Clinical Sports Medicine Update

Midshaft Clavicle Fractures: Surgery Provides Better Results as Compared With Nonoperative Treatment

A Meta-analysis

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Background: There is no agreement on the best treatment for displaced midshaft clavicle fractures (MCFs), which are currently addressed by nonoperative or surgical approaches.

Purpose: The aim of this meta-analysis was to compare fracture healing and functional outcome after surgical versus nonsurgical treatment of MCFs, to help specialists in deciding between these different strategies by providing a synthesis of the best literature evidence.

Study Design: Meta-analysis.

Methods: A systematic research of the literature was performed in different online databases: PubMed, Web of Science, Cochrane library, and grey literature. PRISMA (Preferred Reporting Items for Systematic Meta-Analyses) guidelines were used. The risk of bias was evaluated with the Cochrane Collaboration's ''risk of bias'' tool, and the quality of evidence was graded according to Grading of Recommendations Assessment, Development and Evaluation (GRADE) guidelines. Randomized controlled trials investigating differences between surgery and nonoperative treatment for displaced MCFs were included. The primary outcome was the nonunion rate. Other outcomes analyzed were time to union and to return to activities, Constant score, and Disabilities of the Arm, Shoulder and Hand (DASH) index. Patients' satisfaction, secondary operations, and complications were also recorded.

Results: Out of 832 records found, 14 randomized controlled trials with 1546 patients were included. A significantly lower risk ratio was found for nonunion (10%; 95% CI, 6%-18%, $P < .001$) favoring surgery. Time to union was 5.1 weeks shorter with surgery ($P = .007$). The complication rate (including the number of reinterventions) was higher in the surgical group (31.3% vs 20.5%, $P < .001$). Shoulder function at short-term follow-up was significantly better in the surgical group (DASH index mean difference = 4.0 points), while no statistical difference was found in the Constant score and in the DASH index at midterm follow-up ($P = .41$ and .80, respectively). At long-term follow-up, both shoulder functional scores were significantly better in the surgery group: the overall Constant score mean difference was 5.3 points (95% CI, 2.3-8.4 points; $P < .001$), and the DASH index mean difference was 4.3 points (95% CI, 0.2-8.4 points; $P = .04$).

Conclusion: Surgical treatment of MCFs significantly reduces the nonunion rate and shortens the time to union as compared with the nonoperative approach and, despite a slightly higher incidence of complications, leads to better shoulder functional scores at short- and long-term follow-up. Further studies should address the clinical significance of the documented improvement.

Keywords: clavicle fractures; midshaft; surgery; nonoperative; nonunion; shoulder

Clavicle fractures are one of the most common injuries among adults, representing 2% to 5% of all fractures.[28,42] These are twice more frequent among young males than females, probably because of a major risk of trauma.[15,40] Nearly 70% of these breakages occur in the middle third of the bone, which is the thinnest segment of the clavicle and, for this reason, the most easily broken.[3,31] The primary aim in the treatment of clavicle fractures is to rapidly restore function of the upper limb and avoid disability.[45] Historically, midshaft clavicle fractures (MCFs) have mostly been treated nonoperatively by closed reduction, immobilization, and physical therapy, with an expectation of good outcomes and a high rate of fracture union.[26,33] However, recent studies demonstrated that nonunion and

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malunion rates with nonsurgical treatment are greater than believed in the past, especially for displaced fractures,[27] thus suggesting the need for a different treatment.[19,23] Accordingly, surgical treatment has been increasing in recent years, despite some controversies regarding the risk of complications after surgery.[37,47]

Previous evaluations were performed comparing nonoperative treatment, such as sling or figure-of-8 harness, and surgical management, such as plate or nail fixation.[12,37,47,49] Nonetheless, the currently available literature includes only a limited number of trials, which does not allow for any clear conclusions, and as of today, there is still no consensus about the best treatment for MCFs. Some new randomized controlled trials (RCTs) were recently published, adding important data on the comparison of these 2 approaches, which could help to clarify this controversial issue.[37] Thus, the aim of this meta-analysis was to compare fracture healing and functional outcomes after nonsurgical versus surgical treatment of MCFs, to help specialists in the decision between these different strategies by providing a synthesis of the best literature evidence.

METHODS

Search Strategy and Article Selection

A systematic search of the literature was performed on November 29, 2018, in the following databases: PubMed, Web of Science, Cochrane library, and grey literature (clinicaltrials.gov, isrctn.org, greylit.org, and opengrey.eu) with the following string: ((clavicle OR clavicular OR collarbone) AND (midshaft OR middle third) AND (fracture OR broken) AND (surgery OR conservative OR non-operative)). We supplemented the electronic database examination by manually searching the reference lists of selected articles. The PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) were used.[22] This study includes published RCTs written in English that concern the comparison between nonoperative and surgical treatments in displaced MCFs, evaluated in terms of nonunion rate or the most commonly used shoulder functional scores, such as Constant score or Disabilities of the Arm, Shoulder and Hand (DASH) index.

