Are two plates better than one? A systematic review of dual plating for acute midshaft clavicle fractures

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Abstract
Background: The rate of operative fixation of acute midshaft clavicle fractures has exponentially increased in recent years; however, the rate of reoperation for symptomatic hardware removal remains high and the optimal fixation strategy unknown. This systematic review aimed to summarize available evidence for dual plating of acute displaced midshaft clavicle fractures.

Methods: EMBASE, MEDLINE, and PubMed searches identified clinical studies evaluating dual plate fixation of acute midshaft clavicle fractures. Pooled analysis was performed using a random-effects model in RevMan 5.3.

Results: Eleven studies including 672 patients were included. Hardware removal occurred in 4.4% and 12.3% of patients undergoing dual and single plate fixation, respectively. Compared to single plating, dual plating had significantly lower odds of hardware removal (P = 0.001) with no difference in union rates. There were no significant differences in reoperation (excluding hardware removal), complications, and patient-reported outcomes between the two groups (P > 0.05).

Conclusions: This study suggests that dual plating of acute displaced midshaft clavicle fractures may lead to lower rates of reoperation for symptomatic hardware removal without compromising fracture healing. Ultimately, well-designed randomized trials are needed to further investigate the findings from this systematic review.

Keywords
Clavicle fracture, precontoured plate, mini-fragment plate, hardware removal, reoperation

Introduction
Midshaft clavicle fractures have traditionally been treated non-operatively with immobilization in a sling or a figure-of-eight bandage.¹,² Early studies reported a non-union rate of 1% and negligible functional consequence with conservative management. However, the inclusion of pediatric fractures and an absence of modern functional assessments in these studies resulted in an underestimation of non-union rates and overly optimistic clinical outcomes.¹⁻³ More recent data have demonstrated a non-union rate of 15% with approximately 30% of patients dissatisfied with their outcome following non-operative treatment.⁴⁻⁸ As a result, there has been renewed interest in surgical fixation of displaced midshaft clavicle fractures. In fact, the rate of operative fixation has exponentially increased following the publication of a landmark randomized controlled trial by the Canadian Orthopaedic Trauma Society which was the first of many level I studies to demonstrate higher union rates, decreased rates of symptomatic malunion, earlier return to function, and improved patient-reported outcomes with plate fixation of displaced midshaft clavicle fractures.⁶,⁹⁻¹¹

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Traditional plating techniques for open reduction and internal fixation of clavicle fractures involve the use of a single 3.5-mm plate placed superiorly or anteriorly. However, these plates are often very prominent under the skin causing irritation, and in many cases result in reoperation for hardware removal. The rate of reoperation for removal of symptomatic hardware has been reported to range from 8% to 66%. For this reason, there have been a number of different fixation strategies described to minimize the need to return to the operating room for implant-related symptoms. These include intramedullary nailing and the use of anatomic precontoured clavicle plates positioned superiorly or anteroinferiorly.

More recently, a dual plate construct using two mini-fragment plates placed orthogonally has been advocated as a means of decreasing the rate of reoperation for symptomatic hardware removal. In 2015, Prasarn et al. reported on a series of 17 patients undergoing clavicle fixation using a 2.7-mm plate positioned superiorly and a 2.4-mm plate positioned anteriorly and had no reoperations while noting a 100% union rate. The idea of dual plating is not new and is commonly used in the setting of clavicle fracture non-union fixation. Its efficacy has also been described in distal clavicle fractures. Biomechanical studies investigating dual plating versus single plating specifically for midshaft clavicle fracture have mostly found dual plating to be equivalent to single plating, though this finding is not unanimous. In their cadaveric study, Ziegler et al. found no significant differences between a single 3.5-mm anteroinferior plate, a single 3.5-mm superior plate, and dual 2.7-mm plates in axial stiffness, bending stiffness, torsional stiffness, or bending load to failure. Prasarn et al. utilized a sawbones model to similarly conclude that dual plating was biomechanically equivalent to single plating. Furthermore, a recent finite element analysis by Zhang et al. found no significant difference in cantilever bending, axial compression, and axial torsion between single and dual plate constructs, while also noting the highest stiffness and least micromotion with dual plate fixation. However, a recent study by Boyce et al. cautioned against conclusions of equivalence between dual and single plate constructs, finding that dual fixation demonstrated lower stiffness and strength than single fixation in their sawbones model. Of note, all such biomechanical studies are limited by a lack of knowledge on the minimum strength truly required for clavicle fixation in vivo. Dual plating may serve as an alternative to a single precontoured plate with a biomechanically similar or equivalent profile and the additional benefit of being a lower profile implant to which may help diminish the high rate of symptomatic implant removal observed with single plating.

