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Original Article

Plating versus intramedullary fixation for acute displaced mid-shaft clavicle fractures: a meta-analysis

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Abstract: Background: Surgical treatment of acute displaced mid-shaft fractures of the clavicular remains challenging. In this meta-analysis, we pooled studies to compare plating with intramedullary fixation for this injury. Methods: The electronic databases MEDLINE, EMABSE, BIOSIS and Google scholar were searched. RCTs and cohort studies evaluating plating versus intramedullary fixation for displaced mid-shaft clavicle fracture were collected. The quality of the study was assessed, and meta-analyses were performed with the Cochrane Collaboration's REVMAN 5.0 software. Results: Three RCTs and eleven cohort studies involving 934 patients were included. There were 421 patients treated with intramedullary fixation and 513 cases for plating. Functional outcomes, rate of bone union, infection and implant failure were compared and no significant difference was found. Intramedullary fixation was associated with a shorter time to bone union (MD -0.60 weeks, 95% CI -1.11 to -0.10) and for surgery (MD -21.29 minutes; 95% CI -27.93 to -14.65). Conclusion: Both plating and intramedullary fixation techniques are equally effective for the surgical treatment of acute displaced mid-shaft clavicle fractures and the intramedullary fixation technique is quicker with a shorter operative time and faster to bone union. It can be regard as an attractive alternative to plating. In the future, high quality and well designed RCTs are required to support these findings.

Keywords: Acute displaced mid-shaft clavicle fracture, plating, intramedullary fixation, meta-analysis

Introduction

Clavicle fracture, a most common injury in children and adults, accounts for about 2.6% to 4% of all fractures [1]. Mid-shaft fractures consist of up to 85% of these cases and about three quarters of these are displaced [2, 3]. Conservative treatment has been widely used for mid-shaft clavicle fractures, given the generally low rate of nonunion [4]. However, many patients may experience nonunion, cosmetic deformity and poor outcomes when this injury is associated with risk factors such as female, eld, and severe displacement [5]. Robinson et al. [6] reported an increased nonunion rate in conservatively treated displaced fractures with 19% to 33%. A multicenter, randomized clinical trial by Canadian Orthopaedic Trauma Society reported higher nonunion rates and functional deficits after non-operative treatment of displaced fractures of the clavicular shaft when comparing with internal fixation [7]. Therefore, there is a tendency towards surgical treatment for patients with the above risk factor.

Plate and intramedullary fixation are two of the most commonly used surgical procedures, and both have unique advantages and disadvantages [8-10]. They have been found to be superior to conservative treatment of displaced mid-shaft clavicle fractures in many publications. The optimal implant of clavicle fixation remains controversial. In this meta-analysis, we compare the clinical outcomes of displaced mid-shaft clavicle fractures treated with plate or intramedullary fixation. We combine the data from all available studies to date to establish the best evidence currently.

Materials and methods

Search strategy and data extraction

The electronic databases MEDLINE, EMABSE, BIOSIS and Google scholar, last updated on

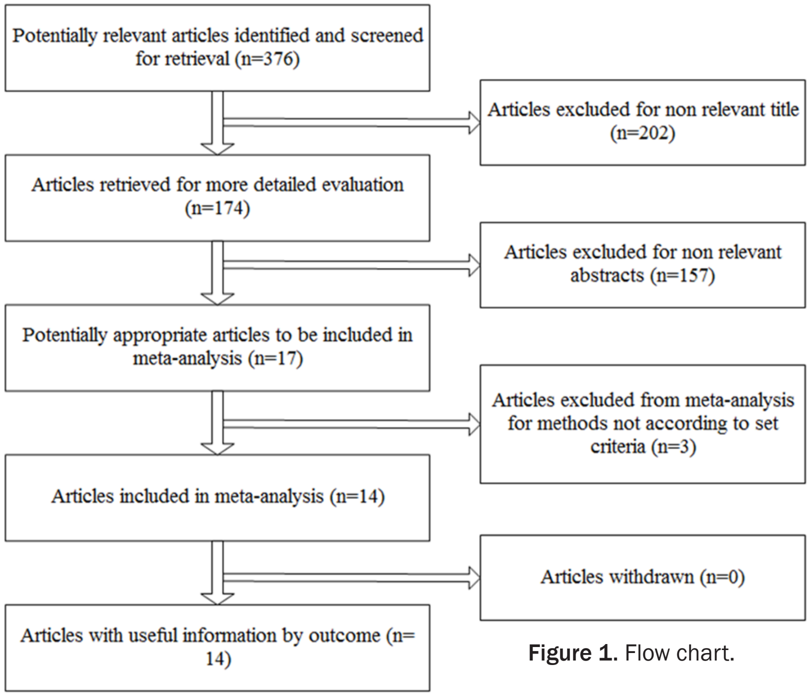

Figure 1. Flow chart.