Two authors (S.T. and D.P.) performed the article selection independently, and duplicate articles were removed. Titles and abstracts were initially screened, and then both reviewers read potentially suitable articles in full for evaluation, in case eligibility could not be assessed after the first screening. In the event of disagreement, consensus was reached by discussion and by consultation with a third reviewer (G.F.). Preclinical studies, meta-analysis and review articles, cohort studies, non-RCTs, surgical technique articles, case reports, editorials, letters to the editor, and studies not available in English were excluded.

Data Extraction and Synthesis and Outcome Measurement

An electronic table for data extraction was created prior to the study. Information was extracted about the demography of the included patients, such as sex, age, and fracture type, and the study design, such as inclusion and exclusion criteria, number of patients included, number of patients at final follow-up, surgical and nonoperative treatments performed, rehabilitation protocol, and follow-up duration.

Nonunion, defined as a lack of complete osseous bridging after >3 months, was the primary outcome of this meta-analysis. When patients had nonunions, they were computed as such according to the group to which they belonged and whether they were subsequently treated with open reduction and internal fixation (ORIF) or not.

Moreover, the effectiveness of surgical or nonsurgical treatment was evaluated with functional scores, such as the DASH index and the Constant score, analyzed at short-term (6 weeks), midterm (3-6 months), and long-term (>9 months) follow-up.[7,34] Other extracted outcomes were pain (as estimated with the visual analog scale [VAS]), time to union, time to return to previous activities, patient satisfaction, secondary operations, and complications.

Assessment of Risk of Bias and Quality of Evidence

The Cochrane Collaboration's tool for assessing risk of bias in randomized trials[9] was used to evaluate the risk of bias. For each outcome, the overall quality of evidence was graded as high, moderate, low, or very low, according to the Grading of Recommendations Assessment, Development and Evaluation (GRADE) guidelines.[35] Assessment of risk of bias and quality of evidence was completed independently for all outcomes by 2 authors (S.T. and D.P.), and a third author (G.F.) solved any possible discrepancy.

Statistical Analysis

The influence of surgery, with plate and nail subanalysis, on fracture nonunion was assessed by a z test on the pooled risk ratios with their corresponding 95% CIs. The influence of surgery (including plate and nail subanalysis) on time to union, Constant score, DASH index, and time to return to previous activities was assessed by a z test on the pooled

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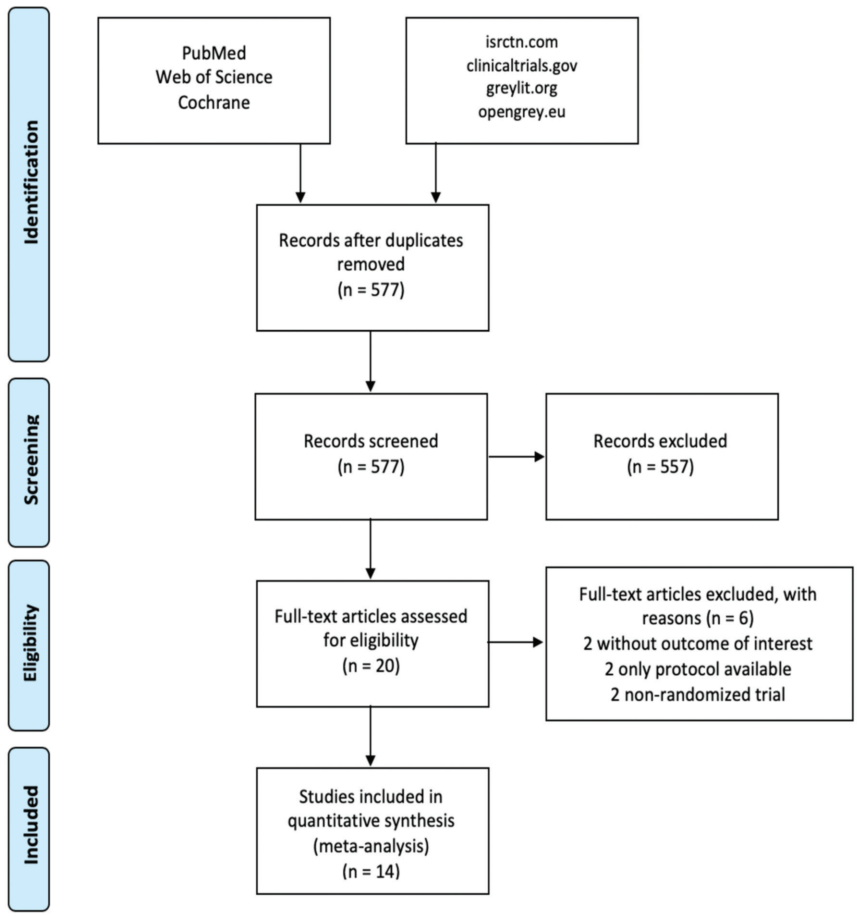

Figure 1. PRISMA (Preferred Reporting Items for Systematic Meta-Analyses) flowchart of the study selection process.

