6 Clavicle Fractures: To Operate or Not?

Alonso Moreno-García
and E. Carlos Rodríguez-Merchán

6.1 Introduction

Clavicle fractures are common injuries, especially in young active individuals. A recent study on high school athletes reported an injury rate of 1.80 per 100,000 [1]. These fractures account for approximately 2.6–4% of all fractures in adults [2]. A study from the Swedish Fracture Register showed a male predominance, with 68% of the clavicle fractures occurring in males, the largest subgroup aged 15–24 years. However, over the age of 65, females sustained more clavicle fractures than males [3].

These fractures are usually related to sport injuries and road traffic accidents. A direct blow on the point of the shoulder is the commonest reported mechanism of injury. Most of these fractures occur in the midshaft of the clavicle, followed by the distal third. Fractures of the medial third are the most uncommon ones.

Clavicle fractures were originally divided by Allman into proximal (Group I), middle (Group II), and distal (Group III) third fractures. This classification was posteriorly enhanced by Neer and Rockwood in an attempt to take into account factors that influence treatment and outcome. Posteriorly, Robinson developed a classification scheme based on prognostic variables from a population-based study [2]. This classification keeps the division of the clavicle into thirds, adding variables that are of proven diagnostic value: intra-articular extension, displacement, and comminution. Robinson classification is based on an extensive database that helps to predict outcome and hence guide treatment.

Regarding the treatment of clavicle fractures, there is still controversy in the surgical indications. A comprehensive epidemiological study from Sweden revealed important changes in the rates of surgery over the time independently to the actual fracture rates [4]. Local traditions and surgeon preferences have been suggested as important factors for the choice of surgical treatment. In this chapter, we review the most updated evidence concerning treatment of clavicle fractures to help the reader to decide on the treatment approach based on the best clinical evidence available.

6.2 Fractures of the Middle Third of the Clavicle

Fractures of the middle third of the clavicle are the most common ones. Traditionally, these fractures have been treated conservatively with generally good results. Neer, in a classical study that dominated the clinical approach to clavicular fractures for decades, reported nonunion in only three of 2235 patients with middle-third fractures

A. Moreno-García · E. C. Rodríguez-Merchán (✉)
Department of Orthopedic Surgery, "La Paz" University Hospital-IdiPaz, Madrid, Spain

E. C. Rodríguez-Merchán, A. Moreno-Garcìa (eds.), *Controversies in Orthopedic Surgery of The Upper Limb*, https://doi.org/10.1007/978-3-031-04907-1_6

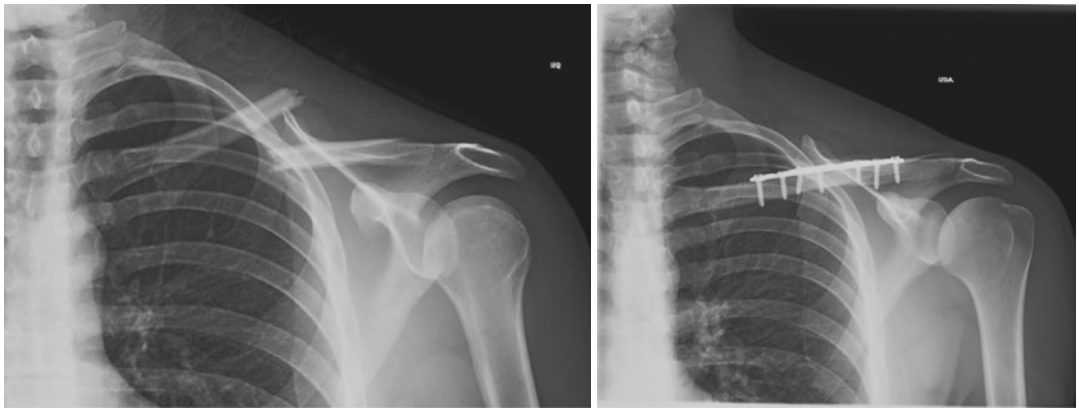

Fig. 6.1 Midshaft displaced fracture treated with open reduction and plate fixation (ORPF). Preoperative and postoperative X rays