June 30, 2014, were searched. No language, date or publication status restrictions were applied. The search terms with displaced midshaft clavicle fracture, plate fixation, and intramedullary fixation were retrieved in the titles, abstracts, and Medical Subject Headings. Studies were independently assessed for inclusion by two reviewers. In cases of disagreement, it was discussed and consulted by a third author.

All relevant data were extracted by two reviewers independently. Differences were resolved by discussion and, when necessary, with adjudication by a third author. Effective data included trial methods, populations, interventions and outcomes. When necessary, detail was sought from the authors of the primary studies.

Inclusion and exclusion criteria

Inclusion criteria included (1) randomized controlled trial (RCT) and prospective or retrospective cohort study; (2) skeletally mature patients, aged 18 and older with acute displaced midshaft clavicle fracture; (3) interventions comparing plate fixation with intramedullary fixation; (4) outcomes including functional outcomes, time to union in weeks, union rate, infection, implant failure, and operative time; (5) > 10 patients in each group; and (6) at least six-months follow-up. Exclusion criteria included (1) early failure of conservative treatment, pathological fracture, open fracture, and fracture nonunions; (2) animal models and children; (3) individuals with any stated serious co-morbidity.

Statistical analysis

Study data were pooled together and analyzed by Cochrane Collaboration's REVAMAN 5.0 software. Relative risks (RR) and 95% confidence intervals (CIs) were calculated for dichotomous outcomes, and standard mean differences (SMD) and 95% confidence intervals (CIs) were calculated for continuous outcomes. A meta-analysis with a fixed-effect model used the inverse-variance test for continuous variables and the Mantel-Haenszel test for dichotomous variables. Random-effect model was used when there was heterogeneity. Heterogeneity was assessed by Chi-square tests (with $P < 0.05$ representing heterogeneity) and I^2 statistic (with $I^2 > 50\%$ indicating high heterogeneity).

Assessment of methodological quality and publication bias

The risk of bias of RCTs was evaluated by the Cochrane Collaboration's tool. Assessments of five main fields included sequence generation, allocation concealment, blinding, incomplete outcome data and selective outcome reporting. For cohort study, we used methodological index for non-randomized studies (MINORS) score [11]. A study with score more than twelve was considered for inclusion. Funnel plot was created to visually evaluate for the presence of publication bias.

Results

376 articles were identified with use of our search strategy; of these, 17 studies comparing plate with intramedullary fixation for dis-

Table 1. Characteristics of the included trials

Study	Study design	No. of patients		Mean age (years)		Sex (M%)		Mean follow-up (months)	
		IM	Plate	IM	Plate	IM	Plate	IM	Plate
Assobhi 2011	RCT	19	19	30.3	32.6	84.2%	89.5%	14.5	18.6
Bohme 2010	P	20	53	36	36	79.2%		8	8
Chen 2012	R	57	84	34.3	36.5	71.9%	72.6%	24	24
Ferran 2010	RCT	17	15	23.5	35.4	82.3%	86.7%	12.7	12.1
Jones 2014	R	25	24	27.1	27.1	84%		30	30
Kleweno 2011	R	18	14	35	28	83.3%	71.4%	8	17
Kwak-Lee 2014	R	34	67	27.6	31.7	85.3%	94.0%	19	22
Liu 2010	R	51	59	33.6	31.7	62.7%	49.1%	17.7	17.7
Narsaria 2014	RCT	33	32	38.9	40.2	72.7%	81.2%	24	24
Tabatabaei 2011	P	25	25	29	27.3	84%	84%	14	14
Tarng 2012	R	25	32	38	46.5	40%	56.2%	12	12
Thyagarajan 2009	R	17	17	28	32.1	94.1%	88.2%	6	6
Wenninger 2013	R	33	29	25.2	26.9	97.0%	89.6%	12	12
Wijdicks 2012	R	47	43	33.1	39.4	70.2%	76.7%	6	8

RCT: Randomized controlled trial; P: Prospective cohort study; R: Retrospective cohort study; IM: Intramedullary fixation.