mean differences with their corresponding 95% CIs. Taking into consideration possible heterogeneity among studies, a statistical test for heterogeneity was first conducted with the Cochran Q statistic and I^2 metric.[10] We considered the presence of significant heterogeneity with I^2 values $\geq$25%. When no heterogeneity was found with $I^2 \geq$25%, a fixed effect model was used to estimate the pooled odds ratios and 95% CIs. Otherwise, a random effect model was applied, and a I^2 metric was evaluated for the random effect to check the correction of heterogeneity. A Begg funnel plot was used to assess the potential for publication bias. A *P* value of .05 was used as the level of statistical significance. All statistical analysis was carried out with RevMan 5.3.[30]

RESULTS

Article Selection and Study Design

The database search resulted in 832 records, 255 of which were duplicates. Of the remaining 577 articles, 20 were considered suitable for inclusion; 6 further studies were excluded after full-text reading for the following reasons: 2 were about a noncompleted RCT with only the protocol available;[‡] 2 were non-RCTs; and 2 were excluded during data extraction because they were updates of 2 studies already included, without further information that could be useful for the present analysis. Thus, 14 articles were included in the analysis (Figure 1). All selected RCTs were about the treatment of MCFs and compared nonoperative management and surgery. Surgery was performed with plate fixation in 11 studies and with intramedullary nail in 3 studies. The nonoperative treatment consisted predominantly of immobilization with a sling, an arm pouch, or a figure-of-8 harness. The rehabilitation protocol was always similar in the 2 groups. The possibility of blinding was hindered by the nature of the interventions. A power analysis was performed in 7 studies; specifically, it was based on a nonunion rate in 3, on the Constant score in 2, and on the DASH index in 2.

Patients' Characteristics and Treatments

Overall, 1536 patients were included, and 1372 were included for analysis (11% lost at follow-up). The minimum number of patients included was 30,[36] while the maximum

‡References 1, 4-6, 11, 20, 21, 29, 32, 36, 38, 39, 45, 48.

was 300.[1] Most injuries happened in males, as only 18% were in females, despite the study of Bhardwaj et al,[4] which randomized more females than males. The mean age was 33.9 and 33.0 years in the surgical and nonoperative groups, respectively, and ages ranged from 25 years in the nonoperative group of Judd et al[11] to 41 years in the surgical group of Virtanen et al.[44] Patients' body mass index, involved side, preinjury sports participation, and etiology were examined only in a minority of studies. There were no significant differences in the baseline characteristics of patients randomized to the 2 arms in all RCTs included, except for Virtanen et al,[44] in which the surgery group was significantly older (41 vs 33 years, P = .009). However, Chen et al,[6] Melean et al,[20] and Shetty et al[36] did not perform a comparative analysis of the demographic data of the 2 study arms. The inclusion criterion was the diagnosis of a completely displaced fracture in 12 studies, whereas Mirzatolooei[21] focused on comminuted fractures and Shetty et al[36] on mild to moderate displaced fractures (Table 1).

Outcomes of Surgery vs Nonoperative Treatment

Fracture nonunion was documented with a radiograph in all studies except for Robinson et al,[32] who used a computed tomography scan. Lack of bone bridging was evident in 10 out of 705 patients (1.4%) in the surgical treatment group and 110 out of 667 patients (16.5%) treated nonoperatively. A significantly lower risk ratio (0.10, $P < .001$) favoring surgery was found, with no significant difference between the results of plate and nail subgroups (0.09 and 0.16, respectively; P = .38) (Figure 2). This is also reflected by the analysis of the time to union, which was 5.1 weeks (P = .007) shorter for surgically treated patients (although only 3 of the included studies provided mean and SD for this outcome). After nonunion, ORIF was generally offered; therefore, the number of patients who underwent ORIF after the first treatment was significantly higher in the nonoperative group (78 vs 15). Nonetheless, the frequency of further surgery was significantly higher in the surgical group than in the nonoperative group (17.16% vs 13.18%, P = .02), with the most frequent reintervention being planned removal of hardware owing to local irritation (92 times); surgical debridement for deep wound infection was required for only 5 patients, while superficial wound problems requiring local care and antibiotics affected 17 patients. After surgical and nonoperative treatment, 75 and 29 patients, respectively, experienced neurological symptoms, such as nerve and brachial plexus palsy, local paresthesia, or numbness. Malunion was present among 20 surgically treated and 58 nonoperatively treated patients, despite only 6 of the latter group requiring corrective osteotomy. The overall incidence of complications (including the number of reinterventions) other than nonunions was higher in the surgical group (31.3% vs 20.5%, $P < .001$).

The shoulder function scores at short-term follow-up were documented with the DASH index in 3 studies and favored surgery, with a mean difference of 4.0 points (P = .03), while meta-analysis of the Constant score was not possible owing to a lack of data. Three studies reported a faster return to previous activities after surgical treatment, although without reaching a significant difference when data were plotted (mean ± SD: –13 ± 17 days, P = .14). At midterm follow-up, no statistical difference was found in the Constant score and the DASH index (P = .41 and P = .80, respectively). Nonetheless, after 9 months, both shoulder functional scores were significantly better in the surgery group: the Constant score was 5.3 points higher ($P < .001$; 9 studies), whereas the DASH index was 4.3 points higher (P = .04; 7 studies) (Figures 3 and 4). The mean difference in the Constant score between the surgical and nonoperative approaches was similar in the plate and the nail subgroups (5.7 and 4.0, respectively; P = .45). Virtanen et al[44] and Tamaoki et al[39] monitored the level of pain with the VAS for 1 year after injury; both documented a progressive and significant decrease over time, with no significant difference between groups at the last follow-up (P = .46).