treated by closed methods [5]. However, recent reports of large randomized control trials (RCT) have identified a subgroup of patients that may benefit from surgical treatment (Fig. 6.1). In a recent meta-analysis addressing this question, Qid et al. compared open reduction and plate fixation (ORPF) with nonsurgical treatment for displaced midshaft clavicle fractures. They conclude that ORPF yielded better results than conservative treatment in terms of fracture healing and appearance. However, the rate of complication was significantly lower in the nonsurgical treatment group, ranging from 3% to 7% when accounting for complications directly related to the surgery [6]. A multicenter randomized controlled trial comparing operative with nonoperative treatment of displaced midshaft clavicle fractures showed at 9 months a significantly lower proportion of nonunion ($p < 0.001$) in the operative group (0.8%) compared with the nonoperative group (11%). This study included 301 patients with an age of 18 to 65 years, with displaced midshaft fracture of the clavicle, Robinson classification 2B1 or 2B2, and being medically fit to undergo surgery. Fixation was performed using a precontoured titanium plate, while the conservative treatment consisted of a sling for up to 6 weeks or until there was clinical and/or radiographic evidence of union. The risk of complications in both treatment groups was low [7]. The DASH and Constant-Murley scores and patient satisfaction were all significantly better in the operative group than in the nonoperative group at 6 weeks and 3 months; however, they were equivalent at 9 months [7]. These findings of faster functional recovery in the surgical treated patients have been supported by Echalier et al. who reported a significant and clinically relevant difference in the functional scores favoring the surgical treatment in the first 6 weeks after the fracture event. Also, they showed that fracture fixation allows significantly faster return to work [8]. There is some discussion in relation to long-term clinical results, although the Canadian Orthopaedic Trauma Society reported in a large prospective clinical trial that Constant shoulder and DASH scores significantly improved in the operative fixation group at all time-points, with a total follow-up of 1 year [9]. Another interesting study evaluating the long-term results of nonsurgical treatment of midshaft clavicle fractures reported that patients with fractures with vertical displacement of ≥100% may eventually require surgical treatment due to unsatisfactory results secondary to residual deformities [10].

Under a societal perspective, and regarding cost-effectiveness, Sørensen et al. in a recent study concluded that operative treatment with locking plate fixation does not represent a cost-effective treatment option vs. nonoperative treatment in Denmark. However, the authors acknowledge that their results are subject to uncertainties and

advise to interpret the results cautiously and take local context and patient profession into consideration [11]. Another study from the USA, however, found early operative fixation of displaced midshaft clavicle fractures more cost-effective than nonoperative treatment [12]. A systematic literature review on this matter have suggested that routine operative treatment seems to be more expensive, although cost-effective in some cases, recommending cost-effectiveness analysis in RCT studies in the future [13].

A recent meta-analysis including 11 high-quality trials has revealed a significantly lower relative risk of developing nonunion and symptomatic malunion in patients undergoing surgical treatment. A subgroup analysis of plate fixation versus intramedullary nailing was performed which suggested that the incidence of nonunion after plate fixation was lower as compared to intramedullary nailing [14]. Another reported complication of intramedullary nailing is axial instability resulting in telescoping and shortening of the clavicle length. To avoid this complication, a recent publication has proposed the use of S-shaped titanium endomedullary nails with good results [15]. For displaced midshaft fractures of the lateral diaphysis, and when using intramedullary nailing, a recent study advises the use of a lateral approach instead of the classical medial one. The authors report excellent functional results with this novel technique [16].

Currently, there is sufficient evidence to assume that surgical treatment of displaced midshaft fractures in adults produce better results when compared to the nonsurgical approach. In order to define displacement, it has been accepted, after the study of Hill et al., a distance >2 cm as the threshold for conservative management [17]. Regarding children and adolescents, surgical and conservative management may yield similar results, as presented by Swarup et al. in a recent study. Both operatively and nonoperatively treated patients had excellent functional and pain outcomes, similar refracture rates, and no nonunions [18]. Nonoperative management should be considered as first-line treatment for most pediatric displaced clavicle fractures, and operative management should potentially be reserved for atypical cases such as floating shoulder, multitrauma, open fractures, nonunions, and symptomatic malunions. Another study reporting long-term outcomes supports nonsurgical treatment as the treatment of choice for displaced midshaft clavicular fractures in adolescents [19].