The objective of this systematic review is to summarize the available clinical evidence for dual plating of acute displaced midshaft clavicle fractures. An evaluation of the available clinical outcomes including comparisons to conventional plating techniques (i.e. single precontoured plate) will allow for the assessment of the safety and efficacy of dual plating.

Materials and methods

This systematic review was conducted following the Preferred Reporting Items for Systematic Reviews (PRISMA) guidelines.

Literature search

The electronic databases EMBASE, MEDLINE, PubMed, and Google Scholar were searched for articles available as of 6 June 2020. A title, abstract, and full-text screen were performed to identify relevant articles. The following search terms were used: “dual” or “double” or “mini-frag” or “mini plates” or “semi-tubular plates” or “tubular plates” and “clavic*” or “fracture” and “minifrag*” or “min plates” or “semi-tubular plates” or “tubular plates” and “clavic*”. This search was limited to the English language. References of included studies were reviewed for additional relevant articles that met the inclusion criteria.

Eligibility criteria

Studies were included if they addressed acute, midshaft clavicle fractures managed with dual plate fixation and were published in English. Technical and clinical studies were included. Restrictions for years of publication were not deemed necessary. Studies were excluded if they discussed dual plate fixation in the setting of distal clavicle fracture or non-union. Review articles and expert opinions were also excluded. Studies with small sample size (i.e. less than 10) or case reports were included to increase the pool of data.

Study selection

Two independent reviewers (CEF and AMM) screened the titles and abstracts of all identified articles for eligibility. Duplicate articles were manually excluded. Both reviewers evaluated the full text of all potentially eligible studies identified by title and abstract screening to determine final eligibility. Disagreements were resolved by a consensus decision in conjunction with the senior author.

Data extraction

Data were extracted independently and in duplicate by both reviewers. Data collected from all relevant studies.
included: author, year of publication, title, journal, level of evidence, sample size, sex and age of participants, surgical technique, length of follow-up, union rate, complications, reoperations, patient-reported outcomes, and other notable results.

**Assessment of performed risk of bias in eligible studies**

Two reviewers (CEF and AMM) performed an independent assessment of the methodological quality of each eligible study using the Methodological Index for Non-Randomized Studies (MINORS). The MINORS criteria is a validated 12-item instrument used to evaluate the methodological quality of non-randomized (non-comparative and comparative) surgical studies. Items are scored as 0 (not reported), 1 (reported but inadequate), or 2 (reported and adequate). The maximum global score for non-comparative and comparative studies was 16 and 24, respectively.43

**Statistical analysis**

Descriptive statistics were calculated with categorical data presented as frequency with percentages and continuous data as a mean ± standard deviation (SD). Weighted means were calculated for all parameters. Mean differences were calculated for continuous outcomes and odds ratios (ORs) for dichotomous outcomes. Ninety-five percent confidence intervals (CIs) were reported for all point estimates. A random-effects model was used for pooled comparisons. Pooled estimates were calculated using Review Manager 5.3.44

**Results**

**Study characteristics**

The initial search yielded 928 articles, of which 650 were duplicates. Following application of inclusion and exclusion criteria, 11 articles were included in this systematic review.29–31,39,40,45–52 (Figure 1). A summary of included studies is demonstrated in Table 1. Among the 11 clinical studies, there were a total of 672 patients, including 389 who underwent dual plating and 283 who had single plate fixation of their acute midshaft clavicle fracture. The majority of patients were male (78.2%) with a mean age of 37.2 years. The mean follow-up across all clinical studies was 23.2 months.

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**Figure 1.** PRISMA flow diagram.
Quality assessment

An assessment of the methodological quality of eligible studies was performed using the MINORS criteria (Supplemental File 1). The mean scores for non-comparative and comparative studies were 9.7 (out of 16) and 19 (out of 24), respectively.

