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Functional outcomes and complications of plate fixation for midshaft clavicle fractures by type and location: a systematic review and meta-analysis

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A R T I C L E I N F O

Keywords:
Systematic review
Midshaft clavicle fracture
Plate fixation
Compression plate
Reconstruction plate
Locking plate

Level of evidence: Level IV; Meta-Analysis

Background: Various plate types are used in the surgical treatment of displaced midshaft clavicle fractures. These plates can be positioned in different locations on the clavicle, although no studies to date have elucidated optimal plate type and location of fixation. This systematic review compares the functional outcomes and complications in the management of displaced midshaft clavicle fractures using plate fixation by stratifying by both plate type and location.

Methods: A systematic review according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines was conducted to identify all papers reporting functional outcomes, union rates, and/or complications using plates for the management of midshaft clavicle fractures. Multiple databases and trial registries were searched from inception until March 2022. A meta-analysis was conducted for functional outcomes and type of complication, stratified by plate type (locking, compression, or reconstruction) and location (superior or anteroinferior). Pooled estimates of functional outcome scores and incidence of complications were calculated using a random effects model. Risk of bias and quality were assessed using the risk of bias version 2 and ROBINS-I (Risk Of Bias In Non-randomised Studies - of Interventions) tools. The confidence in estimates were rated and described according to the recommendations of the GRADE (Grading of Recommendations, Assessment, Development, and Evaluations) working group.

Results: Forty-five studies were included in the systematic review and 43 were included in the meta-analysis. Depending on plate type and location, pooled Constant-Murley Scores ranged from 89.23 to 93.48 at 12 months. Nonunion rates were 3% (95% confidence interval [CI] 1-6) for superior locking plates (GRADE Low). Rates of any complication (nonunion, hardware failure, hardware irritation, wound dehiscence, keloid, superficial infection, deep infection, delayed union, malunion, and/or persistent pain) by plate type and location ranged from 3% to 17% (GRADE Very Low to Moderate). Superior compression plates had the highest incidence of any complications (17% [95% CI 5-44], GRADE Very Low), while anterior inferior compression plates had the lowest incidence of any complication (3% [95% CI 0-15], GRADE Very Low). Hardware irritation was the most reported individual complication for superior locking plates and superior compression plates, 11% (95% CI 7-17, GRADE Low) and 11% (95% CI 3-33, GRADE Very Low), respectively.

Conclusion: Although most studies were of low quality, studies reporting functional outcomes generally showed good functional results and similar incidence of any complication regardless of plate type and location. There is no evidence of a plate and location combination to optimize patient functional outcomes or complications. We were unable to reliably evaluate union rates or individual complications for most plate types stratified by location.

Clavicle fractures are common fractures with a reported incidence of 59.3 per 100,000 person-years.[33] Historically, these fractures were predominantly treated nonoperatively. However, it has been reported that surgical treatment of displaced midshaft clavicle fractures (DMCF) leads to better union rates, improved early

Institutional review board approval was not required for this meta-analysis.

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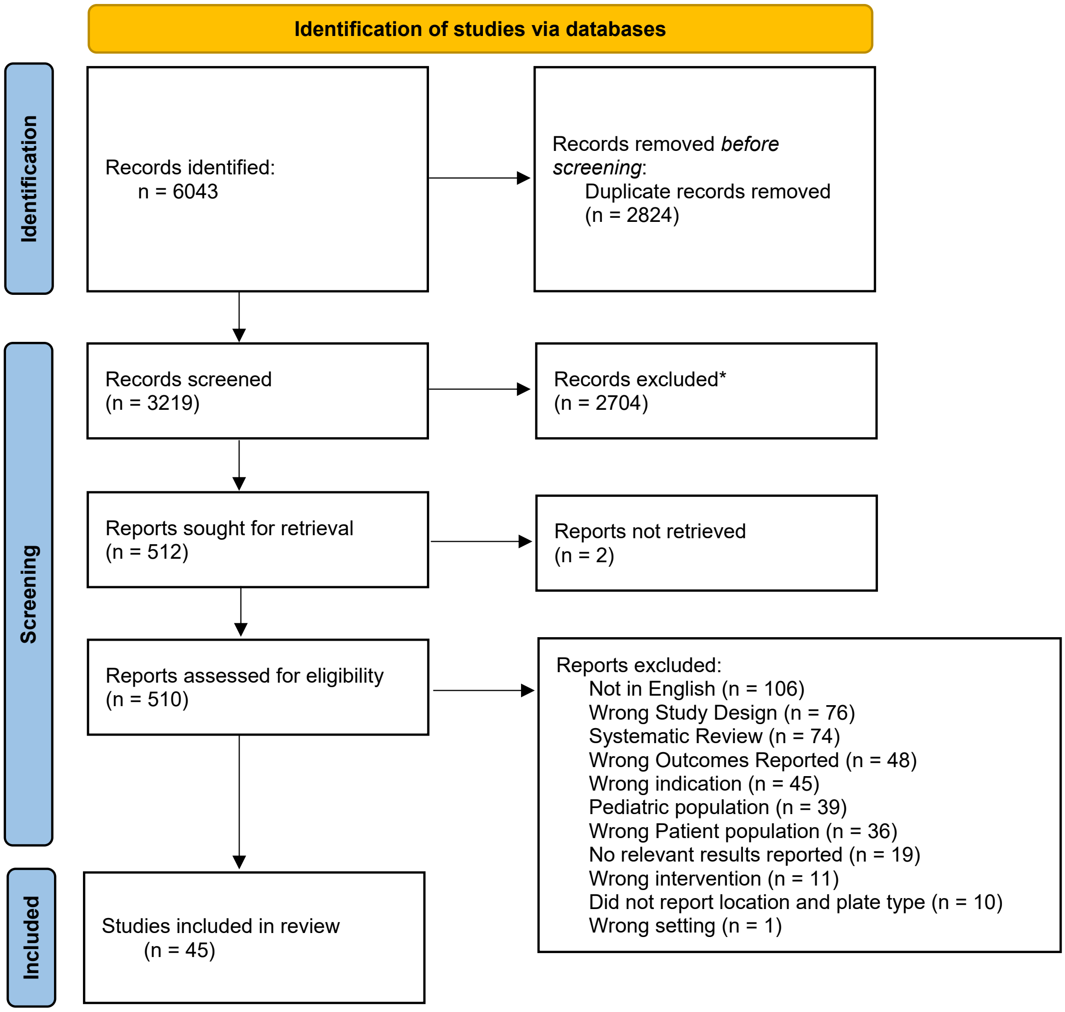

Figure 1 PRISMA flow diagram.

functional outcomes, and increased patient satisfaction.[42,47,71] The most common surgical operative treatment is Open Reduction Internal Fixation (ORIF) using plates and screws. In recent years, multiple meta-analyses have compared plate fixation and intramedullary devices for the management of midshaft clavicle fractures.[29,32,68,72-75,77] Complications after ORIF with plates include, but are not limited to, hardware prominence[27] infection, mechanical failure,[44] nonunion,[70] and neurovascular injury.[3] These complications can result in reoperation as well as decreased patient satisfaction.[27] However, many different types of plates exist such as low contact dynamic compression plates, anatomically precontoured plates, double plating, reconstruction plates, and locking plates. Furthermore, plates can be fixated anteroinferior or superior along the clavicle which may influence the complication profile.

A review of PubMed and search of PROSPERO showed no systematic reviews investigating the functional outcomes and complications of ORIF for DMCF stratified by both plate type and location. A study comparing ORIF of midshaft clavicle fractures by plate type and location of fixation will give surgeons information to provide optimal surgical management of clavicle fractures. The aim of this systematic review and meta-analysis was to compare functional outcomes and complication rates between plate types and locations of fixation for midshaft clavicle fractures.

Methods

This study was conducted and reported in accordance with the reporting guidance provided in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement.[51] The protocol was prospectively registered in PROSPERO (CRD42022310818).

Data sources

Electronic databases (PubMed, ScienceDirect, Embase, and Cochrane) and clinical trial registries (ClinicalTrials.gov, isrctn.com, Australian New Zealand Clinical Trials Registry, Chinese Clinical Trial Registry, EU Clinical Trials Register, and International Clinical Trials Registry Platform) were searched from their inception to March 2022. Keywords used to develop our search strategy were 'clavicle', 'fracture', and 'plate'. The full search strategy can be found in Supplemental additional file 1.

All titles and abstracts were screened, and study inclusion was decided on by 2 reviewers (J.L./R.K.). In case of discrepancy in study inclusion, disagreements were discussed until consensus on eligibility was reached. If disagreement persisted after discussion, consensus was reached by consulting P.H. or C.H. References of

Table I
Study characteristics for studies by plate type and location.