Although further analysis was not feasible because of the high heterogeneity of the available data, the mean proportion of patients with the highest level of satisfaction at the final follow-up was 80% (range, 73%-84%) in the surgical group and 57% (range, 41%-73%) in the nonoperative group.[1,6,21]

Risk of Bias and Quality of Evidence

The risk of bias varied among studies. In particular, regarding the selection bias, all studies except Chen et al,[6] Shetty et al,[36] and Smekal et al[38] provided sufficient information about the random generation sequence and the method of patient allocation and can be considered at low risk of bias. Blinding of the assessors was present in only the study of Qvist et al.[29] A significant loss to follow-up (>15%) was present in Ahrens et al,[1] Canadian Orthopaedic Trauma Society,[5] Mirzatolooei,[21] and Tamaoki et al,[39] whereas all other studies had a low risk of attrition bias. A protocol was recorded for 6 of the included RCTs and were thus considered at low risk of reporting bias.[1,29,32,39,45,48] Mirzatolooei[21] was also considered at low risk for this item because the outcomes were considered to be fully comprehensive. Chen et al,[6] Melean et al,[20] Shetty et al,[36] and Smekal et al[38] were at high risk of other potential bias because they did not analyze the presence of baseline differences between groups or did not specify the assessment time points (Figure 5).

Following the GRADE guidelines and based on the risk of bias of the included studies, the level of evidence (LOE) for nonunion rate was downgraded 1 point. With regard to the clinical score, the lack of blinding was suspected to have influenced the results. However, since clinical results were not different in the primary analysis and in the sensitivity analysis, where only trials with moderate to low risk of bias were included, the LOE for the long-term follow-up analysis of the Constant and DASH scores was downgraded only 1 point. For the other outcomes measured, where a sensitivity analysis could not be performed

TABLE 1
Characteristics of the Studies[a]

	Demographic								Treatment	
	Patients (S:C)[b]		Sex (M:F)		Age, y, Mean ± SD					
Study	Baseline	Follow-up	Surgery	Closed	Surgery	Closed	Inclusion Criteria	Trial Duration,[c] mo	Nonsurgical	Surgical
COTS (2007)[5]	132 (67:65)	111 (62:49)	53:9	34:15	33.5	33.5	Completely displaced midshaft fracture, 16-60 y, no pathological or open fracture, <28-d-old fracture, no neurovascular injury, GCS >12, no other fracture, informed consent	12	Sling	Plate fixation
Smekal (2009)[38]	68 (33:35)	60 (30:30)	26:4	26:4	35.5 ± 11.8	39.8 ± 14.5	Unilateral isolated displaced midshaft clavicle fracture with no contact between fragments, age 18-65 y, no shoulder disease, no open or pathological fractures, no neurovascular injury	24	Sling	Intramedullary nail
Judd (2009)[11]	57 (29:28)	57 (29:28)	27:2	25:3	28	25	Age 17-40 y; isolated acute, displaced, angulated, closed fracture of the midshaft; no neurovascular injury	12	Sling	Intramedullary nail
Chen (2011)[6]	60 (30:30)	60 (30:30)	16:14	16:14	39 ± 11.9	38.4 ± 13.3	Unilateral isolated displaced midshaft clavicle fracture with no contact between fragments, age 18-65 y, no shoulder disease, no open or pathological fractures, no neurovascular injury,	15 (10-20)	Sling	Intramedullary nail
Mirzatolooei (2011)[21]	60 (29:31)	50 (26:24)	20:6	21:3	36	35.3	Comminuted displaced midshaft fracture of the clavicle, age >18 y and <65 y, no medical contraindication to anesthesia, no others or pathological fractures, no neurovascular injury	12	Sling	Plate
Virtanen (2012)[44]	60 (28:32)	51 (26:25)	24:4	28:4	41 ± 10.8	33 ± 12	Middle third clavicle fracture completely displaced closed treated within 7 d, age 18-70 y, informed consent, no neurovascular injury, no severe illness, no pregnancy, and no other fractures	12	Sling	Plate
Robinson (2013)[32]	200 (95:105)	178 (86:92)	83:12	92:13	32.3	32.5	Age 16-60 y, isolated displaced middle shaft fracture, <2 wk from fracture, no shoulder abnormalities, no pathological or open fractures, no neurovascular or head injury	12	Collar and cuff	Plate
Melean (2015)[20]	76 (34:42)	76 (34:42)	NR	NR	38.1 ± 13	37.2 ± 11.2	Displaced middle third clavicle fracture, >18 y, signed consent, isolated clavicle fracture, patients under working compensation, no neurovascular injury, no open fracture, <21 d from fracture	12	Sling	Plate
Ahrens (2017)[1]	301 (154:147)	254 (131:123)	132:22	130:17	36.1 ± 12.3	36.4 ± 11.8	Age 18-65 y, midshaft displaced fracture, ASA 1-3, other clavicle fractures or nonunion, previous operation of the clavicle, metabolic bone disease, neuromuscular upper limb disability	9 (9-12)	Sling	Plate