Surgical technique

Plating construct. Various implants were used for dual and single plate fixation across studies (Table 2). Implant choice was based on surgeon preference and construct availability. In most cases, dual plating consisted of a 2.0/2.4/2.7-mm plate superiorly and a 2.0/2.4/2.7-mm plate anteriorly or anteroinferiorly. Zhuang et al. used a 3.5-mm locking compression plate or reconstruction plate superiorly and a mini-fragment placed anteriorly. Two studies used one-third tubular plates, while Chen et al. used a combination of one-third tubular, locking, and reconstruction plates.

Clinical outcomes

Non-union. Non-union was reported in 10 studies. The overall non-union rate was 3.4%, with 0.8% (N = 254) of dual plated and 2.9% (N = 339) of single plated clavicles going on to non-union. Pooled comparison across the five comparative studies demonstrated no significant difference in the odds of fracture non-union with dual and single plate fixation methods (OR, 0.60; 95% CI, 0.13 to 2.79; P = 0.52) (Figure 2(a)).

Delayed union. The incidence of delayed union was noted in two comparative studies. The rate of delayed union among patients with a single plate construct was 3.7% (N = 214), while no case of delayed union was noted among the dual plated group.

Table 1. Summary of clinical studies.

| Study           | Sample Size, N | Mean Age, years (SD) | Male Sex, N (%) | Mean follow-up, months (SD) | Outcome measures                  |
|-----------------|---------------|----------------------|----------------|----------------------------|-----------------------------------|
|                 | Single | Dual | Single | Dual | Single | Dual |                  |
| Allis et al.    | 21     | 23   | 36 (14.0) | 36 (12.0) | NR     | NR     | 39.2 (16.1) | Union rate, reoperation rate, ASES score |
| Chen et al.     | 125    | 34   | 39.7 (15.2) | 39.1 (18.1) | 96 (76.8) | 28 (82.0) | 9.6 (4.8) | Union rate, complications, reoperation rate |
| Chen et al.     | –      | 36   | –      | 40.6 (15.3) | –      | 24 (66.7) | 23.5 (41) | Union rate, complications, reoperation rate, QuickDASH score |
| Czajka et al.   | –      | 81   | –      | 31.3 (8.3) | –      | 63 (77.8) | 15.7 (8.5) | Reoperation rate, QuickDASH score |
| DeBaun et al.   | 74     | 60   | 44 (14) | 44 (16) | 60 (81.1) | 43 (71.7) | 9.0 (7.5) | Union rate, complications, reoperation rate |
| Giordano et al. | –      | 1    | –      | 23 (N/A) | –      | 1 (100) | 12 (N/A) | Union rate |
| Lee et al.      | 33     | 89   | 30.6 (10.3) | 28.9 (10.4) | 77 (86.5) | 28 (85) | 24 (NR) | Union rate, complications, reoperation rate, operating time |
| Prasarn et al.  | –      | 17   | –      | 31.3 (12.8) | –      | 15 (88.2) | 16.1 (6.5) | Union rate, reoperation rate, DASH score |
| Qamar et al.    | –      | 20   | –      | 39.2 (11.0) | –      | 15 (75) | 36 (10.5) | Union rate, complications, reoperation rate, DASH score |
| Shannon et al.  | –      | 13   | –      | 41.2 (18.1) | –      | 12 (92.3) | 22.3 (11.8) | Union rate |
| Zhuang et al.   | 30     | 17   | 37.0 (12.2) | 39.3 (13.6) | 17 (56.7) | 12 (70.6) | 10.3 (3.5) | Union rate, Constant-Murley score |

N: count; SD: standard deviation; NR: not reported; ASES: American Shoulder and Elbow Score; DASH: Disabilities of the Arm Shoulder and Hand; N/A: not applicable.
Complications. Complications were described in 10 studies29–31,45–51 and included intraoperative and postoperative complications such as neurovascular injury and infection. Complications were defined in a heterogeneous manner across studies, as such, we defined a complication as an unintended negative outcome other than non-union, delayed union, and reoperation, which were reported separately in this review.

The overall complication rate was 5.9%. The complication rate in the dual and single plate groups were 3.1% (N = 318) and 8.7% (N = 309), respectively. Pooled analyses of the four comparative studies45,46,49,51 found no significant difference in the odds of a complication occurring with dual and single plate constructs (OR, 0.63; 95% CI, 0.23 to 1.75; P = 0.38) (Figure 2(b)).