Author	Level of evidence	Study design	Number of clavicles	CMS (SD) at 6 months	CMS (SD) at 12 months	DASH (SD) at 6 months	DASH (SD) at 12 months	Number of complications by plate type	Number hardware irritation	Number wound dehiscence	Number keloid or scarring	Number hardware failure	Number superficial infection	Number deep infection	Number nonunion	Number delayed union	Number malunion	Number persistent pain
Anteroinferior locking plates																		
Annicchiarico 2020[4]	II	Retrospective chart review	22															
Hulsmans 2016[31]	III	Retrospective chart review	39					11	6			2	3					
Superior locking plates																		
Allis 2020[1]	III	Retrospective chart review	21					1	5				1					
Anand 2021[2]	II	Randomized controlled trial	50				1.5*	37				4	6	3				24
Annicchiarico 2020[4]	II	Retrospective chart review	10				42 (5)											
Beirer 2015[9]	II	Nonrandomized experimental study	24															
Bhardwaj 2018[10]	II	Randomized controlled trial	36					4	2				1				1	
Chechik 2019[12]	III	Retrospective chart review	38					8	5						2	1		
Chu 2018[13]	III	Retrospective chart review	60					12				6				6		
Delvaque 2019[17]	IV	Retrospective chart review	19					0										
Douraiswami 2013[19]		Nonrandomized experimental study	15															
Eden 2015[20]	III	Nonrandomized experimental study	41	93*	97*	9*	5*	1				1						
Fuglesang 2018[24]	I	Randomized controlled trial	60															
Kariya 2019[35]	III	Retrospective chart review	68	86.75 (5.2)				9	6					1	2			
Kc 2021[36]	II	Randomized controlled trial	40	90.87 (3.39)	98.2 (1.2)			3									1	
Kilinc 2020[38]	III	Retrospective chart review	40					9	2		7							
Kim 2018[39]	I	Randomized controlled trial	30					0										
King 2019[40]	I	Randomized controlled trial	37	87 (16)	91 (12)	13 (16)	17 (19)	2				1	1					
Ladermann 2017[43]	III	Case control study	31					2					2					
Pathak 2021[52]	III	Randomized controlled trial	18			10.4 (3.04)	6.3 (2.64)	5	4				1					
Ranalletta 2015[54]	IV	Retrospective chart review	68					13	9		2	1	1					
Saha 2014[57]	II	Randomized controlled trial	37	86.33 (4.44)	90.72 (4.62)			14	9					4	1			
Storti 2021[63]	III	Retrospective chart review	36					11				9	1			1		
Uchiyama 2021[66]	I	Randomized controlled trial	42					3				3						
Zhou 2019[76]		Retrospective chart review	130			6.25 (3.28)	5.58 (1.91)	27	6			3	5	1	3	5		4
Anteroinferior reconstruction plates																		
Arojuraye 2021[5]	III	Cohort study	11					1										
Assobhi 2011[6]	II		19					9	3		4		1		1			

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Table I (*continued*)

Author	Level of evidence	Study design	Number of clavicles	CMS (SD) at 6 months	CMS (SD) at 12 months	DASH (SD) at 6 months	DASH (SD) at 12 months	Number of complications by plate type	Number hardware irritation	Number wound dehiscence	Number keloid or scarring	Number hardware failure	Number superficial infection	Number deep infection	Number nonunion	Number delayed union	Number malunion	Number persistent pain
		Randomized controlled trial		84.7 (12.2)	89.9 (11.3)													
Galdi 2013[25]	III	Other: Retrospective cohort study	37		91.2 (12.15)		2.45 (1.4)	1							1			
Tamaoki 2017[64]	I	Randomized controlled trial	51			4 (11.5)	3.3 (10.4)	3				1	2					
Virtanen 2012[67]	I	Randomized controlled trial	28		86.5 (11.5)		4.3 (6.1)	6	1			2				3		
Superior reconstruction plates																		
Andrade-Silva 2015[3]	I	Randomized controlled trial	33	91.1 (9.4)	91.7 (9.3)	9.9 (10.9)	8.7 (11.8)	5				1						4
Shen 2008[58]	II	Randomized controlled trial	66					24								8		16
Garg 2011[26]	II	Nonrandomized experimental study	10					0										
Dhoju 2011[18]	II	Cohort study	13		98.15 (1.78)			0										
Kariya 2019[35]	III	Retrospective chart review	46	85.23 (5.57)				18	15					1	2			
Tarng 2012[65]	III	Retrospective chart review	32	92 (85.3-97.5†)				10	6			2	1		1			
Lee 2020[45]	III	Retrospective chart review	33					0										
Arojuraye 2021[5]	III	Cohort study	15															
Anteroinferior compression plates																		
Arojuraye 2021[5]	III	Cohort study	8					1										
Chan 2017[11]	III	Retrospective chart review	16					1				1						
DeBaun 2020[16]	III	Retrospective chart review	60					0										
Fahey 2019[22]	III	Retrospective chart review	22															
Superior compression plates																		
Arojuraye 2021[5]	III	Cohort study	10															
DeBaun 2020[16]	III	Retrospective chart review	14					0										
Ferran 2010[23]	I	Randomized controlled trial	15		88.7 (9.1)			4			1		3					
Khorami 2014[37]	II	Cohort study	35	20.97 (5.7)		24.6 (0-88)‡		31					4	1	2	18		6
Ko 2021[41]	III	Retrospective chart review	15					1	1									
Narsaria 2014[49]	II	Randomized controlled trial	32					9		3	4		2					
Rongguang 2016[56]	IV	Retrospective chart review	69					22	19				1			2		
Souza 2018[60]	II	Cohort study	26					1	1									
Uchiyama 2021[66]	I	Randomized controlled trial	41					3				2			1			

CMS, Constant-Murley Score; *SD*, standard deviation *DASH*, disabilities of the arm, shoulder, and hand; *IQR*, interquartile range.

*No range reported.

†Median and IQR.

‡Mean and range.

Table II
RoB 2 results.

	Risk of bias domains					
	D1	D2	D3	D4	D5	Overall
Anand 2021[2]	+	+	+	+	+	+
Andrade-Silva 2015[3]	+	+	+	+	+	+
Assobhi 2011[6]	+	+	+	+	+	+
Beirer 2015[9]	×	+	+	+	+	×
Chardwaj 2018[10]	+	+	+	+	+	+
Dhoju 2011[18]	+	+	+	+	+	+
Douraiswami 2013[19]	+	+	−	+	+	−
Eden 2015[20]	×	+	+	+	+	×
Ferran 2010[23]	+	+	+	+	+	+
Fuglesang 2018[24]	+	+	+	+	+	+
Garg 201[26]	−	+	+	+	+	×
Kc 2021[36]	−	+	+	+	+	−
Khorami 2014[37]	×	+	+	+	+	×
Kim 2018[39]	+	+	+	+	+	+
King 2019[40]	+	+	+	+	+	+
Narsaria 2014[49]	+	+	+	+	+	+
Saha 2014[57]	+	+	+	+	+	+
Shen 2008[58]	+	+	+	×	+	×
Shetty 2017	+	+	−	+	−	−

(*continued on next page*)

Table II (*continued*)

	Risk of bias domains					
	D1	D2	D3	D4	D5	Overall
Tamaoki 2017[64]	+	+	+	+	+	+
Uchiyama 2021[66]	+	+	+	+	+	+
Virtanen 2012[67]	+	+	+	+	+	+

RoB 2, risk of bias version 2.
Domains: D1: Bias arising from the randomization process. D2: Bias due to deviations from intended intervention. D3: Bias due to missing outcome data. D4: Bias in measurement of the outcome. D5: Bias in selection of the reported result.

Judgment: + = High; – = Some concerns; ✕ = Low.

retrieved eligible articles were searched for supplementary studies. Studies meeting the following criteria were included.

- Studies describing functional outcomes with the use of any type of plate for DMCF (OTA classification 15.2).
- Studies describing complications (nonunion, hardware failure, hardware irritation, wound dehiscence, keloid, superficial infection, deep infection, delayed union, malunion, and/or persistent pain) with use of any type of plate for DMCF.
- Only original studies were included.
- Studies written in English.
- Studies concerning skeletally mature patients, as reported by the study authors.

Abstracts, theses, case reports, biomechanical studies, surgical technique papers, editorials, letters, and conference proceedings were not included. Studies using intramedullary devices, screws, or Kirschner wires were excluded. Studies concerning plate fixation for open fractures, pathological fractures, multitrauma patients, floating shoulders, nonunions, or malunions were also excluded.

Study selection and data extraction

Studies in the final study selection were divided into subgroups depending on the plate type (locking, compression, or reconstruction) and plate location (anteroinferior or superior) and ranked according to their study design and level of evidence (Oxford Centre of Evidence Based Medicine) by 2 authors (R.K. and J.L.). The level of evidence rating is divided into 5 levels: level I indicates the highest evidence studies, level II high, level III moderate, level IV low, and level V very low-evidence studies.[55] Disagreement between the reviewers concerning quality assessment was resolved by discussion.

Data from all included studies were extracted with respect to specific characteristics including title, author, year of publication, the number of clavicles reported, type of fracture, the plate used, location of plate, length of follow-up, functional outcomes, and type and number of complications using Covidence. Data were extracted and checked for accuracy by J.L. and R.K. Discrepancies were resolved by discussion. If disagreement persisted after discussion, consensus was reached after consulting P.H. or C.H. The confidence in estimates was rated and described according to the recommendations of the GRADE working group as each outcome assessed for potential risk of bias, inconsistency, imprecision, indirectness, and publication bias.[7] Risk of Bias VISualization (robvis) was used for visualizing risk of bias assessments.[46] Functional outcome scores were assessed at 6-month and 12-month time points. Functional outcomes at other time points were discarded.

Risk of bias

The Cochrane risk of bias version 2 (RoB 2) tool was used for assessing the risk of bias in randomized trials. The RoB 2 tool covers 5 domains of bias: bias arising from the randomization process, bias due to deviations from intended interventions, bias due to missing outcome data, bias in measurement of outcome, and bias in selection of the reported result. Each domain leads to a judgment of “low risk of bias,” “some concerns,” or “high risk of bias”. Aggregating these judgments gives an overall risk of bias judgment.[62] The ROBINS-I tool was used for assessing the risk of bias in nonrandomized studies of interventions.[61] This tool assesses 7 domains through which bias might be introduced. The first 2 domains, covering confounding and selection of participants into the study, address issues before the start of the interventions. The third domain addresses classification of the interventions themselves. The other 4 domains address issues after the start of interventions: biases due to deviations from intended interventions, missing data, measurement of outcomes, and selection of the reported result.