(continued)

TABLE 1
(continued)

Study	Demographic: Patients (S:C)[b] Baseline	Follow-up	Sex (M:F) Surgery	Closed	Age, y, Mean ± SD Surgery	Closed	Inclusion Criteria	Trial Duration,[c] mo	Treatment: Nonsurgical	Surgical
Shetty (2017)[36]	30 (16:14)	30 (16:14)	NR	NR	NR	NR	Recent closed midshaft clavicle fracture, mild-moderate displaced; age 20-50 y; no other illness and no ipsilateral upper limb, head, neurovascular, or solid organ injuries; no pathological fractures	6	Brace and arm pouch	Plate
Tamaoki (2017)[39]	117 (59:58)	98 (51:47)	53:6	47:11	30.5 ± 9.6	34.6 ± 12.6	Fracture treated in 15 d, displaced unilateral midshaft fractures with no contact between fragments, no open or pathological fractures, no neurovascular or ipsilateral limb injury	12	Figure-of-8 harness	Plate
Woltz (2017)[47]	160 (82:74)	154 (84:70)	80:6	66:8	38.3 ± 12.7	37.2 ± 12.5	Displaced fracture of the midshaft, age 18-60 y, no open or pathological fractures, no neurovascular injuries, GCS >12, no other fracture or shoulder disability, <14 d from injury	12	Sling	Plate
Bhardwaj (2018)[4]	69 (36:33)	69 (36:33)	8:28	13:20	32.4 ± 43	31.7 ± 26	Displaced closed midshaft clavicle fracture, no other trauma or compound fracture	24	Arm pouch	Plate
Qvist (2018)[29]	146 (75:71)	124 (64:60)	64:11	55:16	40	39	Displaced midclavicular fractures, age 18-60 y, signed consent, no other fracture, no neurovascular injury, no previous clavicular fracture, <2 wk from injury, no cognitive impairment, no contraindications to general anesthesia or surgery	12	Sling	Plate

[a]Data are presented as number or mean ± SD. ASA, American Society of Anesthesiologists; C, nonsurgical treatment; COTS, Canadian Orthopaedic Trauma Society; F, female; GCS, Glasgow Coma Scale; M, male; NR, not reported; S, surgical treatment.
[b]Patients randomized: number of participants reported at baseline. Patients assessed: number of participants completing the study.
[c]Mean (range).

owing to the presence of few unblinded studies with an overall moderate to high risk of bias evaluated, the LOE was downgraded 2 points. One further point in the LOE was lost because of the high variability in the results, for time to return to activities at mid- and long-term follow-up, Constant score at long-term follow-up, and DASH index. Concerning imprecision, the effect estimate below the minimal clinically important difference caused a 1-point downgrading for the long-term follow-up DASH index, whereas the small number of included patients accounts for imprecision in time to union, short-term DASH index, midterm DASH index, and Constant score. No points were lost for indirectness or risk of publication bias (Figure 5). Eventually, we upgraded the LOE for nonunion by 1 point because of the large magnitude effect (risk ratio = 0.11). Thus, the LOE of the obtained results was high for nonunion, low for the long-term follow-up Constant score, and very low for the other pooled outcomes.

DISCUSSION

The main finding of this meta-analysis, comparing surgery versus nonoperative treatment for displaced MCFs, is that surgical management provides a significantly reduced rate of clavicle nonunion and, despite a slight increase in the incidence of complications, leads to better functional outcome scores at short- and long-term follow-up. Various meta-analyses on this topic were published in the past,[12,15,18,37,46,47,49] but their overall results were nonconclusive owing to the low number of studies included or the inclusion of observational studies. Therefore, on the basis of the limited available data and the weak and controversial conclusions of previous studies, there is still no consensus on the best treatment for MCFs.

The present meta-analysis, based on the recent publication of new data[1,4,29,36,38,39] that provided updated information, was able to include 14 RCTs for a total of 1372