Reoperation. Reoperation excluding hardware removal was reported in nine clinical studies.29–31,45–48,49,51,53,54 Indications for reoperation included non-union, mal-union, and deep infections. The overall reoperation rate across all studies was 2.4%. The reoperation rate for dual and single plate fixation was 1.3% (N = 237) and 3.2% (N = 309), respectively. Pooling data across the four comparative studies45,46,49,51 revealed no significant difference in the odds of reoperation for causes other than symptomatic hardware removal when comparing dual and single plate constructs (OR, 0.68; 95% CI, 0.15 to 3.14; P = 0.62) (Figure 2(c)).

Hardware removal. A total of 10 studies provided data on hardware removal.29–31,45–51 The overall rate of hardware removal was 8.3%. Hardware removal occurred in 4.4% (N = 318) and 12.3% (N = 309) of patients undergoing dual and single plate fixation, respectively. Among the four comparative studies,45,46,49,51 dual plating resulted in a 77% lower odds of hardware removal compared to single plate fixation (OR, 0.23; 95% CI, 0.07 to 0.78; P = 0.02) (Figure 2(d)).

Patient-reported outcomes. Patient-reported outcome measures included Disabilities of the Arm, Shoulder,
and Hand (DASH), a shortened version of this score known as the QuickDASH, the American Shoulder and Elbow Surgeon Score (ASES), and the Constant-Murley Score. The DASH score was reported in four studies\(^29,30,47,48\) (\(N = 35\)) with an overall weighted mean score of 6.5 ± 6.6 at final follow-up. The QuickDASH score was collected in two case series\(^48,53\) (\(N = 101\)) and found to have an overall weighted mean score of 7.8 ± 11.8. Allis et al.\(^45\) reported no difference in ASES scores between patients undergoing clavicle fracture fixation using a single 3.5-mm precontoured clavicle plate versus dual mini-fragment plates (\(P = 0.14\)). When comparing the Constant-Murley score between single and dual plate groups at three and six months, Zhuang et al.\(^52\) noted a significant difference favoring dual plating at three months postoperatively (\(P = 0.002\)); however, the difference did not persist at six months (\(P = 0.054\)).

### Implant cost

Czajka et al.\(^48\) found the mean implant cost in 2016 of a dual mini-fragment plate construct for midshaft clavicle fracture fixation to be $1511.38 USD compared to $1253.08 USD for a single, 3.5-mm precontoured plate from the same manufacturer (Synthes, Paoli, PA). However, Qamar et al. in their 2011 publication\(^30\) concluded that their dual plate construct (using two one-third tubular plates) would be less expensive than a similar construct using a locking compression plate with locking screws or a precontoured clavicle plate. The authors note that although the cost of a locking

Figure 2. Clinical outcomes. (a) Non-unions. (b) Complications. (c) Reoperations excluding hardware removal. (d) Hardware removal.

\(S\) Sheth et al.
compression plate is similar to two one-third semi-tubular plates, the locking screws are eight times more expensive than conventional cortical screws, while the precontoured clavicle plate itself is 10 times more expensive than two one-third tubular plates. Of note, this study came out of the United Kingdom and further information beyond relative costs, i.e. exact amounts and currency referenced, was not discussed.\textsuperscript{29}

Operative time

The mean operative time for dual plating was reported in two studies\textsuperscript{48,51} and varied from 97 min (SD 12) to 174 min (SD 45). Lee et al.\textsuperscript{51} was the only study to directly compare operative times between dual and single plate constructs and found a significant difference in mean operative time favoring single plating by nearly 1 h (mean difference 55 min; 95% CI, 39 to 71; $P < 0.001$).

Discussion

Despite variations in implant choice and plating construct, the current systematic review demonstrates that the use of dual orthogonal plating of acute displaced midshaft clavicle fractures may result in lower rates of reoperation for hardware removal compared to single plate fixation without compromising union rates. Moreover, the rate of non-union and complication was two to three times higher among single plate constructs; however, there was no statistically significant difference between single and dual plating.