Statistical analysis

A meta-analysis was performed when 3 or more studies per plate type and location subgroup (ex. superior compression plate) reported a functional outcome measure, nonunion, or type of complication. Studies not included in the meta-analysis were separately described in a narrative analysis. Evaluation of functional outcomes at 6-month and 12-month time points were chosen since they are commonly reported timeframes in existing studies that use validated functional outcome scoring measures. Additionally, clavicle fractures are generally fully healed by 12 months postoperatively. However, a number of studies did not explicitly report the time point when functional outcome scores were calculated. Many studies that did report time points did not use the same time points addressed in this review. Finally, several studies used a functional outcome measure that we were not analyzing,[1,5,12,49,63] which prevented us from including such studies in the meta-analyses. Despite heterogeneity, the individual study

Table III
ROBINS-I results.

	Risk of bias domains							
	D1	D2	D3	D4	D5	D6	D7	Overall
Allis 2020[1]	−	×	+	+	+	+	−	×
Annicchiarico 2020[4]	+	+	+	+	+	+	+	+
Arojuraye 2021[5]	+	+	×	+	+	+	+	×
Chan 2017[11]	×	+	+	+	−	+	+	×
Chechik 2019[12]	+	−	×	+	+	+	+	×
Chu 2018[13]	×	×	+	+	×	+	+	×
DeBaun 2020[16]	−	+	−	+	−	+	+	−
Delvaque 2019[17]	+	+	+	+	+	+	+	+
Fahey 2019[22]	×	+	+	+	×	×	+	×
Galdi 2013[25]	+	+	+	+	+	+	+	+
Hulsmans 2016[30]	×	×	+	+	+	+	+	×
Kariya 2019[35]	×	+	+	+	+	+	+	×
Kilinc 2020[38]	+	+	+	+	+	+	+	+
Ko 2021[41]	+	×	+	+	+	+	+	×
Ladermann 2017[43]	+	+	+	+	+	+	+	+
Lee 2020[45]	−	+	+	+	+	+	+	−
Pathak 2021[52]	+	−	+	+	+	+	+	−
Ranalletta 2015[54]	+	−	+	+	+	−	+	−
Rongguang 2016[56]	×	+	+	+	+	+	+	×

(continued on next page)

Table III (*continued*)

	Risk of bias domains							
	D1	D2	D3	D4	D5	D6	D7	Overall
Souza 2018[60]	+	+	+	+	+	+	+	+
Storti 2021[63]	×	×	+	+	×	+	+	×
Tarng 2012[65]	×	+	+	+	+	+	+	×
Zhou 2019[76]	−	+	+	+	+	+	+	−

ROBINS-I, Risk Of Bias In Non-randomised Studies - of Interventions.
Domains: D1: Bias due to confounding. D2: Bias due to selection of participants. D3: Bias in classification of interventions. D4: Bias due to deviations from intended interventions. D5: Bias due to missing data. D6: Bias in measurement of outcomes. D7: Bias in selection of the reported result.

Judgment: + = High; − = Some concerns; × = Low.

complications and functional outcome scores were pooled. Pooled estimates with their corresponding 95% confidence intervals (CIs) were calculated using logit transformation (complications) or using untransformed data (functional outcome scores) within a random effects model framework. A continuity correction of 0.5 was applied if a study had an event probability of either 0 or 1. This continuity correction is used both to calculate individual study results with confidence limits and to conduct the meta-analysis. Heterogeneity of combined study results was assessed by I^2, and its connected Chi-square test for heterogeneity, and the corresponding 95% CIs were calculated. The restricted maximum likelihood was used to estimate the heterogeneity variance. Ninety-five percent prediction intervals were calculated to present the expected range of true effects in similar studies.[34]

Publication bias was assessed only if 10 or more studies were included in the meta-analysis using funnel plots and Egger's (for continuous outcomes) or Peters' test (for proportions) for funnel plot asymmetry. Sensitivity analyses were performed to assess the influence of study quality when there was more than 1 high-quality study available according to the ROBINS-I.[21,53,59]

Statistical analysis was performed using R version 4.2.2 (R Foundation for Statistical Computing, Vienna, Austria) with package 'meta'.

Results

The search strategy resulted in 3215 unique records. Subsequent selection procedure resulted in 515 eligible articles of which 45 were included in systematic review and 43 in the meta-analysis. One study was excluded from the meta-analysis due to discrepancy between results reported in the manuscript and the table within the manuscript.[37] The other study was excluded due to misreporting of disabilities of the arm, shoulder, and hand (DASH) scores[4] (Fig. 1).

Table 1: Study Characteristics.

Risk of bias assessment

The results of the RoB 2 are summarized in Table 2 and show low to moderate risk of bias in most of the studies. The results of the ROBINS-I risk of bias assessment, summarized in Table 3, show the overall ROBINS-I score for studies.

Locking plates

Anteroinferior locking plates

Only 2 studies were identified regarding anteroinferior locking plates.[4,31] The mean length of follow-up was 27.5 months. No functional outcome scores were reported.

(Figs. 2–9).

Superior locking plates

Concerning superior locking plates, 23 studies were identified.[1,2,4,9,10,12,13,17,19,20,24,28,34-49,51-57,63,66,76] The average patient age from all studies was 37.8 years (range 17-79) with mean length of follow-up of 29.3 months. Five studies reported a Constant-Murley Score (CMS)[14] at 6 months, 1 of these studies did not include a standard error.[20,35,36,57,66] Four studies reported CMS scores at 12 months, 1 of these did not report standard errors.[36,40,57] Four studies reported DASH[28] scores at 12 months of which 1 study did not report standard errors.[20,40,52,76] Six studies reported a DASH score at 12 months, and 1 did not include standard error.[2,4,40,52,76] Other functional incomes reported include the QuickDash[8] (7.5 ± 3.08 at 6 months),[17] ASES (American Shoulder and Elbow Surgeons Standardized Shoulder Assessment)[48] at 6 months and 12 months.[52,76]

Meta-analysis

A metanalysis was performed for all functional outcomes and complications. Data from 4 studies were used to evaluate CMS scores at 6 months. The pooled data for the CMS score at 6 months were 87.89 (95% CI 85.48-90.29 in 182 clavicles). The data for 3 studies were used to evaluate the CMS at 12 months and the DASH at 6 months and 12 months. The pooled CMS score was 93.48 (95% CI 88.49-98.47 in 114 clavicles) and the pooled DASH scores were 9.35 (95% CI 5.62-13.07 in 185 clavicles) for 12 months and 8.99 (95% CI 2.45-15.54 in 185 clavicles) for 6 months. The confidence in the estimates from the meta-analysis according to GRADE concerning the functional outcomes was considered moderate due to the consistency and precision of the data in combination with an intermediate number of clavicles involved (Table 4). The functional outcomes of 2 studies were not included in the meta-analysis.[2,4] Nineteen studies reported on complications, 4 on nonunion, 8 on hardware failure, and 9 on hardware failure. The pooled incidence

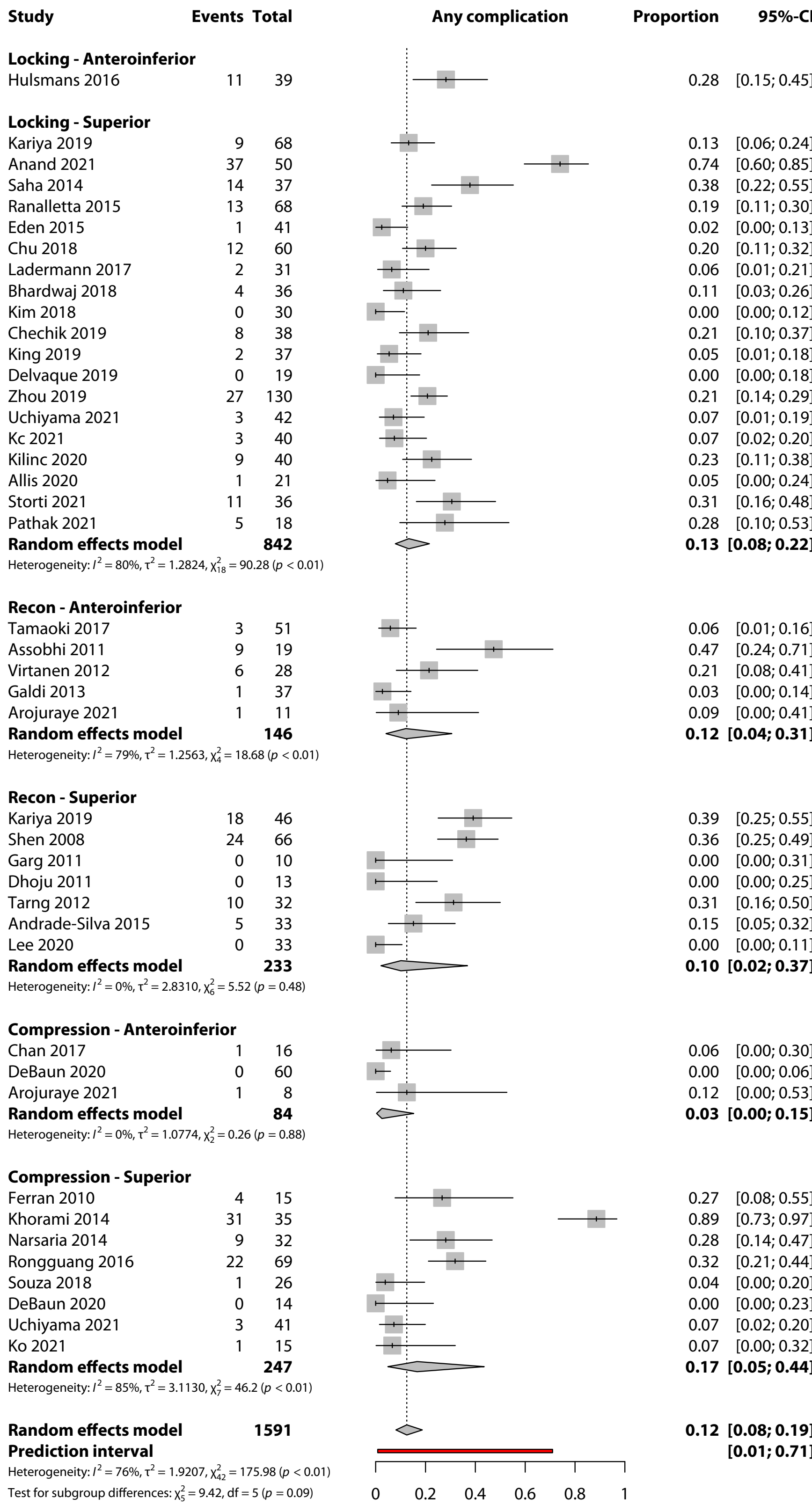

Figure 2 Forest plot of any complication based on plate type and location. *CI*, confidence interval.