Table 2. Clinical outcomes of the included studies

Study	Constant score		Nonunion		Infection		Implant failure		Time to union (months)		Operative time (minutes)	
	IM	Plate	IM	Plate	IM	Plate	IM	Plate	IM	Plate	IM	Plate
Assobhi 2011	95.5±5.3	89.9±11.3	0	1	0	1	0	0	5.2±1.7	7.3±3.1	44.1±9.1	68.1±10.9
Bohme 2010	NR	NR	0	0	0	2	1	6	NR	NR	43±21.25	61±28.25
Chen 2012	95±3.2	94.8±2.5	1	3	1	3	3	6	3.1±1.0	3.6±1.2	48.25±19.76	66.49±22.47
Ferran 2010	92.1±6	88.7±9.1	0	0	0	3	1	0	NR	NR	NR	NR
Jones 2014	NR	NR	0	1	1	0	NR	NR	NR	NR	NR	NR
Kleweno 2011	NR	NR	0	1	1	0	NR	NR	NR	NR	NR	NR
Kwak-Lee 2014	NR	NR	3	4	4	1	3	1	2.4±1.1	3.6±1.7	99.5±31.5	131.8±54
Liu 2010	86.7±5.3	88.0±4.8	5	6	3	6	4	5	4.3±1.5	4.2±1.3	72.8±26.3	75.8±23.0
Narsaria 2014	94.6±3.2	96.2±2.6	1	0	1	2	1	0	6.1±1.8	7.4±2.7	40.2±6.75	58.4±8
Tabatabaei 2011	NR	NR	0	1	2	1	NR	NR	2.5±0.4	2.5±0.4	42.2±2.91	65.8±8.25
Tarng 2012	96±2	92±3.1	0	1	0	1	0	2	NR	NR	32±2.75	65±2.5
Thyagarajan 2009	97.8±2.5	93.7±4.4	0	3	2	2	NR	NR	NR	NR	NR	NR
Wenninger 2013	NR	NR	0	0	1	0	NR	NR	NR	NR	NR	NR
Wijdicks 2012	NR	NR	0	0	4	1	1	6	NR	NR	NR	NR

IM: Intramedullary fixation; NR: Not reported.

Table 3. Assessments of risk of bias of the randomized trials

Studies	Sequence generation	Allocation concealment	Blinding	Incomplete outcome data	Selective outcome reporting
Ferran 2010	Yes	Yes	No	Yes	Yes
Assobhi 2011	Yes	Yes	No	Yes	Yes
Narsaria 2014	Yes	Yes	No	Yes	Yes

placed mid-shaft clavicle fracture were reviewed. Three studies containing open fractures and nonunions were excluded [5, 12, 13]. Finally, 14 studies matched the inclusion criteria, of which three were reported to be RCTs [14-16], two were prospective cohort studies [17, 18] and 9 were retrospective cohort studies [19-27]. All trials were reported in English, except Bohme 2011 (in German) (**Figure 1**). **Tables 1** and **2** presented the characteristics and clinical outcomes of the included studies.

Methodological quality of the included studies was detailed in **Tables 3** and **4**. Funnel plot

Table 4. Methodological items for non-randomized studies

Study	Bohme 2010	Chen 2012	Jones 2014	Kleweno 2011	Kwak-Lee 2014	Liu 2010	Tabata-baei 2011	Tarng 2012	Thyagara-jan 2009	Wenninger 2013	Wijdicks 2012
1. A clearly stated aim	2	2	2	2	2	2	2	2	2	2	2
2. Inclusion of consecutive patients	2	2	2	2	2	2	2	2	2	2	2
3. Prospective collection of data	1	0	0	0	0	0	1	0	0	0	0
4. Endpoints appropriate to the aim of the study	1	2	2	1	2	2	2	2	1	2	1
5. Unbiased assessment of the study endpoint	0	0	2	0	0	0	0	0	0	0	0
6. Follow-up period appropriate to the aim of the study	1	2	2	1	2	2	2	2	1	2	1
7. Loss to follow up less than 5%	2	2	2	2	2	2	1	2	2	2	2
8. Prospective calculation of the study size	0	0	0	0	0	1	0	0	0	0	0
9. An adequate control group	2	2	2	2	2	2	2	2	2	2	2
10. Contemporary groups	2	2	0	2	2	2	2	2	2	2	2
11. Baseline equivalence of groups	2	2	2	2	2	2	2	2	2	2	2
12. Adequate statistical analyses	2	2	2	2	2	2	2	2	2	2	2
Total score	17	18	18	16	18	19	18	18	16	18	16