Although plate fixation of displaced midshaft clavicle fractures has led to lower non-union rates, earlier return to work, and better function than non-operative treatment, the high rates of reoperation due to plate prominence and hardware irritation remain an ongoing concern. The decision to undergo hardware removal is a subjective choice made between patient and surgeon. Although no standardized indications or objective measurements to guide this decision are currently described in the literature, symptomatic hardware removal is frequently reported. The introduction of precontoured clavicle plates has reduced the rate of symptomatic hardware removal, especially when plating anteroinferiorly.\textsuperscript{15,20,55} However, even with the use of precontoured plates, the reported hardware removal rate varies from 5% to 47%.\textsuperscript{55,56} This is likely due to the significant variation in clavicle anatomy (i.e. sigmoid curve, coronal bow, and length) observed between individuals which precludes anatomic fitting of precontoured plates in all patients. In fact, Malhas et al.\textsuperscript{57} published a cadaveric study that found further contouring of precontoured plates was necessary in 73% of cases to optimize plate–bone fit. In contrast, dual mini-fragment plates are lower profile and offer the advantage of precisely contouring the plates to fit individual patient anatomy.\textsuperscript{47}

The benefits associated with a dual plate construct extend beyond a reduction in implant-related soft-tissue irritation. Intraoperatively, dual plating allows for (1) more points of fixation, (2) buttressing of anterior butterfly fragments, (3) mini-fragment plates to be used as washers for multiple lag screws, and (4) the use of either the superior or anterior plate as a reduction aid or clamp while the second plate is applied.\textsuperscript{29} Based on prior biomechanical data, the ability of a dual plate construct to withstand multiplanar bending forces better than a single plate construct may allow for the theoretical advantage of early weight-bearing through the affected extremity.\textsuperscript{29,40} In fact, Czajka et al.\textsuperscript{48} allowed immediate unrestricted range of motion post-operatively and unrestricted weight-bearing at six weeks in a cohort of patients who underwent dual plate fixation of displaced midshaft clavicle fractures.

One of the most significant concerns regarding dual plating techniques has been the theoretical risk of non-union due to compromised vascularity from the soft tissue stripping required to place two orthogonal plates on the clavicle. However, the use of an extraperiosteal exposure results in a minimal increase in soft tissue stripping for application of a second mini-fragment plate.\textsuperscript{51,46} Moreover, the non-union rate following dual plate fixation in the current systematic review was less than 1%, which suggests that fracture healing is not compromised with application of dual orthogonal plates.

A potential barrier to the routine use of a dual plate construct for fixation of displaced midshaft clavicle fractures may be the additional operative time required. Czajka et al.\textsuperscript{48} hypothesized that dual plating would require more surgical time due to the increased soft tissue dissection required for exposure and the time required for contouring and application of two plates. However, operative times varied significantly between and within the two studies that reported these data in our review.\textsuperscript{48,51} For instance, four different surgeons performed dual plating in the study by Lee et al.\textsuperscript{51} with one surgeon’s operative time averaging 55 min longer than the others. There has also been a wide range of reported operative times for single plate fixation, with a mean operative time of 65–80 min (range 35–179 min) noted in the literature.\textsuperscript{58–60} These differences make it difficult to discern if operative time is truly dependent on the plating construct or the individual surgeon. Moreover, dual plating may be more technically challenging due to the need to contour plates to bone with a sinusoidal shape, which has its own learning curve.
The costs associated with a dual plate construct varied greatly between studies secondary to the implant used. Among the two studies that examined costs, Qamar et al.\textsuperscript{30} used two 3.5-mm one-third tubular plates, which was a significantly cheaper construct than a precontoured plate. Meanwhile, Czajka et al.\textsuperscript{48} used two mini-fragment plates, which was approximately $300 more expensive than the precontoured plate. However, the cost of mini-fragment and precontoured plates has recently been shown to vary by as much as $1900 based on vendor.\textsuperscript{51} Despite this variation in implant cost, it still remains to be seen whether dual plating is a cost-effective long-term strategy. However, it stands to reason that the potential cost-savings from decreased reoperation rates of symptomatic hardware removal would also result in greater benefit to the patient with earlier and uninterrupted return to baseline activities.