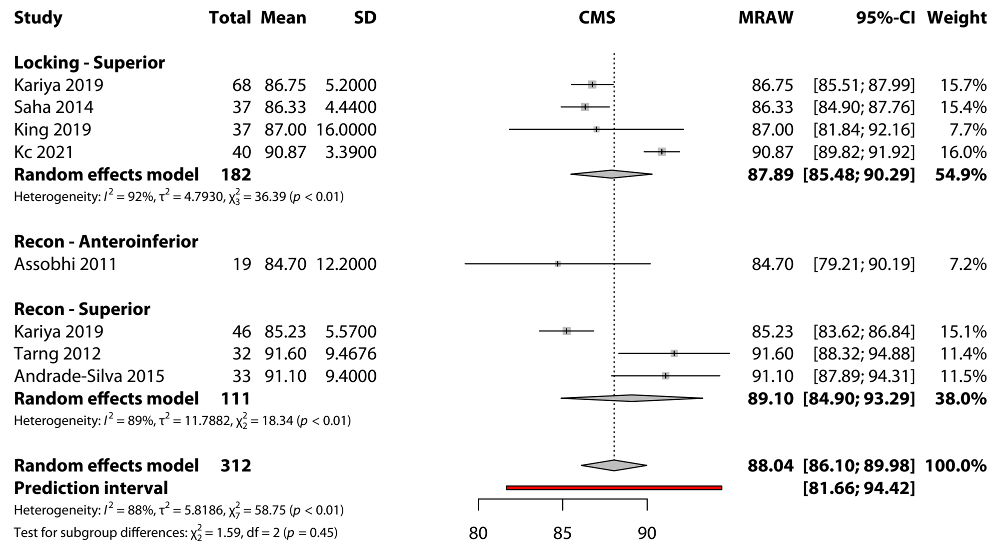

Figure 3 Forest plot of Constant-Murley score at 6 months based on plate type and location. *CI*, confidence interval; *SD*, standard deviation; *CMS*; Constant-Murley Score.

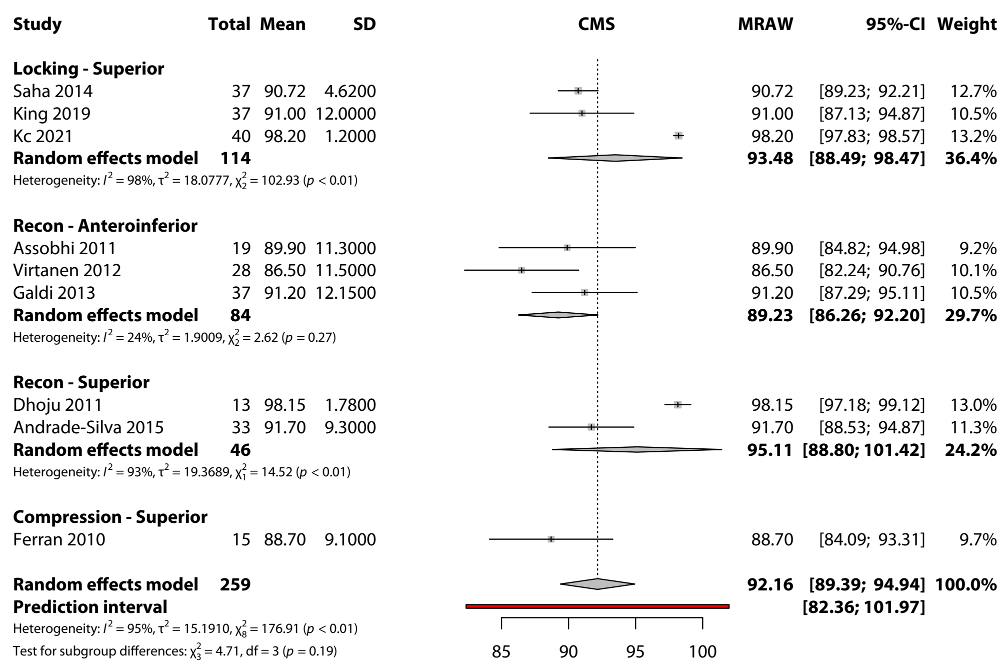

Figure 4 Forest plot of Constant-Murley Score at 12 months based on plate type and location. *CI*, confidence interval; *SD*, standard deviation; *CMS*; Constant-Murley Score.

for any reported complication for superiorly placed locking plates was 13% (95% CI 8-22 in 842 clavicles). Nonunion was found to have a pooled incidence of 3% (95% CI 1-6 in 273 clavicles), hardware failure incidence was 5% (95% CI 3-11 in 464 clavicles), and hardware irritation had an incidence of 11% (95% CI 7-17 in 456 clavicles). The confidence from the meta-analyses according to GRADE concerning the complications ranged from moderate to low (Table 4).

Reconstruction plates

Anteroinferior reconstruction plates

Five studies were identified and included in the systematic review.[5,6,25,64,67] The average age was 40.0 years. The average length of follow-up was 35.7 years (range 26-49). One study reported CMS at 6 months (84.7 ± 12.2)[6]; 3 studies reported a CMS score at 12 months (89.2 ± 11.6).[6,25,67] One study reported a DASH score at 6 months (4 ± 11.6)[64] and 3 studies reported a DASH score at 12 months (3.35 ± 6.0).[25,64,67]

Meta-analysis

A meta-analysis was conducted for 2 functional outcome scores and 1 type of complication. Data from 3 studies were used for both the CMS and DASH scores at 12 months. The pooled CMS score was 89.23 (95% CI 86.26-92.20 in 84 clavicles). The pooled DASH score was 2.93 (95% CI 1.76-4.10). Five studies reported any complication with a pooled incidence of 12% (95% CI 4-31%).[5,6,25,64,67] The confidence from meta-analyses based on GRADE ranged from very low to moderate (Table 4).

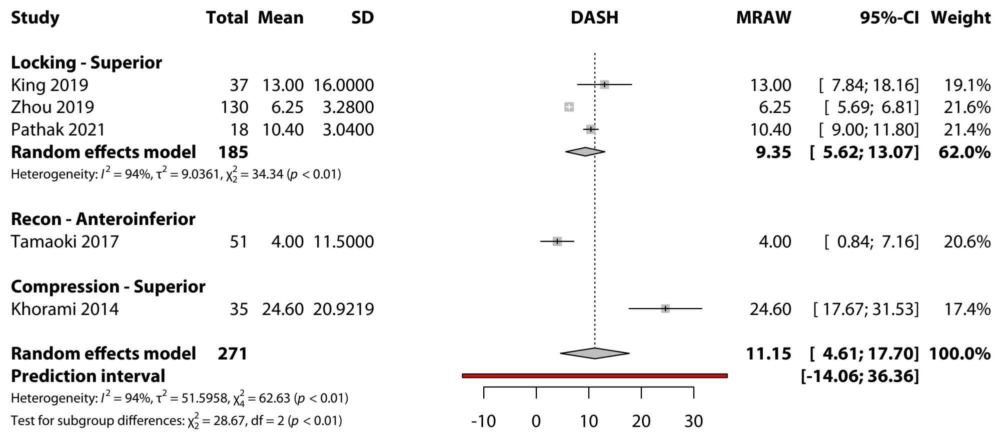

Figure 5 Forest plot of DASH score at 6 months based on plate type and location. *CI*, confidence interval; *SD*, standard deviation; *DASH*, disabilities of the arm, shoulder, and hand.

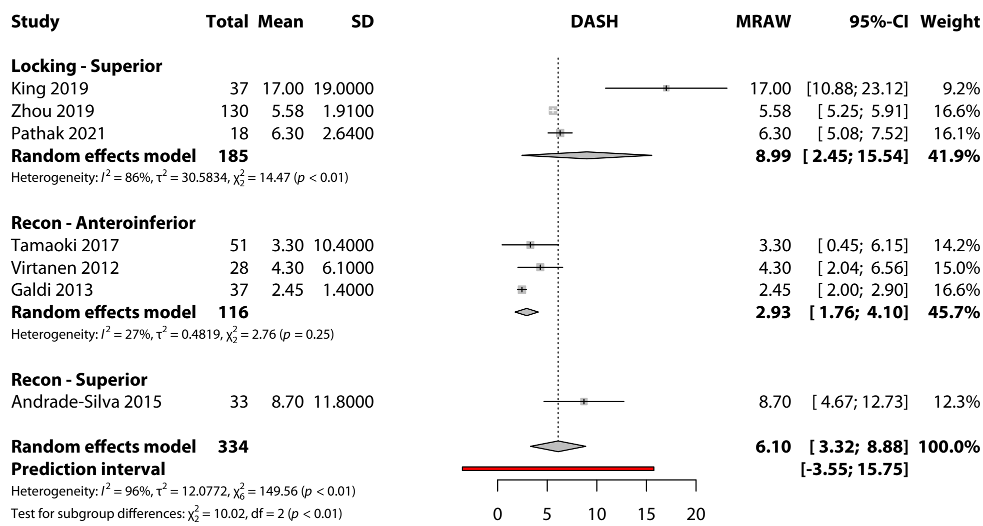

Figure 6 Forest plot of DASH score at 12 months based on plate type and location. *CI*, confidence interval; *SD*, standard deviation; *DASH*, disabilities of the arm, shoulder, and hand.