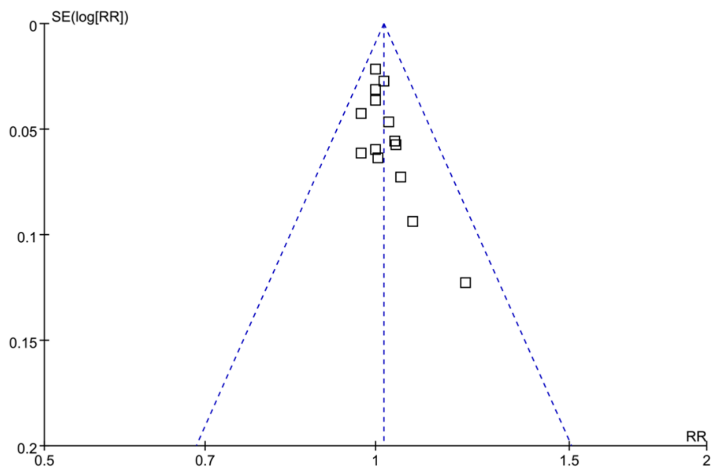

Figure 2. Funnel plot to estimate publication bias.

demonstrated no visual evidence of publication bias (**Figure 2**).

The fourteen studies enrolled a total of 934 participants; of which, 421 patients were treated with intramedullary fixation and 513 cases for plating.

Seven studies, with a total of 477 patients, compared functional Constant score postoperatively. Pooled data demonstrated no significant difference between the two groups (SMD 0.38, 95% CI -0.13 to 0.89) at follow-up of six month or more; however, these results were highly heterogeneous (I^2 = 85%). This result equated to an absolute mean difference of 2.66 points improvement (0.91 worse to 6.23 improvement) in favour of intramedullary fixation on Constant score (0 to 100 scale); this was neither a statistically nor clinically significant difference (**Figure 3**).

The common cause of treatment failure mostly came from symptomatic nonunion and mechanical failure. Pooled data of union rate was possible across 14 studies (**Figure 4**). There was no statistically significant difference in fracture union between plating and nailing (RR 1.02; 95% CI 0.99 to 1.05). Results gave a pooled rate of 95.9% (492 of 513) in the plating group and of 97.6% (411 of 421) in the nailing group. Mechanical/implant failure was reported in nine studies. No significant difference was found between the two groups (RR 0.77; 95% CI 0.42 to 1.41) (**Figure 5**).

Infection-risk analysis across 14 studies showed no significant differences were found when comparing plating groups with nailing groups (4.5% vs 4.7%, respectively; RR 1.03; 95% CI 0.60 to 1.77) (**Figure 6**).

Six studies described the time to bone union. The difference in time to union between the two groups was statistically significant (MD -0.60 weeks, 95% CI -1.11 to -0.10) (**Figure 7**). Data from eight studies found significantly better results in favor of intramedullary fixation group with respect to operative time (MD -21.29 minutes; 95% CI -27.93 to -14.65) (**Figure 8**).

Discussion

The findings of this meta-analysis, based on 14 studies involving 934 participants, demonstrated intramedullary fixation may not result in a significant improvement in functional outcomes, may not improve bone union or may not reduce the incidence of implant failure and infection, when comparing with plating for the treatment of acute displaced mid-shaft clavicle fractures. However, intramedullary fixation was found to shorten the time to bone union and operative time.