The current review has a number of limitations. Firstly, there were very few studies directly comparing single and dual plate constructs, as such, this review was limited to level III and IV studies. Secondly, follow-up intervals varied considerably across studies ranging from 6 to 39 months, which may have an effect on the development of symptomatic hardware. However, the majority of studies did have greater than one year of follow-up. Thirdly, multiple surgeons often performed dual plate fixation in each study, which contributed to the wide range of operative times reported. Despite the use of various dual plating constructs, all included studies were published after 2011, which indicates that modern plating techniques were used. Finally, implant removal is typically a subjective decision between the patient and surgeon, as such, it is subject to multiple biases. There are no standardized indications for hardware removal nor objective measures reported to elucidate how these decisions are made, which remains an important limitation of the existing literature. Despite these limitations, the outcome measures used were homogenous across the 11 included studies which allowed for pooling of common outcome measures across comparative studies.

**Conclusion**

Based on the current literature, dual plating of acute displaced midshaft clavicle fractures may lead to lower rates of reoperation for symptomatic hardware removal without compromising healing. However, further biomechanical and clinical studies are warranted to determine the optimal implant choice (e.g. 2.0 mm versus 2.7 mm), configuration (i.e. plate placement superior/anterior), and cost-effectiveness of dual plating constructs. Ultimately, large, well-designed, randomized trials are needed to further investigate the findings from this review.

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**Supplemental material**

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**References**

1. Rowe CR. An atlas of anatomy and treatment of midclavicular fractures. *Clin Orthop Relat Res* 1968; 58: 29–42.
2. Neer CS 2nd. Nonunion of the clavicle. *J Am Med Assoc* 1960; 172: 1006–1011.
3. Preston CF and Egol KA. Midshaft clavicle fractures in adults. *Bull NYU Hosp Jt Dis* 2009; 67: 52–57.
4. Chan KY, Jupiter JB, Leffert RD, et al. Clavicle malunion. *J Shoulder Elbow Surg* 1999; 8: 287–290.
5. Hill JM, McGuire MH and Crosby LA. Closed treatment of displaced middle-third fractures of the clavicle gives poor results. *J Bone Joint Surg Br* 1997; 79: 537–539.
6. McKee MD, Pedersen EM, Jones C, et al. Deficits following nonoperative treatment of displaced midshaft clavicular fractures. *J Bone Joint Surg Am* 2006; 88: 35–40.
7. McKee MD, Wild LM and Schemitsch EH. Midshaft malunions of the clavicle. *J Bone Joint Surg Am* 2003; 85: 790–797.
8. Nordqvist A, Pettersson CJ and Redlund-Johnell I. Midclavicle fractures in adults: end result study after conservative treatment. *J Orthop Trauma* 1998; 12: 572–576.
9. Schneider P, Bransford R, Harvey E, et al. Operative treatment of displaced midshaft clavicle fractures: has randomised control trial evidence changed practice patterns? *BMJ Open* 2019; 9: e031118.
10. Society COT. Nonoperative treatment compared with plate fixation of displaced midshaft clavicular fractures. *A multicenter, randomized clinical trial. J Bone Joint Surg Am* 2007; 89: 1–10.
11. Smeeing DPJ, van der Ven DJC, Hietbrink F, et al. Surgical versus nonsurgical treatment for midshaft clavicle fractures in patients aged 16 years and older: a systematic review, meta-analysis, and comparison of
randomized controlled trials and observational studies. Am J Sports Med 2017; 45: 1937–1945.

12. Altamimi SA and McKee MD; Society COT. Nonoperative treatment compared with plate fixation of displaced midshaft clavicle fractures. Surgical technique. J Bone Joint Surg Am 2008; 90: 1–8.

13. Kushreshtha V, Roy T and Audige L. Operative versus nonoperative management of displaced midshaft clavicle fractures: a prospective cohort study. J Orthop Trauma 2011; 25: 31–38.

14. Leroux T, Wasserstein D, Henry P, et al. Rate of and risk factors for reoperations after open reduction and internal fixation of midshaft clavicle fractures: a population-based study in Ontario, Canada. J Bone Joint Surg Am 2014; 96: 1119–1125.

15. VanBeek C, Boselli KJ, Cadet ER, et al. Precontoured plating of clavicle fractures: decreased hardware-related complications? Clin Orthop Relat Res 2011; 469: 3337–3343.

16. Khan LA, Bradnock TJ, Scott C, et al. Fractures of the clavicle. J Bone Joint Surg Am 2009; 91: 447–460.

17. Lenza M, Buchbinder R, Johnston RV, et al. Surgical versus conservative interventions for treating fractures of the middle third of the clavicle. Cochrane Database Syst Rev 2019; 1: CD009363.