Superior reconstruction plates

Eight studies concerning superior reconstruction plates were included in the systematic review.[3,5,18,26,35,45,58,65] The mean age of patients was 35.7 years (range 15-57). The average length of follow-up for all studies in the systematic review was 33.3 months. The CMS at 6 months was reported in 3 studies.[3,35,65] One study reported DASH scores at 6 months (9.9).[3]

Meta-analysis

A meta-analysis was conducted for CMS scores at 6 months and total incidence of any complication. The pooled CMS score from the data of 3 studies was 89.10 (95% CI 84.90-93.29 in 111 clavicles). One study was not included in the meta-analysis for functional outcomes.[37] The total incidence of any complications in the 7 pooled studies was 10% (95% CI 2-37 in 233 clavicles). The confidence in the pooled results based on GRADE criteria was moderate for the CMS score and very low for incidence of complications (Table 4).

Compression plates

Anteroinferior placed compression plates

Four studies concerning anteroinferior compression plates were identified and included in the systematic review.[5,11,16,22] The average age for all studies included in the systematic review was 39.1 years (range 18-75). The average range of follow-up was 35.5 months. No studies reported CMS or DASH scores. One study reported a QuickDash score (8.93 ± 8.2).[22]

Meta-analysis

A meta-analysis was conducted on the total incidence of any complication. Using data from 3 studies, the pooled incidence of any complication was 3% (95% CI 0-15 in 84 clavicles). The confidence in the results according to GRADE were deemed very low due to a small number of clavicles reported and lack of precision (Table 4).

Superiorly placed compression plates

Nine studies concerning superior compression plates were identified.[5,16,23,37,41,49,56,60,66] The average age of patients was 38.5 years (range 15-73). The average range of follow-up was 13.2 months. One study reported a CMS and DASH at 6 months.[37] One study reported a CMS at 12 months.[23] Other functional outcome scores reported in this group were the ASES (99.4 ± 0.6)[49] and Oxford Shoulder Score (44.7 ± 3.4).[15,23]

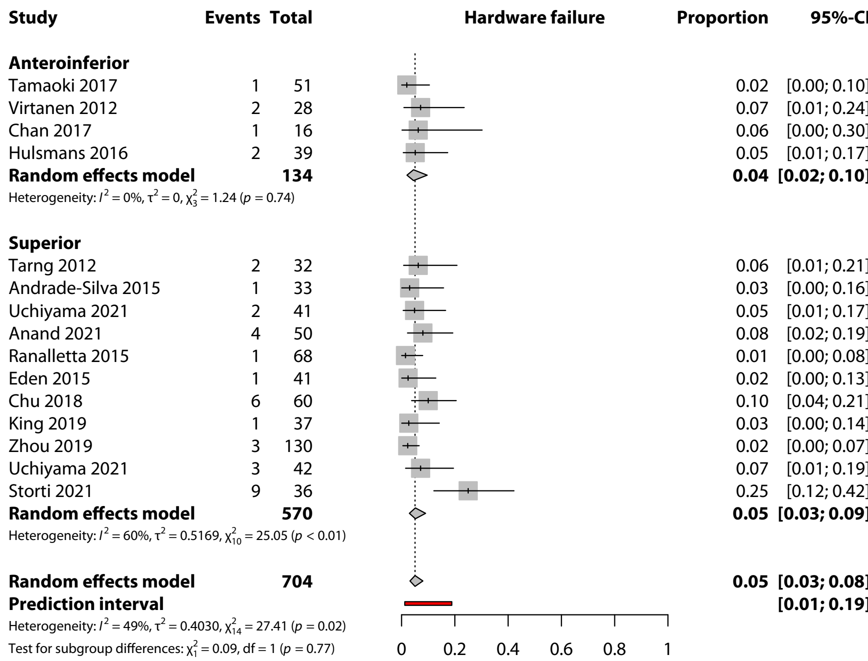

Figure 7 Forest plot of hardware failure based on plate type and location. *CI*, confidence interval.

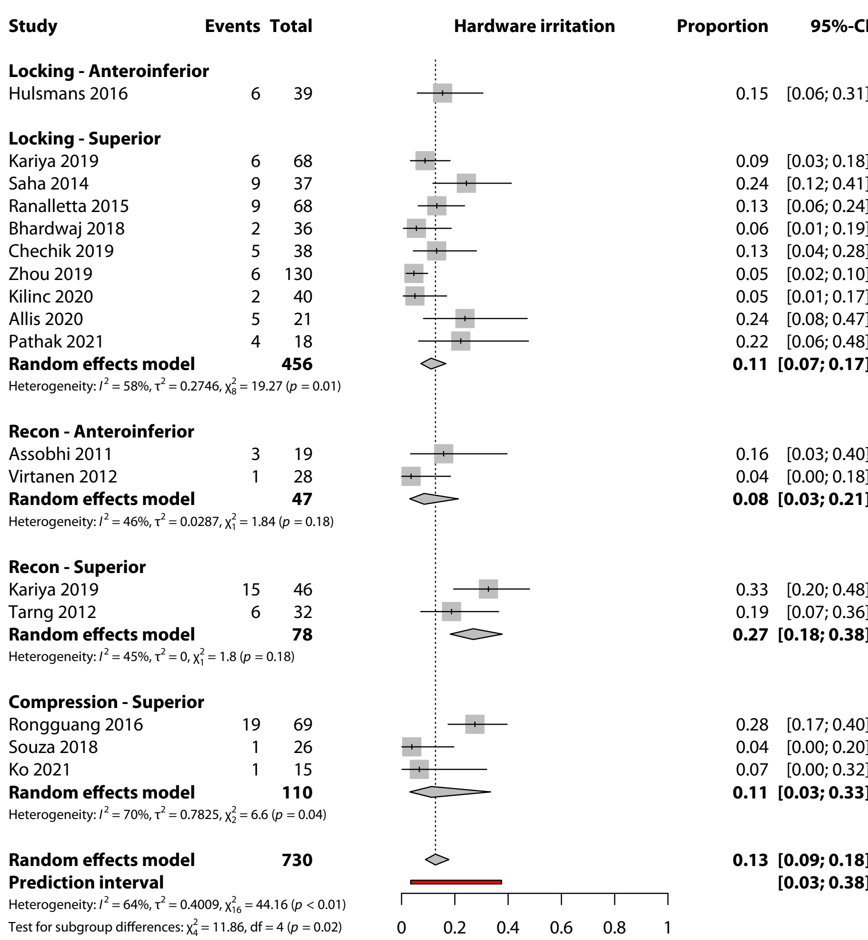

Figure 8 Forest plot of hardware irritation based on plate type and location. *CI*, confidence interval.

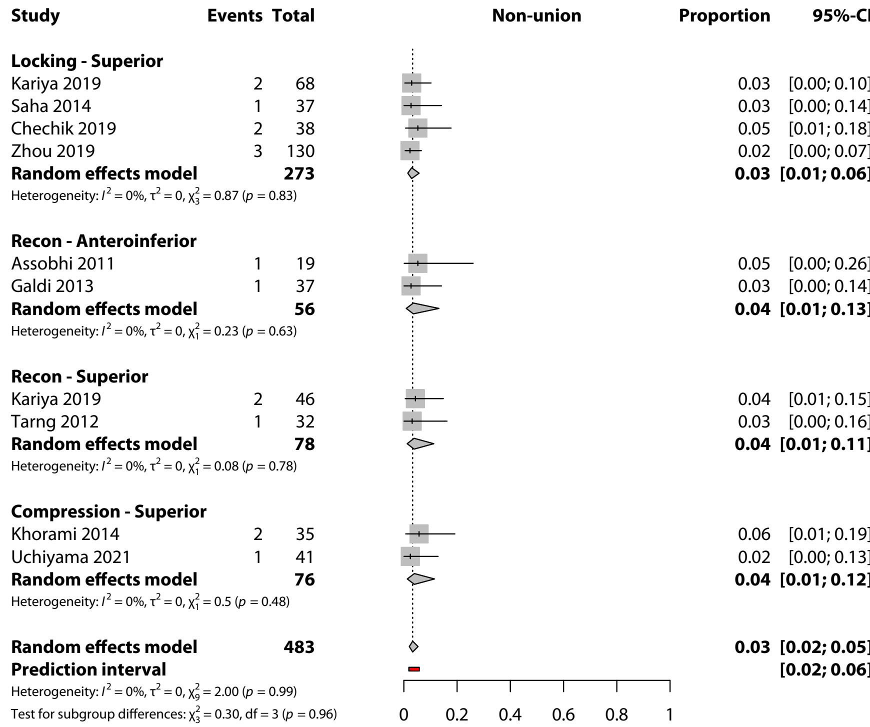

Figure 9 Forest plot of nonunion rate based on plate type and location. *CI*, confidence interval.

Meta-analysis

A meta-analysis was conducted for the incidence of any complication and hardware irritation. Using data from 8 studies, the pooled incidence of any complication was 17% (95% CI 5-44 in 247 clavicles). The incidence of hardware irritation from the pooled data of 3 studies was 11% (95% CI 3-33% 110). The confidence in the results for both outcomes was very low given the lack of precision and small number of sample sizes in the case of hardware irritation (Table 4).