In 2011, a meta-analysis by Duan et al. [28] comparing plating versus intramedullary pinning or conservative treatment of mid-shaft clavicle fracture did not provided a strong recommendation for surgery. The authors suggested that there were no differences in treatment effects between plating and intramedullary pinning, but plating was associated with more side effects. Their meta-analysis included only two RCTs comparing plating versus pinning with low-quality evidence. One of which was omitted from the present meta-analysis because of inadequate inclusion criteria [12]. We included two extra RCTs [15, 16] and more cohort studies [17-27] that did fulfill our strict inclusion criteria. Nevertheless, the results reported by Duan et al. [28] were similar to ours; besides, plating obtained longer time to bone union and operative time. Another meta-analysis based on RCTs comparing plating versus intramedullary fixation for mid-shaft clavicle fractures was published in 2015 [29]. The author pooled five RCTs and claimed that intramedullary fixation has more advantages than plate fixation for treatment of mid-shaft clavicular fracture.

Study or Subgroup	IM Mean	IM SD	IM Total	Plate Mean	Plate SD	Plate Total	Weight	Std. Mean Difference IV, Random, 95% CI
Assobhi 2011	95.5	5.3	19	89.9	11.3	19	13.5%	0.62 [-0.03, 1.27]
Chen 2012	95	3.2	57	94.8	2.5	84	16.1%	0.07 [-0.27, 0.41]
Ferran 2010	92.1	6	17	88.7	9.1	15	13.0%	0.44 [-0.27, 1.14]
Liu 2010	86.7	5.3	51	88	4.8	59	15.8%	-0.26 [-0.63, 0.12]
Narsaria 2014	94.6	3.2	33	96.2	2.6	32	14.9%	-0.54 [-1.04, -0.05]
Tarng 2012	96	2	25	92	3.1	32	14.0%	1.47 [0.88, 2.07]
Thyagarajan 2009	97.8	2.5	17	93.7	4.4	17	12.8%	1.12 [0.39, 1.85]
Total (95% CI)			**219**			**258**	**100.0%**	**0.38 [-0.13, 0.89]**

Heterogeneity: Tau² = 0.39; Chi² = 40.59, df = 6 (P < 0.00001); I² = 85%
Test for overall effect: Z = 1.47 (P = 0.14)

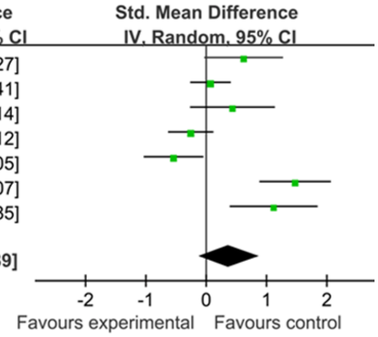

Figure 3. Plating vs intramedullary fixation evaluated by the Constant score.

Study or Subgroup	IM Events	IM Total	Plate Events	Plate Total	Weight	Risk Ratio M-H, Fixed, 95% CI
Assobhi 2011	19	19	18	19	4.2%	1.05 [0.91, 1.22]
Bohme 2010	20	20	53	53	6.8%	1.00 [0.93, 1.07]
Chen 2012	56	57	81	84	15.0%	1.02 [0.97, 1.08]
Ferran 2010	17	17	15	15	3.8%	1.00 [0.89, 1.12]
Jones 2014	25	25	23	24	5.5%	1.04 [0.93, 1.17]
Kleweno 2011	18	18	13	14	3.4%	1.08 [0.90, 1.30]
Kwak-Lee 2014	31	34	63	67	9.7%	0.97 [0.86, 1.09]
Liu 2010	46	51	53	59	11.2%	1.00 [0.89, 1.14]
Narsaria 2014	32	33	32	32	7.5%	0.97 [0.89, 1.06]
Tabatabaei 2011	25	25	24	25	5.6%	1.04 [0.93, 1.16]
Tarng 2012	25	25	31	32	6.3%	1.03 [0.94, 1.13]
Thyagarajan 2009	17	17	14	17	3.3%	1.21 [0.95, 1.53]
Wenninger 2013	33	33	29	29	7.2%	1.00 [0.94, 1.06]
Wijdicks 2012	47	47	43	43	10.4%	1.00 [0.96, 1.04]
Total (95% CI)		**421**		**513**	**100.0%**	**1.02 [0.99, 1.05]**
Total events	411		492			

Heterogeneity: Chi² = 5.99, df = 13 (P = 0.95); I² = 0%
Test for overall effect: Z = 1.15 (P = 0.25)

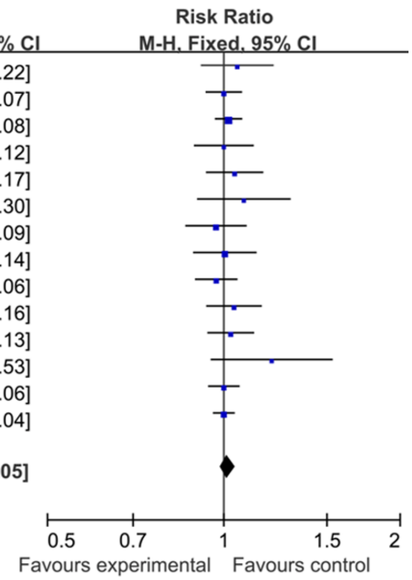

Figure 4. Plating vs intramedullary fixation, results for bone union.