Considering the surgical technique, ORPF is the most common procedure, but intramedullary nails can be also used. In a recent study comparing both techniques, no differences were found regarding clinical results or complications, leaving to the preference of the surgeon the choice of the implant used [20]. Skin erosion with the exposure of the synthesis material was the main complication in the group of ORPF reported in this study. Some authors have recommended incisions following the Langer's line to avoid skin complications; however, Anker et al. found in a recent study that an incision following Langer's lines does not reduce the rate of complications following fixation of displaced middle-third clavicle fractures [21].

Possible complications of ORPF were thoroughly reviewed by Wijdicks et al., finding the vast majority being implant related. Irritation or failure of the plate were consistently reported on average ranging from 9 to 64% [22]. The use of dual mini-fragment plating is an innovative approach to reduce complications. Compared to single plating, dual plating is biomechanically equivalent in axial loading and torsion yet offers better multi-planar bending stiffness despite the use of smaller plates. This technique may decrease the need for secondary surgery due to implant prominence and may aid in fracture reduction by buttressing butterfly fragments in two planes [23]. These good results have been substantiated by other authors [24, 25].When comparing local complications, a total of 8% of dual mini-fragment plating patients had symptomatic implant removal compared with 20% of single traditional plating patients [25]. A recent systematic review of the literature supports the aforementioned advantages of dual plating [26].

For midshaft clavicle fractures, the absence of cortical alignment in wedge and comminuted fractures directly influences the fixation stability of the synthesis, and complications like nonunion or malunion are more frequent [27]. The use of a lag screw in such instances have been recommended, and the AO/OTA advises a screw diameter of 3.5 mm. Wurm et al. have recently published a study comparing the use of lag screws of different diameter (3.5 mm vs. 2.0 mm), concluding that both groups showed comparable results with respect to fracture reduction, fixation, and stability as well as time to consolidation of the fracture, while the 2.0 mm screw diameter was associated with easier handling of small fracture fragments [28].

The floating shoulder, defined as combined clavicle and ipsilateral scapular neck fractures, is an entity that has recently been reviewed regarding its best therapeutic approach. An ample analysis of the literature found satisfactory outcomes following both surgical fixation and nonoperative management. However, floating shoulder injuries with significant displacement of the scapular neck may benefit from surgical fixation of both the clavicle and scapula fractures, while those with minimal or nondisplaced scapular neck fractures may achieve good outcomes when treated nonoperatively or with surgical fixation of the clavicle alone [29].

6.3 Fractures of the Distal Third of the Clavicle

In an ample review of the treatment of fractures of the distal clavicle, Oh et al. concluded that nonsurgical treatment resulted in a nonunion rate of 33.3% [30]. However, the same authors acknowledged no significant difference in the functional scores compared to the surgically treated group. There are up-to-date no high-quality studies to support either approach, and until then it seems prudent to treat these injuries nonoperatively initially and reserve surgery for severely displaced fractures and high-demand patients or for failures of nonoperative care (Fig. 6.2).

Regarding surgical treatment, several different techniques have been proposed, but none has been established as gold standard. Complications have been reviewed in the literature, finding for hook plate fixation a complication rate of 40.7% in one study [30] and 62.5% in another one [31]. Precontoured clavicle plate fixation showed a 16.2% complication rate in the same study, while no complications were found for coracoclavicular (CC) stabilization [31]. This low rate of complications for CC stabilization was reported as well by Oh et al. in a systematic review, reporting a complication rate of 4.8% [30].

A question that remains under discussion is the use of CC ligament augmentation when using