Sensitivity analyses/publication bias

There were not enough high-quality evidence studies to perform sensitivity analysis or publication bias assessment for any of the individual functional outcome or complication end points.

Discussion

In this study, the functional outcomes and complications after surgical treatment of DMCF with respect to plate type and location were systematically reviewed. Good functional results irrespective of plate type or location were found in the reviewed literature.

Both functional outcome scores and rate of any complication for plate types and locations included in the meta-analysis were similar (Table 4). Hardware irritation in the superior locking and superior compression plates was found to be 11% (95% CI 0.07-0.17) and 11% (95% CI 0.03-0.33), respectively. Rates of hardware irritation after plate fixation in the literature range from 9% to 70% and often result in hardware removal.[30] Our findings suggest a hardware irritation rate on the lower end of the range. While it is possible that the hardware irritation rate may be lower in the present study compared to previous studies, another explanation may be that hardware irritation resulted in plate removal and thus the complication was recorded as plate removal in the studies analyzed in the present study. We did not calculate hardware removal rates in this study and many studies do not provide the reason for plate removal. Thus, we may not have an accurate account of hardware irritation rates. Given the design of locking plates, we expect that hardware irritation may theoretically be less common compared to compression plates given the screw sits flush with the device for fixation plates. We were unable to conduct a meta-analysis for hardware irritation for any type of anteroinferior plates due to too few studies reporting the complication. Given anteroinferior plates are not in contact with the skin overlying the clavicle, they should theoretically have a decreased rate of hardware irritation compared to superior plates. This study was the first of its kind to attempt to stratify clavicle plates by type and location, which made it impossible to directly compare our results to existing systematic reviews. However, Nourian et al compared the functional outcomes and complication rate stratified by plate location. They found that superior plates were more likely than anteroinferior plates to result in hardware prominence with associated irritation of the skin.[50] The study did not find significant differences between plate location and functional outcomes, union rates, malunion, nonunion, or implant failure.

A 2011 systematic review of complications after ORIF of clavicle fractures showed the hardware irritation rate ranged from 9% to 64%[69] which appears to be less than our findings of 11%. However, it should be noted that the review only included 5 studies that reported hardware irritation as a complication.

Limitations

The results of this study are limited by the quality of evidence available. In most of our meta-analyses of reported complications, GRADE scores were low to very low. Furthermore, only studies written in English were included in this systematic review. There was considerable heterogeneity between studies. This heterogeneity likely stems from differences in patient selection, surgeon,

Table IV
Evidence summary table.

Device	Outcome	No. of studies	No. of clavicles	Effect estimate (95% CI)	GRADE domains								
					Risk of bias	Inconsistency	Imprecision	Indirectness	Publication bias	Large magnitude of effect	Dose response gradient	Residual confounding	Quality of evidence (GRADE)
Locking - Superior													
	CMS 6 months	4	182	87.89 (85.48-90.29)	X	O	X	NA	NA	O	O	O	⊕⊕⊕⊙ MODERATE
	CMS 12 months	3	114	93.48 (88.49-98.47)	X	X	X	NA	NA	O	O	O	⊕⊕⊕⊙ MODERATE
	DASH 6 months	3	185	9.35 (5.62-13.07)	X	X	X	NA	NA	O	O	O	⊕⊕⊕⊙ MODERATE
	DASH 12 months	3	185	8.99 (2.45-15.54)	X	X	X	NA	NA	O	O	O	⊕⊕⊕⊙ MODERATE
	Any complications	19	842	0.13 (0.08-0.22)	X	X	O	NA	O	O	O	O	⊕⊕⊕⊙ MODERATE
	Nonunion	4	273	0.03 (0.01-0.06)	X	O	X	NA	NA	O	O	O	⊕⊕⊙⊙ LOW
	Hardware failure	8	464	0.05 (0.03-0.11)	X	X	O	NA	NA	O	O	O	⊕⊕⊙⊙ LOW
	Hardware irritation	9	456	0.11 (0.07-0.17)	X	X	O	NA	NA	O	O	O	⊕⊕⊙⊙ LOW
Recon - Anteroinferior													
	CMS 12 months	3	84	89.23 (86.26-92.20)	X	O	X	NA	NA	O	O	O	⊕⊕⊕⊙ MODERATE
	DASH 12 months	3	116	2.93 (1.76-4.10)	X	O	X	NA	NA	O	O	O	⊕⊕⊙⊙ LOW
	Any complications	5	146	0.12 (0.04-0.31)	X	X	X	NA	NA	O	O	O	⊕⊙⊙⊙ VERY LOW
Recon - Superior													
	CMS 6 months	3	111	89.10 (84.90-93.29)	X	O	X	NA	NA	O	O	O	⊕⊕⊕⊙ MODERATE
	Any complications	7	233	0.10 (0.02-0.37)	X	X	X	NA	NA	O	O	O	⊕⊕⊙⊙ LOW
Compression - Anteroinferior													
	Any complications	3	84	0.03 (0.00-0.15)	X	O	X	NA	NA	O	O	O	⊕⊙⊙⊙ VERY LOW
Compression - Superior													
	Any complications	8	247	0.17 (0.05-0.44)	X	X	X	NA	NA	O	O	O	⊕⊙⊙⊙ VERY LOW
	Hardware irritation	3	110	0.11 (0.03-0.33)	X	X	X	NA	NA	O	O	O	⊕⊙⊙⊙ VERY LOW

CMS, Constant-Murley Score; *DASH*, disabilities of the arm, shoulder, and hand; *CI*, confidence interval; *X*, Present; *O*, Not present; *NA*, Not Applicable.
GRADE, Working Group grades of evidence.
High certainty: We are very confident that the true effect lies close to that of the estimate of the effect.
Moderate certainty: We are moderately confident in the effect estimate: The true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different.
Low certainty: Our confidence in the effect estimate is limited: The true effect may be substantially different from the estimate of the effect.
Very low certainty: We have very little confidence in the effect estimate: The true effect is likely to be substantially different from the estimate of effect.

and clinical setting among the studies, but also from not all functional outcomes and complications being reported in a similar manner. To account for the expected heterogeneity, a random effects model was used. In the case of superior locking, anteroinferior reconstruction, and superior reconstruction plates, the GRADE quality of evidence was moderate. This review chose to investigate functional outcomes at 6-month and 12-month time points. However, a number of studies did not explicitly report the time point when functional outcome scores were calculated. Many studies that did report time points did not use the same time points addressed in this review. Finally, several studies used a functional outcome measure that we were not analyzing,[1,5,12,49,63] which prevented us from including such studies in the meta-analyses.

Other information

The detailed search strategy for this systematic review is available in Additional file 1. The review protocol adhered to by the authors is available via PROSPERO (CRD42022310818).

Conclusion

While many studies were of limited quality, those presenting functional outcomes data consistently demonstrated positive functional outcomes and comparable rates of any complication, irrespective of plate type and location. Our results suggest there is no evidence at this time to select a particular plate type or location to optimize functional outcomes or complications in patients treated with ORIF for DMCF.

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Supplementary Data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jseint.2024.01.007.