Study or Subgroup	IM Events	IM Total	Plate Events	Plate Total	Weight	Risk Ratio M-H, Fixed, 95% CI
Assobhi 2011	0	19	0	19		Not estimable
Bohme 2010	1	20	6	53	14.3%	0.44 [0.06, 3.44]
Chen 2012	3	57	6	84	21.1%	0.74 [0.19, 2.83]
Ferran 2010	1	17	0	15	2.3%	2.67 [0.12, 60.93]
Kwak-Lee 2014	3	34	1	67	2.9%	5.91 [0.64, 54.72]
Liu 2010	4	51	5	59	20.2%	0.93 [0.26, 3.26]
Narsaria 2014	1	33	0	32	2.2%	2.91 [0.12, 68.95]
Tarng 2012	0	25	2	32	9.6%	0.25 [0.01, 5.06]
Wijdicks 2012	1	47	6	43	27.3%	0.15 [0.02, 1.22]
Total (95% CI)		**303**		**404**	**100.0%**	**0.77 [0.42, 1.41]**
Total events	14		26			

Heterogeneity: Chi² = 7.74, df = 7 (P = 0.36); I² = 10%
Test for overall effect: Z = 0.84 (P = 0.40)

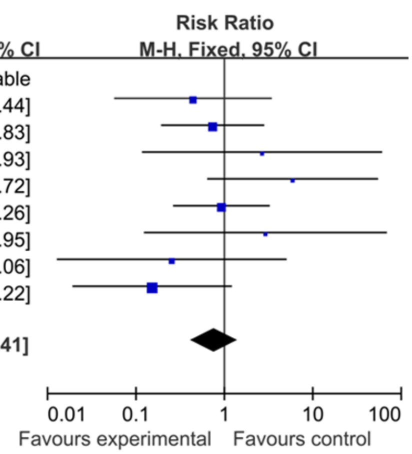

Figure 5. Plating vs intramedullary fixation, results for implant failure.

Unfortunately, three of them contained open fractures and nonunions. Thus we doubted the fractures with varying diagnoses would influence the conclusion.

Study or Subgroup	IM Events	IM Total	Plate Events	Plate Total	Weight	Risk Ratio M-H, Fixed, 95% CI
Assobhi 2011	0	19	1	19	6.2%	0.33 [0.01, 7.70]
Bohme 2010	0	20	2	53	5.8%	0.51 [0.03, 10.27]
Chen 2012	1	57	3	84	10.0%	0.49 [0.05, 4.61]
Ferran 2010	0	17	3	15	15.3%	0.13 [0.01, 2.27]
Jones 2014	1	25	0	24	2.1%	2.88 [0.12, 67.53]
Kleweno 2011	1	18	0	14	2.3%	2.37 [0.10, 54.08]
Kwak-Lee 2014	4	34	1	67	2.8%	7.88 [0.92, 67.81]
Liu 2010	3	51	6	59	22.9%	0.58 [0.15, 2.20]
Narsaria 2014	1	33	2	32	8.4%	0.48 [0.05, 5.09]
Tabatabaei 2011	2	25	1	25	4.1%	2.00 [0.19, 20.67]
Tarng 2012	0	25	1	32	5.4%	0.42 [0.02, 9.96]
Thyagarajan 2009	2	17	2	17	8.2%	1.00 [0.16, 6.30]
Wenninger 2013	1	33	0	29	2.2%	2.65 [0.11, 62.56]
Wijdicks 2012	4	47	1	43	4.3%	3.66 [0.43, 31.48]
Total (95% CI)		**421**		**513**	**100.0%**	**1.03 [0.60, 1.77]**
Total events	20		23			