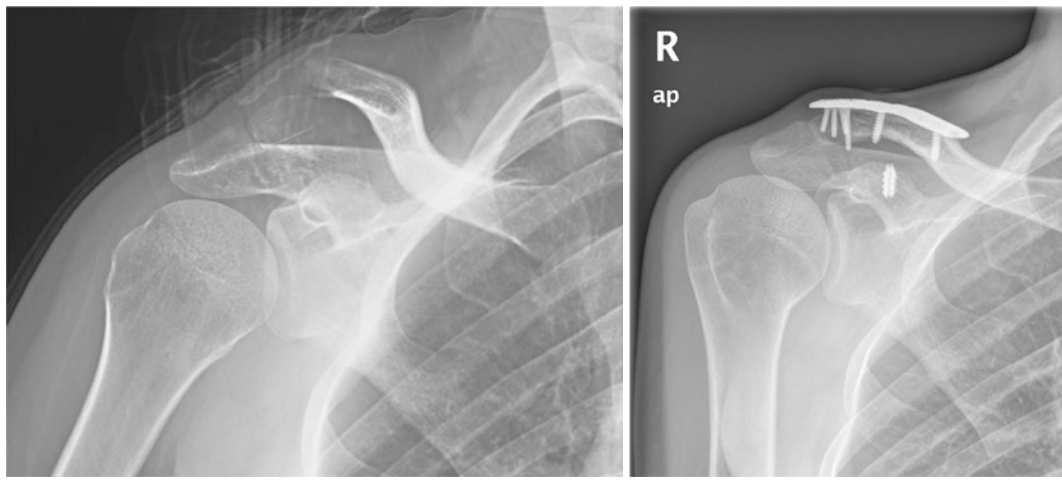

Fig. 6.2 Lateral displaced fracture treated with ORPF and CC augmentation. Preoperative and postoperative X rays

plate fixation of distal clavicle fractures. A recent study demonstrated comparable outcomes after locking plate fixation with and without CC ligament augmentation [32]. Other authors in contradistinction preconize the use of stand-alone coracoclavicular suture repair for the treatment of unstable distal clavicle fractures. In a case series study, the authors describe their technique of coracoclavicular stand-alone cow-hitch suture repair and report the results of 19 cases with a mean follow-up of 5 years [33].

In 2008, Kalamaras et al. described the use of locking T-plate for the treatment of distal clavicle displaced fractures. In an observational study of 9 cases, they reported good clinical results, achieving union in all the cases [34]. Posteriorly, precontoured-specific locking plates for distal clavicle fractures were developed. Vaishya et al., in a prospective study, reported the results of 32 patients treated with locking plates, showing good clinical and functional results with only one nonunion that did not require surgery. The authors consider this surgical treatment the best option available, awaiting for larger randomized studies [35]. A recent biomechanical study aimed to measure the screw angles and the number of screws that can be inserted in different fragment sizes and to elucidate the size limits for locking plate fixation. It concluded that other augmented fixation procedures should be considered for fractures with fragment sizes <25 mm that cannot be fixed with a sufficient number of screws [36].

The combination of locking plate fixation and CC ligament augmentations has been proposed recently based on the vertical and horizontal stress forces that intervene in these type of fractures and assuming that any technique counteracting both the forces should result in a better clinical outcome. Karuppaiah et al. published a prospective series of 19 patients treated with open reduction and internal fixation with lateral end locking plate augmented with a coracoid anchor. The authors reported good clinical and functional outcomes after a mean follow-up of 54 months, with a low rate of the need for implant removal (26%) and no difference in the functional outcome between intra-articular and extra-articular fractures [37]. Another case series of 22 patients treated surgically using precontoured locking plate and coracoclavicular reconstruction with Endobutton and FiberWire was reported by Vikas et al. In their study, clinical outcome was assessed using the University of California Los Angeles (UCLA) shoulder score and Constant-Murley score; the CC distance was also recorded. The CC distance did not vary significantly at a one-year interval when compared to the normal shoulder, there were no major complications in any of the patients, and all were able to return to their pre-injury level of activity. Bony union was achieved in all the cases [38]. The use of a titanium alloy cable system-augmented reconstruction of the CC ligament, along with a precontoured locking compressive distal clavicular plate, has been recently proposed by Xie et al. In a case series study of 28 patients, the authors reported good restoration of function and high level of satisfaction. The mean CC distance was 9.61 ± 0.61 mm on the injured side vs. 9.62 ± 0.57 mm on the contralateral uninjured side. The reported complications were one delayed healing of the skin, one severe shoulder stiffness, three incidences of moderate shoulder stiffness, and five cases of symptomatic hardware [39]. With a similar technical approach, Zhang et al. published their results of a retrospective case series study of 21 patients, using a distal clavicle locking plate and a titanium cable. All patients achieved bony union within 6 months, with good clinical and functional results. They reported only one complication (wound infection), and two patients had the implant removed due to local irritation [40]. In a prospective cohort study, 36 patients with distal clavicle fracture were randomly allocated either to titanium cable group (fixed with a titanium cable in combination with a locking plate) and hook plate group (fixed with a clavicular hook plate only). The VAS score in the titanium cable group was significantly lower than that in the hook plate group 1 year after the operation, and the number of postoperative complications in the titanium cable group was significantly lower than that in the hook plate group. Both groups showed good clinical and functional outcomes [41].