18. Schwarz N and Hocker K. Osteosynthesis of irreducible fractures of the clavicle with 2.7-MM ASIF plates. J Trauma 1992; 33: 179–183.

19. Wijdicks FJ, Van der Meijden OA, Millett PJ, et al. Systematic review of the complications of plate fixation of clavicle fractures. Arch Orthop Trauma Surg 2012; 132: 617–625.

20. Rongguang A, Zhen J, Jianhua Z, et al. Surgical treatment of displaced midshaft clavicle fractures: precontoured plates versus noncontoured plates. J Hand Surg Am 2016; 41: e263–e266.

21. Nourian A, Dhaliwal S, Vangala S, et al. Midshaft fractures of the clavicle: a meta-analysis comparing surgical fixation using anteroinferior plating versus superior plating. J Orthop Trauma 2017; 31: 461–467.

22. Fuglesang HFS, Oksum MA and Wikeroy AKB. Minimally invasive intramedullary fixation of displaced midshaft clavicle fractures with an elastic titanium nail. JBJS Essent Surg Tech 2018; 8: e16.

23. Mueller M, Rangger C, Striepens N, et al. Minimally invasive intramedullary nailing of midshaft clavicular fractures using titanium elastic nails. J Trauma 2008; 64: 1528–1534.

24. Ashman BD, Slobogean GP, Stone TB, et al. Reoperation following open reduction and plate fixation of displaced midshaft clavicle fractures. Injury 2014; 45: 1549–1553.

25. Naimark M, Dufka FL, Han R, et al. Plate fixation of midshaft clavicular fractures: patient-reported outcomes and hardware-related complications. J Shoulder Elbow Surg 2016; 25: 739–746.

26. Galdi B, Yoon RS, Choung EW, 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: 121–125.

27. Gilde AK, Jones CB, Sietsema DL, et al. Does plate type influence the clinical outcomes and implant removal in midclavicular fractures fixed with 2.7-mm anteroinferior plates? A retrospective cohort study. J Orthop Surg Res 2014; 9: 55.

28. Jones CB, Sietsema DL, Ringer JR, et al. Results of anterior-inferior 2.7-mm dynamic compression plate fixation of midshaft clavicular fractures. J Orthop Trauma 2013; 27: 126–129.

29. Prasarn ML, Meyers KN, Wilkin G, et al. Dual minifragment plating for midclavicle fractures: a clinical and biomechanical investigation. Arch Orthop Trauma Surg 2015; 135: 1655–1662.

30. Qamar F, Kadakia AP, Forrester R, et al. Double semitubular plating of clavicle using a piggyback technique – an alternative way of treating clavicle mid-shaft fractures in young patients. Acta Orthop Belg 2011; 77: 727–732.

31. Shannon SF, Chen X, Torchia M, et al. Exteraperiosteal dual plate fixation of acute mid-shaft clavicle fractures: a technical trick. J Orthop Trauma 2016; 30: e346–e350.

32. El Haj M, Khoury A, Mosheiff R, et al. Orthogonal double plate fixation for long bone fracture nonunion. Acta Chir Orthop Traumatol Cech 2013; 80: 131–137.

33. Sadiq S, Waseem M, Peravalli B, et al. Single or double plating for nonunion of the clavicle. Acta Orthop Belg 2001; 67: 354–360.

34. Garlich J, Little M, Nelson TJ, et al. A comparison of three fixation strategies in the treatment of neer type IIB distal clavicle fractures. J Orthop Trauma 2020; 34: e266–e271.

35. Kaipel M, Majewski M and Regazzoni P. Double-plate fixation in lateral clavicle fractures – a new strategy. J Trauma 2010; 66: 896–900.

36. Li L, Wu H, Jiang P, et al. Comparison of four different internal fixation methods in the treatment of distal clavicle fractures. Exp Ther Med 2020; 19: 451–458.

37. Ramirez JM and Cadet ER. Surgical technique: surgical treatment of displaced distal clavicle fractures using a modified dual-plating technique. Tech Shoulder Elbow Surg 2013; 14: 47–50.

38. Suter C, Majewski M and Nowakowski AM. Comparison of 2 plating techniques for lateral clavicle fractures, using a new standardized biomechanical testing setup. J Appl Biomater Funct Mater 2018; 16: 107–112.