Heterogeneity: Chi² = 10.67, df = 13 (P = 0.64); I² = 0%
Test for overall effect: Z = 0.10 (P = 0.92)

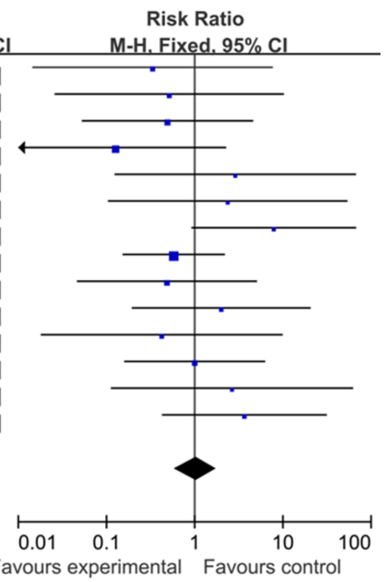

Figure 6. Plating vs intramedullary fixation, results for infection.

Study or Subgroup	IM Mean	IM SD	IM Total	Plate Mean	Plate SD	Plate Total	Weight	Mean Difference IV, Random, 95% CI
Assobhi 2011	5.2	1.7	19	7.3	3.1	19	7.1%	-2.10 [-3.69, -0.51]
Chen 2012	3.1	1	57	3.6	1.2	84	21.3%	-0.50 [-0.87, -0.13]
Kwak-Lee 2014	2.4	1.1	34	3.6	1.7	67	18.7%	-1.20 [-1.75, -0.65]
Liu 2010	4.3	1.5	51	4.2	1.3	59	19.0%	0.10 [-0.43, 0.63]
Narsaria 2014	6.1	1.8	33	7.4	2.7	32	11.0%	-1.30 [-2.42, -0.18]
Tabatabaei 2011	2.5	0.4	25	2.5	0.4	25	22.9%	0.00 [-0.22, 0.22]
Total (95% CI)			**219**			**286**	**100.0%**	**-0.60 [-1.11, -0.10]**

Heterogeneity: Tau² = 0.28; Chi² = 28.41, df = 5 (P < 0.0001); I² = 82%
Test for overall effect: Z = 2.35 (P = 0.02)

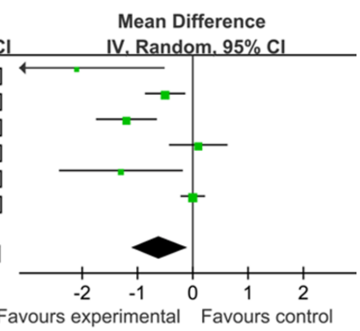

Figure 7. Plating vs intramedullary fixation evaluated by the time to union.

Study or Subgroup	IM Mean	IM SD	IM Total	Plate Mean	Plate SD	Plate Total	Weight	Mean Difference IV, Random, 95% CI
Assobhi 2011	44.1	9.1	19	68.1	10.9	19	13.3%	-24.00 [-30.38, -17.62]
Bohme 2010	43	21.25	20	61	28.25	53	10.1%	-18.00 [-30.02, -5.98]
Chen 2012	48.25	19.76	57	66.49	22.47	84	13.0%	-18.24 [-25.27, -11.21]
Kwak-Lee 2014	99.5	31.5	34	131.8	54	67	7.7%	-32.30 [-49.01, -15.59]
Liu 2010	72.8	26.3	51	75.8	23	59	11.7%	-3.00 [-12.30, 6.30]
Narsaria 2014	40.2	6.75	33	58.4	8	32	14.5%	-18.20 [-21.80, -14.60]
Tabatabaei 2011	42.2	2.91	25	65.8	8.25	32	14.7%	-23.60 [-26.68, -20.52]
Tarng 2012	32	2.75	25	65	2.5	25	15.0%	-33.00 [-34.46, -31.54]
Total (95% CI)			**264**			**371**	**100.0%**	**-21.29 [-27.93, -14.65]**

Heterogeneity: Tau² = 75.82; Chi² = 119.75, df = 7 (P < 0.00001); I² = 94%
Test for overall effect: Z = 6.28 (P < 0.00001)

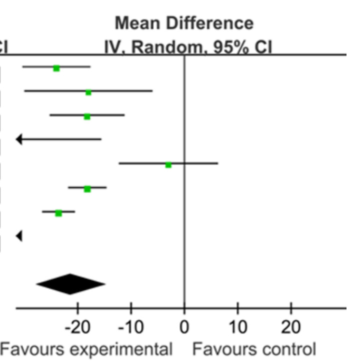

Figure 8. Plating vs intramedullary fixation evaluated by the operative time.