6.4 Fractures of the Proximal Third of the Clavicle

Medial clavicle fractures are rare and traditionally acknowledged to account for only 2–3% of all clavicle fractures. However, a recent big data analysis elevated this figure to 11.6% [42]. They are more frequent in middle-aged males, and two-thirds of these fractures are undisplaced [43]. They are commonly associated with high-energy trauma, with a reported in-hospital mortality rates as high as 20% [44] and a 34% mortality rate at 5 years [45]. In a retrospective review study of this type of fractures, Salipas et al. found 68 cases over a 5-year period in a Level 1 Trauma Center. The majority of patients were males with a median age of 53.5 years. The fracture pattern was almost equally distributed between extra-articular and intra-articular, and 80.9% had minimal or no displacement. Operative fixation was performed for painful atrophic delayed union in only two patients (2.9%). Both patients were under 65 years of age and had a severely displaced fracture. Excellent functional results were reported in this study following conservative management [46].

Among patients with displaced fractures of the medial clavicle, surgical treatment has been advised although no randomized controlled study has been published to date. Sidhu et al. reported their results of 27 patients treated with plate and screws in 19 cases and with transosseous sutures in 8 cases. All patients had full shoulder range of motion at final follow-up and were able to return to preinjury occupational activities. There were no significant complications with a union rate of 100% at 12 months [47]. With the use of locking plates, Frima et al. published their results of a retrospective study including 15 patients. They concluded that operative treatment of displaced medial clavicle fractures with well-fitting "small fragment" locking plates provides an excellent long-term functional outcome. Regarding complications, one patient had an early revision operation and developed an infection after 1.5 years, no mal- or nonunions occurred, and eight patients had their implants removed [48]. Li et al. have recently proposed the use of a bridging plate technique across the sternum. For the one case presented, this technique maintained reduction and achieved union of a medial-end comminuted and displaced fracture. To the view of the authors, this approach is simple, safer, and promising [49]. Zúñiga et al. published a case report of a severely displaced proximal-third clavicle fracture managed with open reduction and double-plate internal fixation obtaining a good result [50].

Although uncommon, nonunions and/or failure of osteosynthesis of this type of fracture pose a difficult problem with scarce experience reported. In an innovative approach, Dion et al. proposed medial clavicle resection and stabilization to the sternum using a palmaris longus autograft as a salvage technique. Excellent functional outcomes at 3 years of follow-up were reported in the case presented [51].

6.5 Conclusions

Clavicle fractures are common injuries accounting for 2.6–4% of all fractures in adults. There are several classifications, but we advise the use of Robinson's which has proven diagnostic and prognostic value.

Fractures of the middle third are the commonest. They have been traditionally treated conservatively; however, in the cases of displacement, surgical treatment has inarguably reduced the rate of nonunions. When it comes to patient satisfaction and function, surgically treated patients showed a faster recovery although equivalent scores are reported on the long term. However, for pediatric and adolescent patients, nonoperative management should be considered as first-line treatment, and operative management should potentially be reserved for atypical cases such as floating shoulder, multitrauma, open fractures, nonunions, and symptomatic malunions.

Plate fixation (ORPF) is the most common procedure used for the treatment of middle-third clavicle fractures; however, intramedullary, nails can be also used with similar functional and clinical results, as well as complication rates. The vast majority of ORPF complications are implant

related. Dual mini-fragment plating is an innovative approach which has shown to reduce these complications. The use of lag screws is advised in wedge and comminuted fractures to reduce complications, traditionally of 3.5 mm of diameter. A recent study using smaller diameter screws (2 mm) showed comparable results with easier handling of small fracture fragments. After a recent review, floating shoulder injuries with significant displacement of the scapular neck may benefit from surgical fixation of both the clavicle and scapula fractures. Cost-effectiveness of surgical treatment of middle-third clavicle fractures has been addressed recently with inconsistent results, for which it has been recommended to add economic studies in future RCT.

