IMN was associated with a higher incidence of implant failure, and an increased risk of re-operation.[6] Wang et al suggested that a significantly lower risk of delayed-union, and re-operation were found for the plating group.[27]

Although ORPF reduce the difficulty of reduction, it requires more time to perform surgical approach. In contrary, MIPO and intramedullary nail technique with smaller incision require more time to finish reduction and need the assistance of c-arm, so the total time of the two methods is similar. As reported, Chen et al performed a retrospective study of humeral shaft fractures treated with MIPO technique. They found that the average duration of the surgery was 60 minutes.[3] Shin et al reported a modified operative technique for MIPO for acute displaced humeral shaft fractures. They showed that the mean operating time was 62.7 minutes.[39] The authors believe that IMN is a minimally invasive surgery, with relatively small incision and less damage to soft tissue vessels, so the bleeding is relatively less.

4.3. Function results

With respect to excellent and good function result, ASES, the pooled results showed that there was no significant difference between plate and IMN. Regarding the risk of restriction of range of motion (ROM) of shoulder and elbow joints, the meta-analysis showed that ORPF group is superior to IMN group, and there was no statistically significant difference between MIPO group and IMN group. This is consistent with previous meta-analyses. Ouyang et al suggested that plating may reduce the occurrence of shoulder problems.[7] The results of a meta-analyses indicated that significantly lower risk of restriction, impingement of the shoulder were found for the plating group.[27] A comparative study showed that there was no significant difference between IMN and DCP, but IMN was not suitable for elderly patients and would cause obvious shoulder joint dysfunction.[40]

This is the first meta-analyses which divided plate group into ORPF group and MIPO group to analysis restriction of shoulder and elbow ROM results. When assessing functional results according to ASES score, all former studies just included patients managed by ORPF technique, so it can be concluded that there was no significant difference between ORPF group and antegrade IMN group for ASES score. Regarding only two studies applying MIPO technology in this study, the results are limited by the small sample size. It has been reported that MIPO is more effective than ORPF in the treatment of humeral shaft fractures.[24] Chen et al retrospectively evaluated 128 cases with humeral shaft fractures that were treated with MIPO technique; according to hospital for special surgery elbow joint score, there were 123 cases of excellent clinical outcome and five cases of fair outcome.[3]

4.4. Strengths and limitations of this study

The main strength of this meta-analysis was high-quality of the eligible studies. Modified Jadad scale ≥ 4 for RCTs and NOS > 7 for CCTs. A total of 15 trials and 898 participants were included in this study, which was the most comprehensive and systematic meta-analysis. Second, plate groups were divided into subgroups of ORPF and MIPO to assess the restriction of shoulder and elbow joints. Third, it was the first updated meta-analysis to compare the treatment effect between plating and antegrade intramedullary nailing for humeral shaft fracture in recent 5 years. Furthermore, heterogeneity analysis of this study was small and no publication biases were found. However, the limitations of the study were obvious. First, not all of the eligible studies were RCT study and the evaluation parameters were not consistent. Second, shoulder and elbow joint function could not be adequately assessed because of inadequate data. It is suggested to adopt unified evaluation indicators in subsequent studies, so as to draw more stable and reliable conclusions. Third, the number of the studies applying MIPO technique was small, which may impair the reliability of the conclusion. Fourth, it is an updated meta-analysis.

We suggest that it is still necessary to perform further prospective larger sized, multi-center clinical RCTs in the future, and obtain higher-level evidence for clinical treatment by using unified and correct scoring system.

5. Conclusions

According to the analyses of the pooled results of plate group and IMN group, the data tend to suggest that antegrade intramedullary nails may be superior to plates for the repair of humeral shaft fractures. Further research is required and future studies should include analysis of assessments at different stages and follow-up after removal of the implants.

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