A majority of acute clavicle fracture used to be managed non-operatively; However, current treatment for some types of clavicle fracture was more interventional, thus involving surgery [30]. The participants of the included studies were acute displaced shortening mid-shaft fracture of the clavicles. We excluded the injury characteristics by early failure of conservative treatment, pathological fracture, open fracture, and fracture nonunions, because intramedullary fixation was usually considered contraindicated in these cases [31].

There were more than one measure of function, and we preferentially included one measure according to the following hierarchy: Constant score, Oxford score, ASES score and DASH score. As the Constant score was more specific for shoulder function and more commonly used in literatures, it was determined as the default. It combined both subjective and objective components, but also assessed pain and strength. Narsaria et al. [16] reported the functional scores were significantly higher for the plating group than the nailing group in the first 12 weeks, and at the 12-month follow-up, there was no significant difference observed. While, other previously listed factors were likely the basis with a better functional scores at the primary follow-up stages in the intramedullary fixation group. Authors believed faster relief of pain from intramedullary fixation with smaller incision would contribute to a better quality of life in the immediate postoperative period [26]. All the functional scores were followed-up at six month or more; as well as up to two years. Our study showed that the functinal outcomes of both groups were satisfactory with no significant difference at the final follow-up.

Surgical treatment allowed realignment of the fracture fragments and recovery a normal anatomic profile [32], but it also caused various complications. We found no significant difference in the rate of delay union and non-union between the two groups. In addition, no significant difference regarding wound infection and implant failure was observed. A recent systematic review found no difference in functional outcomes or complications after plating or nailing for displaced mid-shaft clavicle fractures [33]. In our study, the total rates of bone union (95.9% and 97.6%, respectively), infection (4.5% and 4.7%, respectively) and implant failure (6.4% and 4.6%, respectively) when plating compared with intramedullary fixation were similar to those previously reported.

A significant shorter operative time was found with intramedullary when comparing with plating. It can result from fewer surgical procedures and less tissue exposure with the use of intramedullary fixation technique. It also indicated that patient with intramedullary fixation had a shorter anesthesia time and less potential for anesthesia-induced complications.

Time to union, significantly, was shorter after intramedullary fixation than with plate fixation. Poor blood supply impeded the fracture healing process [34] and intramedullary fixation generally prevented further damage to the periosteum than the plate insertion during surgery. Also, it would seem more likely that this was a reflection of the basic healing mechanism of plate versus intramedullary fixation: there really should be no callus formation with plate fixation since healing taking place through primary direct bone healing rather than callus healing-therefore, one would not really expect, or hope to see callus healing with a plate since "perfect" plate fixation results in direct primary bone healing-not callus healing as seen with IM fixation. Callus healing had typically taken place quicker and it was simply more obvious than direct, primary bone healing and this, more than anything else was probably what resulted in the shorter time to bone union with IM fixation [24]. As this might have an impact on when the patients could start with weight bearing exercise, it also supported the view that patients in the intramedullary fixation group attained better functional scores in the early follow-up stages.

The following limitations of this study have to be addressed. First, besides RCTs, 11 cohort studies were included in this meta-analysis. It might be the main weakness of our meta-analysis, resulting in a certain degree selection bias to our study. Second, heterogeneity of the outcome parameters was high. Heterogeneity was accounted for by using random-effects modeling. It was probably due to differences in surgical experience and study design. Third, three of the included studies [17, 24, 26] only reported the median, range and the size of the studies while the mean value and the standard deviation was necessary for data calculation. Hozo et al. [35] described a simple method to calculate SDs and it widely improved the inclusiveness of all data for the meta-analysis. It certainly caused data bias and was lower with large samples.

Conclusion

Both plating and intramedullary fixation techniques are equally effective for the surgical treatment of acute displaced mid-shaft clavicle fractures. The two techniques can achieve high rates of bone union, with low rates of infection and implant failure. However, the intramedullary fixation technique is quicker with a shorter operative time and faster to bone union. It can be regard as an attractive alternative to plating. In the future, high quality and well designed RCTs are required to support these findings.

Disclosure of conflict of interest

None.

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