Fractures of the distal third of the clavicle treated conservatively are prone to nonunion with a reported rate of 33%. However, studies comparing surgical and conservative treatment have not shown differences regarding function and pain. There are up-to-date no high-quality studies to support either approach, and until then it seems prudent to treat these injuries nonoperatively initially and reserve surgery for severely displaced fractures, high-demand patients, or failures of nonoperative care. Hook plate fixation has a high reported rate of complications, for which locking plate fixation seems a wiser approach especially if using precontoured implants. The use of coracoclavicular (CC) ligament augmentation would add further stability to the construct facilitating faster recovery and better clinical outcomes. Encouraging case series in this respect have been published, but no RCTs are available to date.

Medial clavicle fractures account for 2–11% of all clavicle fractures and are usually associated with high-energy trauma. In displaced fractures, surgical treatment has been advised although no randomized controlled study has been published to date. Locking plates are the implants of choice in the published series. Recently, medial clavicle resection and stabilization to the sternum using a palmaris longus autograft as a salvage technique has been described.

References

1. McCarthy MM, Bihl JH, Frank RM, Salem HS, McCarty EC, Comstock RD. Epidemiology of clavicle fractures among US high school athletes, 2008-2009 through 2016-2017. Orthop J Sports Med. 2019;7:2325967119861812.
2. Robinson CM. Fractures of the clavicle in the adult: epidemiology and classification. J Bone Joint Surg. 1998;80:476–84.
3. Kihlström C, Möller M, Lönn K, Wolf O. Clavicle fractures: epidemiology, classification and treatment of 2 422 fractures in the Swedish Fracture Register; an observational study. BMC Musculoskelet Disord. 2017;18(1):82.
4. 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.
5. Neer CS. Nonunion of the clavicle. J Am Med Assoc. 1960;172:1006–11.
6. Qin M, Zhao S, Guo W, Tang L, Li H, Wang X, et al. Open reduction and plate fixation compared with non-surgical treatment for displaced midshaft clavicle fracture: a meta-analysis of randomized clinical trials. Medicine (Baltimore). 2019;98(20):e15638.
7. Ahrens PM, Garlick NI, Barber J, Tims EM. The clavicle trial. J Bone Joint Surg Am. 2017;99:1345–54.
8. Echalier C, Sakek F, Soumagne T, el Rifaï S, Berthier F, Uhring J, et al. Prospective evaluation of early functional recovery of displaced fractures of the middle third of the clavicle whether operated or not. Orthop Traumatol Surg Res. 2021;107:102768.
9. Canadian Orthopaedic Trauma Society. Nonoperative treatment compared with plate fixation of displaced midshaft clavicular fractures. J Bone Joint Surg. 2007;89:1–10.
10. Lee GB, Kim H, Jeon I-H, Koh KH. Long-term outcomes of initially conservatively treated midshaft clavicle fractures. Clin Shoulder Elbow. 2021;24:9–14.
11. Sørensen A-KR, Hammeken LH, Qvist AH, Jensen SL, Ehlers LH. Operative treatment of displaced midshaft clavicular fractures is not cost-effective. J Shoulder Elb Surg. 2020;29:27–35.
12. Liu J, Srivastava K, Washington T, Hoegler J, Guthrie ST, Hakeos W, et al. Cost-effectiveness of operative versus nonoperative treatment of displaced midshaft clavicle fractures. J Bone Joint Surg. 2019;101:35–47.
13. Kask G, Raittio L, Mattila VM, Launonen AP. Cost-effectiveness of operative versus non-operative treatment for clavicle fracture: a systematic literature review. Curr Rev Musculoskeletal Med. 2020;13:391–9.
14. Amer K, Smith B, Thomson JE, Congiusta D, Reilly MC, Sirkin MS, et al. Operative versus nonoperative outcomes of middle-third clavicle fractures: a systematic review and meta-analysis. J Orthop Trauma. 2020;34:e6–e13.