39. Ziegler CG, Aman ZS, Storaci HW, et al. Low-profile dual plate fixation of acute mid-shaft clavicle fractures: a biomechanical study. J Orthop Surg Res 2020; 15: 248.

40. Moher D, Liberati A, Tetzlaff J, et al. Group P. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med 2009; 6: e1000097.
43. Slim K, Nini E, Forestier D, et al. Methodological index for non-randomized studies (MINORS): development and validation of a new instrument. *ANZ J Surg* 2003; 73: 712–716.

44. The Cochrane Collaboration. *Review Manager (RevMan)*. Version 5.3 ed. Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2014.

45. Allis JB, Cheung EC, Farrell ED, et al. Dual Versus single-plate fixation of midshaft clavicular fractures: a retrospective comparative study. *JBJS Open Access* 2020; 5: e0043.

46. Chen X, Shannon SF, Torchia M, et al. Radiographic outcomes of single versus dual plate fixation of acute mid-shaft clavicle fractures. *Arch Orthop Trauma Surg* 2017; 137: 749–754.

47. Chen MJ, DeBaun MR, Salazar BP, et al. Safety and efficacy of using 2.4/2.4 mm and 2.0/2.4 mm dual mini-fragment plate combinations for fixation of displaced diaphyseal clavicle fractures. *Injury* 2020; 51: 647–650.

48. Czajka CM, Kay A, Gary JL, et al. Symptomatic implant removal following dual mini-fragment plating for clavicular shaft fractures. *J Orthop Trauma* 2017; 31: 236–240.

49. DeBaun MR, Chen MJ, Campbell ST, et al. Dual mini-fragment plating is comparable to precontoured small fragment plating for operative diaphyseal clavicle fractures: a retrospective cohort study. *J Orthop Trauma* 2019; 34: e229–e232.

50. Giordano V, Pires RES, Pesántez R, et al. Expanding the indications for mini plates in the orthopedic trauma scenario: a useful alternative technique for maintaining provisional reduction and improving stability for complex periarticular fracture fixation of the upper limbs. *J Orthop Case Rep* 2018; 8: 42–46.

51. Lee C, Feaker DA, Ostrofe AA, et al. 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: 741–749.

52. Zhuang Y, Zhang Y, Zhou L, et al. Management of comminuted mid-shaft clavicular fractures: comparison between dual-plate fixation treatment and single-plate fixation. *J Orthop Surg (Hong Kong)* 2020; 28(2): 1–6. DOI: 10.1177/2309499020915797.

53. Chen MJ, DeBaun MR, Salazar BP, et al. Safety and efficacy of using 2.4/2.4 mm and 2.0/2.4 mm dual mini-fragment plate combinations for fixation of displaced diaphyseal clavicle fractures. *Injury* 2020; 51: 647–650.

54. Formaini N, Taylor BC, Backes J, et al. Superior versus anteroinferior plating of clavicle fractures. *Orthopedics* 2013; 36: e898–e904.

55. Baltes TPA, Donders JCE and Kloen P. What is the hardware removal rate after anteroinferior plating of the clavicle? A retrospective cohort study. *J Shoulder Elbow Surg* 2017; 26: 1838–1843.

56. Hulsmans MH, van Heijl M, Houwert RM, et al. Anteroinferior versus superior plating of clavicular fractures. *J Shoulder Elbow Surg* 2016; 25: 448–454.

57. Malhas AM, Skarpasir YG, Sripada S, et al. How well do contoured superior midshaft clavicle plates fit the clavicle? A cadaveric study. *J Shoulder Elbow Surg* 2016; 25: 954–959.

58. King PR, Ikram A, Eken MM, et al. 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: 628–634.

59. Reisch T, Camenzind RS, Fuhrer R, et al. The first 100 patients treated with a new anatomical pre-contoured locking plate for clavicular midshaft fractures. *BMC Musculoskelet Disord* 2019; 20: 4.

60. Sohn HS, Shon MS, Lee KH, et al. Clinical comparison of two different plating methods in minimally invasive plate osteosynthesis for clavicular midshaft fractures: a randomized controlled trial. *Injury* 2015; 46: 2230–2238.

61. Schweser K, Della Rocca G, Volgas D (eds). *Is cheaper always better for clavicle ORIF?* Kissimmee (Orlando), FL: Orthopaedic Trauma Association, 2008.