References

1. Allis JB, Cheung EC, Farrell ED, Johnson EE, Jeffcoat DM. Dual versus single-plate fixation of midshaft clavicular fractures: a retrospective comparative study. JB JS Open Access 2020;5:e0043. https://doi.org/10.2106/JBJS.OA.19.00043.
2. Anand A, Manav AK. Midshaft clavicular fractures: intramedullary nailing versus plate fixation. Int J Curr Pharmaceut Clin Res 2021;13:48-54.
3. Andrade-Silva FB, Kojima KE, Joeris A, Santos Silva J, Mattar R. Single, superiorly placed reconstruction plate compared with flexible intramedullary nailing for midshaft clavicular fractures: a prospective, randomized controlled trial. J Bone Joint Surg Am 2015;97:620-6. https://doi.org/10.2106/JBJS.N.00497.
4. Annicchiarico N, Latta A, Santolini E. Plate osteosynthesis for mid-shaft clavicle fractures: an update. Injury 2020;54:S53. https://doi.org/10.1016/j.injury.2020.10.085.
5. Arojuraye SA, Salihu MN, Mustapha IU, Alabi IA, Okoh N, Ayeni FB. Anteroinferior versus superior plating techniques for displaced midshaft clavicle fractures: a retrospective single centre cohort study from Northern Nigeria. Surgeon 2021;20:101168329. https://doi.org/10.1016/j.surge.2021.07.006.
6. Assobhi JEH. Reconstruction plate versus minimal invasive retrograde titanium elastic nail fixation for displaced midclavicular fractures. J Orthop Traumatol 2011;12:185-92. https://doi.org/10.1007/s10195-011-0158-7.
7. Atkins D, Best D, Briss PA, Eccles M, Falck-Ytter Y, Flottorp S, et al. Grading quality of evidence and strength of recommendations. BMJ 2004;328:1490. https://doi.org/10.1136/bmj.328.7454.1490.
8. Beaton DE, Wright JG, Katz JN. Upper Extremity Collaborative group. Development of the QuickDASH: comparison of three item-reduction approaches. J Bone Joint Surg Am 2005;87:1038-46. https://doi.org/10.2106/JBJS.D.02060.
9. Beirer M, Postl L, Crönlein M, Siebenlist S, Huber-Wagner S, Braun KF, et al. Does a minimal invasive approach reduce anterior chest wall numbness and postoperative pain in plate fixation of clavicle fractures? BMC Musculoskeletal Disord 2015;16:128. https://doi.org/10.1186/s12891-015-0592-4.
10. Bhardwaj A, Sharma G, Patil A, Rahate V. Comparison of plate osteosynthesis versus non-operative management for mid-shaft clavicle fractures-a prospective study. Injury 2018;49:1104-7. https://doi.org/10.1016/j.injury.2018.04.012.
11. Chan G, Korac Z, Miletic M, Vidovic D, Phadnis J, Bakota B. Plate versus intramedullary fixation of two-part and multifragmentary displaced midshaft clavicle fractures - a long-term analysis. 0226040, gon Injury 2017;48:S21-6. https://doi.org/10.1016/S0020-1383(17)30734-9.
12. Chechik O, Batash R, Goldstein Y, Snir N, Amar E, Drexler M, et al. Surgical approach for open reduction and internal fixation of clavicle fractures: a comparison of vertical and horizontal incisions. Int Orthop 2019;43:1977-82. https://doi.org/10.1007/s00264-018-4139-9.
13. Chu J-Y, Yeh K-T, Lee R-P, Yu T-C, Chen I-H, Peng C-H, et al. Open reduction and internal fixation with plating is beneficial in the early recovery stage for displaced midshaft clavicular fractures in patients aged 30-65 years old. Ci Ji Yi Xue Za Zhi 2018;30:242-6. https://doi.org/10.4103/tcmj.tcmj_25_18.
14. Constant CR, Murley AH. A clinical method of functional assessment of the shoulder. Clin Orthop Relat Res 1987:160-4.
15. Dawson J, Fitzpatrick R, Carr A. Questionnaire on the perceptions of patients about shoulder surgery. J Bone Joint Surg Br 1996;78:593-600.
16. DeBaun MR, Chen MJ, Campbell ST, Goodnough LH, Lai C, Salazar BP, et al. Dual Mini-fragment plating is comparable with precontoured small fragment plating for operative diaphyseal clavicle fractures: a retrospective cohort study. J Orthop Trauma 2020;34:e229. https://doi.org/10.1097/BOT.0000000000001727.
17. Delvaque J-G, Begue T, Villain B, Mebtouche N, Auregan J-C. Surgical treatment of mid-shaft clavicle fractures by minimally invasive internal fixation facilitated by intra-operative external fixation: a preliminary study. Orthop Traumatol Surg Res 2019;105:847-52. https://doi.org/10.1016/j.otsr.2019.01.022.
18. Dhoju D, Shrestha D, Parajuli NP, Shrestha R, Sharma V. Operative fixation of displaced middle third clavicle (Edinburg Type 2) fracture with superior reconstruction plate osteosynthesis. Kathmandu Univ Med J (KUMJ) 2011;9:286-90. https://doi.org/10.3126/kumj.v9i4.6346.
19. Douraiswami B, Naidu DK, Thanigai S, Anand V, Dhanapal R. Open reduction and plating for displaced mid third clavicle fractures - a prospective study. J Clin Orthop Trauma 2013;4:174-9. https://doi.org/10.1016/j.jcot.2013.09.002.
20. Eden L, Ziegler D, Gilbert F, Fehske K, Fenwick A, Meffert RH. Significant pain reduction and improved functional outcome after surgery for displaced midshaft clavicular fractures. J Orthop Surg Res 2015;10:190. https://doi.org/10.1186/s13018-015-0336-z.
21. Egger M, Smith GD, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. BMJ 1997;315:629-34.
22. Fahey EJ, Galbraith JG, Kaar K. A single centre experience of pre-contoured clavicle plates by an anterior approach. J Orthop 2019;16:171-4. https://doi.org/10.1016/j.jor.2019.02.001.
23. Ferran NA, Hodgson P, Vannet N, Williams R, Evans RO. Locked intramedullary fixation vs plating for displaced and shortened mid-shaft clavicle fractures: a randomized clinical trial. J Shoulder Elbow Surg 2010;19:783-9. https://doi.org/10.1016/j.jse.2010.05.002.
24. Fuglesang HFS, Flugsrud GB, Randsborg P-H, Hammer O-L, Utvag SE. Five-year follow-up results of a randomized controlled study comparing intramedullary nailing with plate fixation of completely displaced midshaft fractures of the clavicle in Adults. JB JS Open Access 2018;3:e0009. https://doi.org/10.2106/JBJS.OA.18.00009.
25. Galdi B, Yoon RS, Choung EW, Reilly MC, Sirkin M, Smith WR, et al. Anteroinferior 2.7-mm versus 3.5-mm plating for AO/OTA type B clavicle fractures: a comparative cohort clinical outcomes study. J Orthop Trauma 2013;27:121-5. https://doi.org/10.1097/BOT.0b013e3182693f32.
26. Garg AK, Mukhopadhyay KK, Shaw R, Roy SK, Banerjee K, Mukhopadhyay K. Displaced middle-third fractures of the clavicle-operative management. J Indian Med Assoc 2011;109:409-10.
27. Guerra E, Previtali D, Tamborini S, Filardo G, Zaffagnini S, Candrian C. Midshaft clavicle fractures: surgery provides better results as compared with nonoperative treatment: a meta-analysis. Am J Sports Med 2019;47:3541-51. https://doi.org/10.1177/0363546519826961.
28. Gummesson C, Atroshi I, Ekdahl C. The disabilities of the arm, shoulder and hand (DASH) outcome questionnaire: longitudinal construct validity and measuring self-rated health change after surgery. BMC Musculoskelet Disord 2003;4:11. https://doi.org/10.1186/1471-2474-4-11.
29. Houwert RM, Smeeing DPJ, Ahmed Ali U, Hietbrink F, Kruyt MC, van der Meijden OA. Plate fixation or intramedullary fixation for midshaft clavicle fractures: a systematic review and meta-analysis of randomized controlled trials and observational studies. J Shoulder Elbow Surg 2016;25:1195-203. https://doi.org/10.1016/j.jse.2016.01.018.
30. Hulsmans MHJ, van Heijl M, Houwert RM, Hammacher ER, Meylaerts SAG, Verhofstad MHJ, et al. High irritation and removal rates after plate or nail fixation in patients with displaced midshaft clavicle fractures. Clin Orthop Relat Res 2017;475:532-9. https://doi.org/10.1007/s11999-016-5113-8.
31. Hulsmans MHJ, van Heijl M, Houwert RM, Timmers TK, van Olden G, Verleisdonk EJMM. Anteroinferior versus superior plating of clavicular fractures. J Shoulder Elbow Surg 2016;25:448-54. https://doi.org/10.1016/j.jse.2015.09.005.