15. Langenhan R, Bushuven S, Reimers N, Probst A. S-shaped titanium endomedullary nail reduces telescoping of comminuted midshaft clavicular fractures. Eur J Orthop Surg Traumatol. 2021;31:391–8.
16. Kabelitz N, Kabelitz M, Frima H, Rehm A, Sommer C, Michelitsch C. Lateral approach for intramedullary nailing of displaced midshaft clavicle fractures; a retrospective cohort study. Eur J Trauma Emerg Surg. 2021; https://doi.org/10.1007/s00068-021-01620-4. Online ahead of print.
17. Hill JM, McGuire MH, Crosby LA. Closed treatment of displaced middle-third fractures of the clavicle gives poor results. J Bone Joint Surg. 1997;79:537–9.
18. Swarup I, Maheshwer B, Orr S, Kehoe C, Zhang Y, Dodwell E. Intermediate-term outcomes following operative and nonoperative management of midshaft clavicle fractures in children and adolescents. JBJS Open Access. 2021;6:–e20.00036.
19. Riiser MO, Molund M. Long-term functional outcomes and complications in operative versus nonoperative treatment for displaced midshaft clavicle fractures in adolescents: a retrospective comparative study. J Pediatr Orthop. 2021;41:279–83.
20. Storti TM, Camilo MS, Silva RFA, Faria RSS, Simionatto CL, Paniago AF. Clinical evaluation of the treatment of clavicle fractures: intramedullary nail × plate. Acta Ortop Bras. 2021;29:34–8.
21. Ankers T, Sawalha S, Nixon M, Kenyon P, Webb M. Does a skin incision along Langer's lines reduce complications following fixation of displaced middle-third clavicle fractures? Arch Orthop Trauma Surg. 2021; https://doi.org/10.1007/s00402-021-03766-7. Online ahead of print.
22. 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.
23. Prasarn ML, Meyers KN, Wilkin G, Wellman DS, Chan DB, Ahn J, et al. Dual mini-fragment plating for midshaft clavicle fractures: a clinical and biomechanical investigation. Arch Orthop Trauma Surg. 2015;135:1655–62.
24. Chen MJ, DeBaun MR, Salazar BP, Lai C, Bishop JA, Gardner MJ. 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;51:647–50.
25. 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:e229–32.
26. Sheth U, Fernandez CE, Morgan AM, Henry P, Nam D. Are two plates better than one? A systematic review of dual plating for acute midshaft clavicle fractures. Shoulder Elbow. 2021; https://doi.org/10.1177/17585732211002495.
27. Hulsmans MH, van Heijl M, Houwert RM, Burger BJ, Verleisdonk E, Jan M, Veeger DJ, et al. Surgical fixation of midshaft clavicle fractures: a systematic review of biomechanical studies. Injury. 2018;49:753–65.
28. Wurm M, Zyskowski M, Greve F, Gersing A, Biberthaler P, Kirchhoff C. Comparable results using 2.0-mm vs. 3.5-mm screw augmentation in midshaft clavicle fractures: a 10-year experience. Eur J Med Res. 2021;26(1):122.
29. Dombrowsky AR, Boudreau S, Quade J, Brabston EW, Ponce BA, Momaya AM. Clinical outcomes following conservative and surgical management of floating shoulder injuries: a systematic review. J Shoulder Elb Surg. 2020;29:634–42.
30. Oh JH, Kim SH, Lee JH, Shin SH, Gong HS. Treatment of distal clavicle fracture: a systematic review of treatment modalities in 425 fractures. Arch Orthop Trauma Surg. 2011;131:525–33.
31. Singh A, Schultzel M, Fleming JF, Navarro RA. Complications after surgical treatment of distal clavicle fractures. Orthop Traumatol Surg Res. 2019;105:853–9.
32. Salazar BP, Chen MJ, Bishop JA, Gardner MJ. Outcomes after locking plate fixation of distal clavicle fractures with and without coracoclavicular ligament augmentation. Eur J Orthop Surg Traumatol. 2021;31:473–9.
33. Laux CJ, Villefort C, el Nashar R, Farei-Campagna JM, Grubhofer F, Bouaicha S, et al. Stand-alone coracoclavicular suture repair achieves very good results in unstable distal clavicle fractures at a minimum follow-up of 1 year. J Shoulder Elb Surg. 2021;30:2090–6.
34. Kalamaras M, Cutbush K, Robinson M. A method for internal fixation of unstable distal clavicle fractures: early observations using a new technique. J Shoulder Elb Surg. 2008;17:60–2.
35. Vaishya R, Vijay V, Khanna V. Outcome of distal end clavicle fractures treated with locking plates. Chin J Traumatol. 2017;20:45–8.
36. Abe S, Koizumi K, Murase T, Kuriyama K. Comparing the locking screw direction of three locking plates for lateral clavicle fractures: a simulation study. BMC Musculoskelet Disord. 2021;22(1):812.
37. Karuppaiah K, Bilal A, Colegate-Stone T, Sinha J, Tahmassebi R, Tavakkolizadeh A. Outcome following management of unstable lateral end clavicle fractures with locking plate and coracoid anchor augmentation. Shoulder Elbow. 2021; https://doi.org/10.1177/1758573220981708.
38. Vikas V, Bhatia N, Jalan D, Prakash J, Singh J, Khare S. Clinical outcome of Neer type II lateral end clavicle fractures with coracoclavicular ligament disruption treated with pre-contoured locking plate and endobutton. Cureus. 2021;13(1):e12585.
39. Xie Z, Song M, Zhou J, Yin G, Lin H. Precontoured locking compression plate with titanium alloy cable system: in treatment of Neer type IIb distal clavicle fracture. Orthop Surg. 2021;13:451–7.
40. Zhang F, Fu Q, Li Y, Lu N, Chen A, Zhao L. Locking plate combined with titanium cable for Neer type II