Study or Subgroup	Surgery Events	Surgery Total	Conservative Events	Conservative Total	Weight	Risk Ratio M-H, Fixed, 95% CI	Year
1.1.1 Plate vs Conservative							
Canadian Ortho Soc 2007	1	62	7	49	6.8%	0.11 [0.01, 0.89]	2007
Mirzatolooei & al. 2011	1	26	1	24	0.9%	0.92 [0.06, 13.95]	2011
Virtanen & al. 2012	0	26	6	25	5.8%	0.07 [0.00, 1.25]	2012
Robinson & al. 2013	1	86	24	92	20.3%	0.04 [0.01, 0.32]	2013
Melean & al. 2015	0	34	4	42	3.5%	0.14 [0.01, 2.45]	2015
Shetty & al. 2017	0	16	0	14		Not estimable	2017
Tamaoki & al. 2017	0	51	7	47	6.8%	0.06 [0.00, 1.05]	2017
Woltz & al. 2017	2	84	15	70	14.3%	0.11 [0.03, 0.47]	2017
Ahrens & al. 2017	1	131	13	123	11.7%	0.07 [0.01, 0.54]	2017
Bhardwaj & al. 2018	0	36	2	33	2.3%	0.18 [0.01, 3.69]	2018
Qvist & al. 2018	1	64	12	60	10.8%	0.08 [0.01, 0.58]	2018
Subtotal (95% CI)		**616**		**579**	**83.4%**	**0.09 [0.05, 0.18]**	
Total events	7		91				
Heterogeneity: $Chi^2 = 3.87$, df = 9 (P = 0.92); $I^2 = 0\%$							
Test for overall effect: Z = 6.93 (P < 0.00001)							
1.1.2 Nail vs Conservative							
Smekal & al. 2009	1	30	9	30	7.9%	0.11 [0.01, 0.82]	2008
Judd & al. 2009	1	29	1	28	0.9%	0.97 [0.06, 14.70]	2009
Chen & al. 2011	1	30	9	30	7.9%	0.11 [0.01, 0.82]	2011
Subtotal (95% CI)		**89**		**88**	**16.6%**	**0.16 [0.05, 0.51]**	
Total events	3		19				
Heterogeneity: $Chi^2 = 1.94$, df = 2 (P = 0.38); $I^2 = 0\%$							
Test for overall effect: Z = 3.06 (P = 0.002)							
Total (95% CI)		**705**		**667**	**100.0%**	**0.10 [0.06, 0.18]**	
Total events	10		110				
Heterogeneity: $Chi^2 = 6.40$, df = 12 (P = 0.89); $I^2 = 0\%$							
Test for overall effect: Z = 7.62 (P < 0.00001)							
Test for subgroup differences: $Chi^2 = 0.62$, df = 1 (P = 0.43), $I^2 = 0\%$							

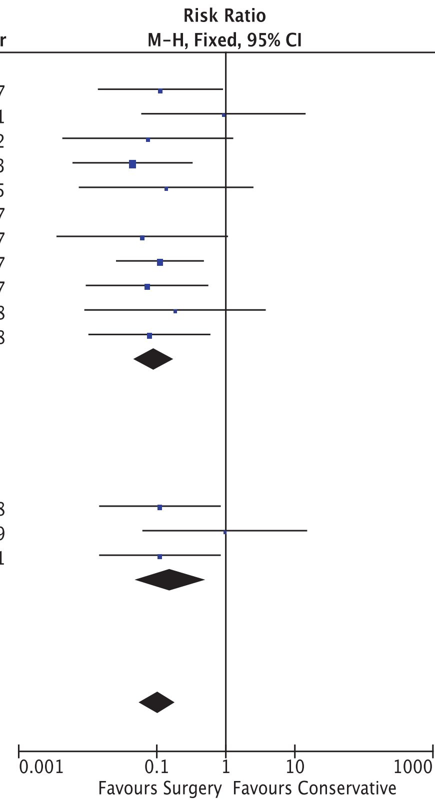

Figure 2. Forest plot of the nonunion rate.

Study or Subgroup	Surgery Mean	Surgery SD	Surgery Total	Conservative Mean	Conservative SD	Conservative Total	Weight	Mean Difference IV, Random, 95% CI	Year
1.8.1 Plate vs Conservative									
Canadian Ortho Soc 2007	96	5	62	90	20	49	8.8%	6.00 [0.26, 11.74]	2007
Mirzatolooei & al. 2011	89.8	6	26	78.8	8	24	10.6%	11.00 [7.06, 14.94]	2011
Virtanen & al. 2012	86.5	11.5	26	86.1	8.9	25	8.9%	0.40 [−5.23, 6.03]	2012
Robinson & al. 2013	92	9.5	86	87.8	12.5	92	11.2%	4.20 [0.95, 7.45]	2013
Melean & al. 2015	93	1	34	87	4	42	12.6%	6.00 [4.74, 7.26]	2015
Woltz & al. 2017	95.4	7.8	84	96.6	6.3	70	12.0%	−1.20 [−3.43, 1.03]	2017
Bhardwaj & al. 2018	89.42	5.61	36	76.24	3.43	33	12.1%	13.18 [11.01, 15.35]	2018
Subtotal (95% CI)			**354**			**335**	**76.1%**	**5.75 [1.72, 9.77]**	
Heterogeneity: $Tau^2 = 26.03$; $Chi^2 = 93.18$, df = 6 (P < 0.00001); $I^2 = 94\%$									
Test for overall effect: Z = 2.80 (P = 0.005)									
1.8.2 Nail vs Conservative									
Smekal & al. 2009	97.9	1.7	30	93	6	30	12.0%	4.90 [2.67, 7.13]	2008
Chen & al. 2011	97	4.24	30	94	5.42	30	11.9%	3.00 [0.54, 5.46]	2011
Subtotal (95% CI)			**60**			**60**	**23.9%**	**4.02 [2.17, 5.88]**	
Heterogeneity: $Tau^2 = 0.37$; $Chi^2 = 1.26$, df = 1 (P = 0.26); $I^2 = 20\%$									
Test for overall effect: Z = 4.25 (P < 0.0001)									
Total (95% CI)			**414**			**395**	**100.0%**	**5.34 [2.33, 8.36]**	
Heterogeneity: $Tau^2 = 18.38$; $Chi^2 = 98.75$, df = 8 (P < 0.00001); $I^2 = 92\%$									
Test for overall effect: Z = 3.47 (P = 0.0005)									
Test for subgroup differences: $Chi^2 = 0.58$, df = 1 (P = 0.45), $I^2 = 0\%$									