32. Hussain N, Sermer C, Prusick PJ, Banfield L, Atrey A, Bhandari M. Intramedullary nailing versus plate fixation for the treatment displaced midshaft clavicular fractures: a systematic review and meta-analysis. Sci Rep 2016;6:34912. https://doi.org/10.1038/srep34912.
33. Huttunen TT, Launonen AP, Berg HE, Lepola V, Felländer-Tsai L, Mattila VM. Trends in the incidence of clavicle fractures and surgical Repair in Sweden: 2001-2012. J Bone Joint Surg Am 2016;98:1837-42. https://doi.org/10.2106/JBJS.15.01284.
34. IntHout J, Ioannidis JPA, Rovers MM, Goeman JJ. Plea for routinely presenting prediction intervals in meta-analysis. BMJ Open 2016;6:e010247. https://doi.org/10.1136/bmjopen-2015-010247.
35. Kariya AD, Jain PA, Patond K. Middle third clavicular fractures fixed with precontoured locking compression plate or reconstruction plate: comparison of outcomes and complications. Curr Orthop Pract 2019;30:257-62. https://doi.org/10.1097/BCO.0000000000000740.
36. Kc KM, Acharya P, Rc DR, Marahatta SB, Niroula A, Kc A. Comparative study between the precontoured anatomical locking plate and clavicle Brace for displaced mid-shaft clavicle fractures. J Nepal Health Res Counc 2021;19:337-42. https://doi.org/10.33314/jnhrc.v19i2.3234.
37. Khorami M, Fakour M, Mokarrami H, Arti HR, Nasab AM, Shahrivar F. The comparison of results of treatment of midshaft clavicle fracture between operative treatment with plate and non-operative treatment. Arch Bone Jt Surg 2014;2:210-4.
38. Kilinc BE, Oc Y, Erturer RE. Treatment of midshaft clavicle fracture with superior plate placement. Acta Ortop Bras 2020;28:88-91. https://doi.org/10.1590/1413-785220202802226166.
39. Kim JY, Yoo BC, Yoon JP, Kang SJ, Chung SW. A comparison of clinical and radiological outcomes of minimally invasive and conventional plate osteosynthesis for midshaft clavicle fractures. Orthopedics 2018;41:e649-54. https://doi.org/10.3928/01477447-20180711-05.
40. King PR, Ikram A, Eken MM, Lamberts RP. The effectiveness of a flexible locked intramedullary nail and an anatomically contoured locked plate to treat clavicular shaft fractures: a 1-year randomized control trial. J Bone Joint Surg Am 2019;101:628-34. https://doi.org/10.2106/JBJS.18.00660.
41. Ko MS, Ri K-I, Mun T-W, Song K-I, Choe K-I. Minimally invasive plate osteosynthesis of clavicular midshaft fractures under insertion guide. Ulus Travma Acil Cerrahi Derg 2021;27:552-7. https://doi.org/10.14744/tjtes.2020.94728.
42. Kong L, Zhang Y, Shen Y. Operative versus nonoperative treatment for displaced midshaft clavicular fractures: a meta-analysis of randomized clinical trials. Arch Orthop Trauma Surg 2014;134:1493-500. https://doi.org/10.1007/s00402-014-2077-6.
43. Lädermann A, Abrassart S, Denard PJ, Tirefort J, Nowak A, Schwitzguebel AJ. Functional recovery following early mobilization after middle third clavicle osteosynthesis for acute fractures or nonunion: a case-control study. Orthop Traumatol Surg Res 2017;103:885-9. https://doi.org/10.1016/j.otsr.2017.03.021.
44. Ledger M, Leeks N, Ackland T, Wang A. Short malunions of the clavicle: an anatomic and functional study. J Shoulder Elbow Surg 2005;14:349-54. https://doi.org/10.1016/j.jse.2004.09.011.
45. Lee C, Feaker DA, Ostrofe AA, Smith CS. No difference in risk of implant removal between orthogonal mini-fragment and single small-fragment plating of midshaft clavicle fractures in a military population: a preliminary study. Clin Orthop Relat Res 2020;478:741-9. https://doi.org/10.1097/CORR.0000000000000877.
46. McGuinness LA, Higgins JPT. Risk-of-bias VISualization (robvis): an R package and Shiny web app for visualizing risk-of-bias assessments. Res Synth Methods 2021;12:55-61. https://doi.org/10.1002/jrsm.1411.
47. McKee RC, Whelan DB, Schemitsch EH, McKee MD. Operative versus nonoperative Care of displaced midshaft clavicular fractures: a meta-analysis of randomized clinical trials. J Bone Joint Surg 2012;94:675-84. https://doi.org/10.2106/JBJS.J.01364.
48. Michener LA, McClure PW, Sennett BJ. American shoulder and Elbow surgeons Standardized shoulder assessment Form, patient self-report section: reliability, validity, and responsiveness. J Shoulder Elbow Surg 2002;11:587-94. https://doi.org/10.1067/mse.2002.127096.
49. Narsaria N, Singh AK, Arun GR, Seth RRS. Surgical fixation of displaced midshaft clavicle fractures: elastic intramedullary nailing versus precontoured plating. J Orthop Traumatol 2014;15:165-71. https://doi.org/10.1007/s10195-014-0298-7.
50. Nourian A, Dhaliwal S, Vangala S, Vezeridis PS. Midshaft fractures of the clavicle: a meta-analysis comparing surgical fixation using anteroinferior plating versus superior plating. J Orthop Trauma 2017;31:461. https://doi.org/10.1097/BOT.0000000000000936.
51. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. https://doi.org/10.1136/bmj.n71.
52. Pathak SK, Gautam RK, Godara A, Singh M, Kumar N, Sharma A, et al. Plate osteosynthesis or Figure-of-eight Brace: which one is better in midshaft clavicle fractures? Cureus 2021;13:e14339. https://doi.org/10.7759/cureus.14339.
53. Peters JL, Sutton AJ, Jones DR, Abrams KR, Rushton L. Comparison of two methods to detect publication bias in meta-analysis. JAMA 2006;295:676-80. https://doi.org/10.1001/jama.295.6.676.
54. Ranalletta M, Rossi LA, Bongiovanni SL, Tanoira I, Piuzzi NS, Maignon G. Surgical treatment of displaced midshaft clavicular fractures with precontoured plates. J Shoulder Elbow Surg 2015;24:1036-40. https://doi.org/10.1016/j.jse.2014.12.013.
55. Robinson CM. Fractures of the clavicle in the adult. Epidemiology and classification. J Bone Joint Surg Br 1998;80:476-84.
56. Rongguang A, Zhen J, Jianhua Z, Jifei S, Xinhua J, Baoqing Y. Surgical treatment of displaced midshaft clavicle fractures: precontoured plates versus noncontoured plates. J Hand Surg Am 2016;41:e263-6. https://doi.org/10.1016/j.jhsa.2016.06.007.
57. Saha P, Datta P, Ayan S, Garg AK, Bandyopadhyay U, Kundu S. Plate versus titanium elastic nail in treatment of displaced midshaft clavicle fractures: a comparative study. Indian J Orthop 2014;48:587-93. https://doi.org/10.4103/0019-5413.144227.
58. Shen J-W, Tong P-J, Qu H-B. A three-dimensional reconstruction plate for displaced midshaft fractures of the clavicle. J Bone Joint Surg 2008;90:1495-8. https://doi.org/10.1302/0301-620X.90B11.21096.
59. Simmonds M. Quantifying the risk of error when interpreting funnel plots. Syst Rev 2015;4:24. https://doi.org/10.1186/s13643-015-0004-8.
60. Souza NASM, Belangero PS, Figueiredo EA, Pochini AC, Andreoli CV, Ejnisman B. Displaced midshaft clavicle fracture in athletes - should we operate? Rev Bras Ortop 2018;53:171-5. https://doi.org/10.1016/j.rboe.2018.02.002.
61. Sterne JA, Hernán MA, Reeves BC, Savović J, Berkman ND, Viswanathan M, et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. BMJ 2016;355:i4919. https://doi.org/10.1136/bmj.i4919.
62. Sterne JAC, Savović J, Page MJ, Elbers RG, Blencowe NS, Boutron I, et al. RoB 2: a revised tool for assessing risk of bias in randomised trials. BMJ 2019;366:l4898. https://doi.org/10.1136/bmj.l4898.
63. Storti TM, Camilo MS, Silva RFA, Faria RSS, Simionatto CL, Paniago AF. Clinical evaluation of the treatment of clavicle fractures: intramedullary nail x plate. Acta Ortop Bras 2021;29:34-8. https://doi.org/10.1590/1413-785220212901231439.
64. Tamaoki MJS, Matsunaga FT, Costa ARFD, Netto NA, Matsumoto MH, Belloti JC. Treatment of displaced midshaft clavicle fractures: figure-of-eight harness versus anterior plate osteosynthesis. J Bone Joint Surg Am 2017;99:1159-65. https://doi.org/10.2106/JBJS.16.01184.
65. Tarng Y-W, Yang S-W, Fang Y-P, Hsu C-J. Surgical management of uncomplicated midshaft clavicle fractures: a comparison between titanium elastic nails and small reconstruction plates. J Shoulder Elbow Surg 2012;21:732-40. https://doi.org/10.1016/j.jse.2011.08.065.
66. Uchiyama Y, Handa A, Omi H, Hashimoto H, Shimpuku E, Imai T, et al. Locking versus nonlocking superior plate fixations for displaced midshaft clavicle fractures: a prospective randomized trial comparing clinical and radiografic results. J Orthop Sci 2021;26:1094-9. https://doi.org/10.1016/j.jos.2020.09.017.
67. Virtanen KJ, Remes V, Pajarinen J, Savolainen V, Bjorkenheim J-M, Paavola M. Sling compared with plate osteosynthesis for treatment of displaced midshaft clavicular fractures: a randomized clinical trial. J Bone Joint Surg 2012;94:1546-53. https://doi.org/10.2106/JBJS.J.01999.
68. Wang X-H, Cheng L, Guo W-J, Li A-B, Cheng G-J, Lei T, et al. Plate versus intramedullary fixation care of displaced midshaft clavicular fractures: a meta-analysis of prospective randomized controlled trials. Medicine 2015;94:e1792. https://doi.org/10.1097/MD.0000000000001792.
69. Wijdicks F-J, Houwert M, Dijkgraaf M, de Lange D, Oosterhuis K, Clevers G, et al. Complications after plate fixation and elastic stable intramedullary nailing of dislocated midshaft clavicle fractures: a retrospective comparison. Int Orthop 2012;36:2139-45. https://doi.org/10.1007/s00264-012-1615-5.
70. Wijdicks F-JG, Van der Meijden OAJ, Millett PJ, Verleisdonk EJMM, Houwert RM. Systematic review of the complications of plate fixation of clavicle fractures. Arch Orthop Trauma Surg 2012;132:617-25. https://doi.org/10.1007/s00402-011-1456-5.
71. Woltz S, Stegeman SA, Krijnen P, van Dijkman BA, van Thiel TPH, Schep NWL, et al. Plate fixation compared with nonoperative treatment for displaced midshaft clavicular fractures: a Multicenter randomized controlled trial. J Bone Joint Surg 2017;99:106-12. https://doi.org/10.2106/JBJS.15.01394.
72. Xiao H, Gao H, Zheng T, Zhao J, Tian Y. Plate fixation versus intramedullary fixation for midshaft clavicle fractures: meta-analysis of complications and functional outcomes. J Int Med Res 2016;44:201-15. https://doi.org/10.1177/0300060515621638.
73. Xie L, Zhao Z, Zhang S, Hu Y. Intramedullary fixation versus plate fixation for displaced mid-shaft clavicle fractures: a systematic review of overlapping meta-analyses. Medicine 2018;97:e9752. https://doi.org/10.1097/MD.0000000000009752.
74. Xu B, Lin Y, Wang Z, Cao J, Yang Y, Xia H, et al. Is intramedullary fixation of displaced midshaft clavicle fracture superior to plate fixation? Evidence from a systematic review of discordant meta-analyses. Int J Surg 2017;43:155-62. https://doi.org/10.1016/j.ijsu.2017.05.069.
75. Zhang B, Zhu Y, Zhang F, Chen W, Tian Y, Zhang Y. Meta-analysis of plate fixation versus intramedullary fixation for the treatment of mid-shaft clavicle fractures. Scand J Trauma Resusc Emerg Med 2015;23:1-11. https://doi.org/10.1186/s13049-015-0108-0.
76. Zhou X, Li J, Yang H, Li D, Zhang J, Zhang Y, et al. Comparison of 2 different fixation implants for operative treatment of mid-shaft clavicle fractures: a retrospective study. Med Sci Mon 2019;25:9728-36. https://doi.org/10.12659/MSM.918773.
77. Zhu Y, Tian Y, Dong T, Chen W, Zhang F, Zhang Y. Management of the mid-shaft clavicle fractures using plate fixation versus intramedullary fixation: an updated meta-analysis. Int Orthop 2015;39:319-28. https://doi.org/10.1007/s00264-014-2655-9.