distal clavicle fractures. BMC Musculoskelet Disord. 2021;22(1):269.
41. Wang J, Guan J, Liu M, Cui Y, Zhang Y. Treatment of distal clavicle fracture of Neer type II with locking plate in combination with titanium cable under the guide. Sci Rep. 2021;11(1):4949.
42. Bakir MS, Unterkofler J, Haralambiev L, Kim S, Carbon R, Ekkernkamp A, et al. Medial injuries of the clavicle: more prevalent than expected? A big data analysis of incidence, age, and gender distribution based on nationwide routine data. Eur J Trauma Emerg Surg. 2021;47:1175–82.
43. Gumina S, Carbone S, Polizzotti G, Paglialunga C, Preziosi Standoli J, Candela V. The rare medial-end clavicle fractures: epidemiological study on inhabitants of a suburban area. Cureus. 2021;13(9):e18008.
44. Throckmorton T, Kuhn JE. Fractures of the medial end of the clavicle. J Shoulder Elb Surg. 2007;16:49–54.
45. Lindsey MH, Grisdela P, Lu L, Zhang D, Earp B. What are the functional outcomes and pain scores after medial clavicle fracture treatment? Clin Orthop Relat Res. 2021;479:2400–7.
46. Salipas A, Kimmel LA, Edwards ER, Rakhra S, Moaveni AK. Natural history of medial clavicle fractures. Injury. 2016;47:2235–9.
47. Sidhu VS, Hermans D, Duckworth DG. The operative outcomes of displaced medial-end clavicle fractures. J Shoulder Elb Surg. 2015;24:1728–34.
48. Frima H, Houwert RM, Sommer C. Displaced medial clavicle fractures: operative treatment with locking compression plate fixation. Eur J Trauma Emerg Surg. 2020;46:207–13.
49. Li Z, Liu H, Chen D, Chen C, Zhang Y, Xue E. A new technique for medial-end comminuted clavicle fractures. Injury. 2019;50:811–3.
50. Zúñiga DG, García LF, Leal JA. Biplanar osteosynthesis for severely displaced proximal-third clavicle fracture: a case report. JBJS case. Connect. 2021;11(2) https://doi.org/10.2106/JBJS.CC.20.00584.
51. Dion MO, Martel S, Pelet S. Surgical treatment of a medial clavicle fracture nonunion with medial clavicle resection and stabilization to the sternum with palmaris longus graft. Case Rep Orthop. 2019;2019:7123790.