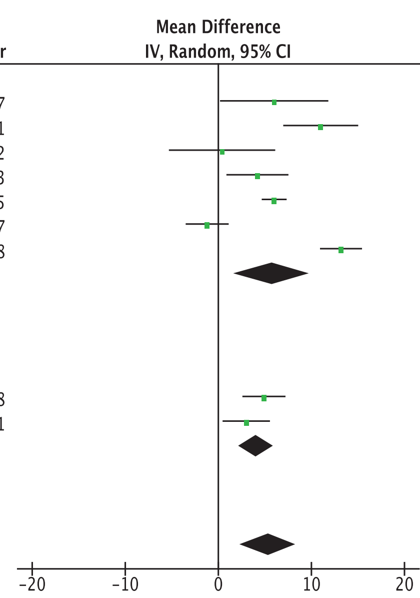

Figure 3. Forest plot of Constant score at long-term follow-up.

patients treated with a nonoperative or surgical approach for displaced MCFs. Findings about the nonunion rate are in line with those previously published and actually provide stronger evidence favoring surgery because of the large number of patients evaluated. The nonunion rate was the main outcome of the study, with all articles

Study or Subgroup	Surgery Mean	Surgery SD	Surgery Total	Conservative Mean	Conservative SD	Conservative Total	Weight	Mean Difference IV, Random, 95% CI	Year
Canadian Ortho Soc 2007	5	2.5	62	13	6.25	49	15.5%	−8.00 [−9.86, −6.14]	2007
Mirzatolooei & al. 2011	8.6	2	26	21.3	6	24	15.1%	−12.70 [−15.22, −10.18]	2011
Chen & al. 2011	2.74	3.57	30	7.91	12.6	30	13.2%	−5.17 [−9.86, −0.48]	2011
Virtanen & al. 2012	4.3	6.1	26	7.1	13.5	25	12.1%	−2.80 [−8.59, 2.99]	2012
Robinson & al. 2013	3.4	7.1	86	6.1	9.8	92	15.1%	−2.70 [−5.20, −0.20]	2013
Tamaoki & al. 2017	3.3	10.4	51	3	9.4	47	13.9%	0.30 [−3.62, 4.22]	2017
Woltz & al. 2017	4.5	7.6	84	3.2	7.4	70	15.2%	1.30 [−1.08, 3.68]	2017
Total (95% CI)			**365**			**337**	**100.0%**	**−4.34 [−8.44, −0.24]**	

Heterogeneity: Tau^2 = 27.37; Chi^2 = 83.54, df = 6 (P < 0.00001); I^2 = 93%
Test for overall effect: Z = 2.08 (P = 0.04)

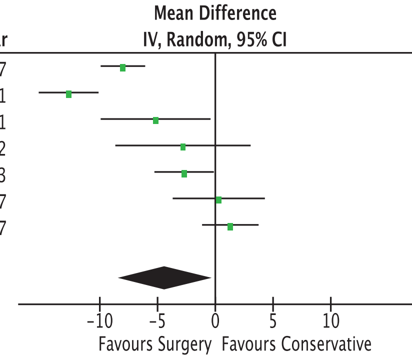

Figure 4. Forest plot of Disabilities of the Arm, Shoulder and Hand (DASH) index at long-term follow-up.

reporting these data for both nonoperative and operative treatment. Since fracture healing is the goal of displaced MCF treatment, the number of nonunions is a key factor in evaluating the success of a procedure, also affecting patients' recovery and often leading to secondary operations. Furthermore, the surgical procedure was able to reduce the time to union of the fracture, which could lead to faster as well as better functional recovery.

Functional recovery, assessed by clinical scores such as the Constant score or DASH index, is another crucial outcome that influences the quality of life of patients, including key aspects such as pain, range of motion, and normal life activities. In this light, this meta-analysis also focused on functional outcomes. Better results were documented in the surgery group, with a statistically significant difference. Although the mean documented difference did not reach the 10-point threshold that is often deemed to be clinically relevant for both the Constant score and the DASH index, the retrieved data are in favor of the surgical approach, with all but 1 study in favor of the surgical approach.[8,13,34] The large number of high-level studies also allowed, for the first time, the evaluation of results at different follow-up times, thus providing insight into the real benefit of surgery over time. In this regard, this meta-analysis underlined interesting aspects—namely that the recovery from injury was faster and more complete with surgical treatment than with nonoperative management. Moreover, a remarkable finding was that not only were greater functional scores documented in terms of recovery speed, but the short-term benefit was also confirmed at long-term follow-up. The positive effects of surgery at the earlier timeline are probably related to the shorter time to union and the faster rehabilitation protocol, which started nearly immediately after the surgery given the stability provided by the internal fixation. In contrast, patients treated nonoperatively usually had to rest the limb in a sling for at least 3 weeks, possibly causing a delay in the recovery of the function of the injured side.[17] This probably influenced the time needed to return to previous activities and the short-term outcomes, which is particularly important in an active population.[43] The persistence of the benefit of surgery at long-term follow-up can be explained by the higher rate of nonunion in the nonoperative group, which often leads to ORIF among patients initially treated nonoperatively. Furthermore, malunions, which were significantly more common without surgery, can yield a worse functional outcome, limiting the range of movement of the shoulder.[14] This might also explain, although evaluated by only a minority of the studies and in a heterogeneous way, the overall higher satisfaction of patients after surgery, despite the invasiveness of this treatment approach. Nonoperative treatment was preferred in the past because it was thought to present a lower number of complications.[26] This meta-analysis found that the number of complications was higher after surgery, but when the programmed removal of plates and nails used for surgical fixation was excluded, significantly more reoperations were observed in the nonsurgical arm ($P < .001$).

Despite the number of studies included and the clinical relevance of the aforementioned results, this meta-analysis still presents some weaknesses reflecting current literature limitations. As previously mentioned, the LOE of the majority of the pooled outcomes was low to very low, with the important exception of nonunion rate, the primary outcome of the study, the LOE of which was high. The factor affecting the LOE the most was the high risk of bias from a part of the included studies owing to the unavoidable lack of blinding and the loss of some patients at follow-up. Another limit of this meta-analysis is the low number of studies with nail fixation as operative treatment as compared with articles about the plating method, which hinders the possibility to compare the 2 approaches. A larger number of patients and new high-level studies that directly compare these 2 treatments could allow a more precise comparison among the surgical methods to provide more specific results and indications for surgical treatment. The included studies also used different types of plates and different positionings, which could have influenced the results about rate of implant failure and removal, accounting for a certain degree of heterogeneity. However, even though biomechanical studies documented a slight difference in stiffness and strength after plating with various techniques,[2,41] no statistical difference was found in the clinical outcomes,[39] and no evidence can be currently drawn on the most suitable technique to optimize the clinical outcome. Some studies highlighted the importance

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Ahrens & al. 2017	+	+	−	−	−	+	+
Bhardwaj & al. 2018	+	+	−	−	+	−	+
Canadian Ortho Soc 2007	+	+	−	−	−	−	+
Chen & al. 2011	?	?	−	−	+	−	−
Judd & al. 2009	+	+	−	−	+	−	+
Melean & al. 2015	+	+	−	−	+	−	−
Mirzatolooei & al. 2011	+	+	−	−	−	+	+
Qvist & al. 2018	+	+	−	+	+	+	+
Robinson & al. 2013	+	+	−	−	+	+	+
Shetty & al. 2017	?	?	−	−	+	−	−
Smekal & al. 2009	+	?	−	−	+	−	−
Tamaoki & al. 2017	+	+	−	−	−	+	+
Virtanen & al. 2012	+	+	−	−	+	+	+
Woltz & al. 2017	+	+	−	−	+	+	+

Figure 5. Risk-of-bias summary of the included studies.

of patient-related risk factors for nonunion of MCFs, such as smoking, grade of displacement, and comminution.[16,25] Unfortunately, in this case, it was impossible to analyze in more detail the outcomes of surgical and nonoperative treatment considering these patient characteristics, given the limited number of studies available for such subanalysis. Concerning functional scores, the risk of their limited reliability should be acknowledged—as related to the influence of patients' individual feelings—especially in consideration of the lack of blinding. Finally, all included RCTs focused on a skeletally mature population, and future studies are needed to investigate the importance of age in the management of MCFs.[24]

Even though some limitations could not be overcome, the present meta-analysis documented the advantages of surgical fixation over nonoperative treatment for displaced MCFs in terms of union rate and clinical scores. Despite treatment invasiveness and a higher rate of complications after surgery and reoperations in the surgical group, the clinical benefit provided by a faster time to union was strengthened by the confirmed long-term benefit. Thus, physicians and patients should be aware of advantages and disadvantages of the 2 approaches to undertake an informed decision in light of these literature findings, which support surgery as the more advisable option to address MCFs among active patients seeking a quick and optimal functional recovery.

CONCLUSION

This meta-analysis shows that, when compared with the nonoperative management, surgical treatment significantly reduced nonunion rates in displaced MCFs, shortened the time to union, and, despite a higher rate of complications and further operations, led to better functional scores (although without reaching the values suggested for a minimal clinically important difference). The advantages of surgery in short-term functional recovery were confirmed at the long-term follow-up. While a high LOE supported the superiority of surgery in terms of nonunion rate, other outcomes presented lower evidence and should be therefore addressed by further studies aimed at optimizing the management of MCFs.

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