Dual- Versus Single-Plate Fixation of Clavicle Fractures

Understanding the Rationale Behind both Approaches

Lisa M. Tamburini, MD, Benjamin C. Mayo, MD,
Cory Edgar, MD, PhD*

KEYWORDS

• Clavicle • Single place • Dual plate • Orthogonal plating • Precontoured plates

KEY POINTS

- Midshaft clavicle fracture is treated nonoperatively and operatively, with higher union rates and faster return to activity after operative treatment.
- Operative treatment options for clavicle fractures include a single plate placed either superiorly or anteroinferiorly or two plates placed orthogonally.
- Single- and dual-plate fixation result in acceptable union rates.
- Dual-plate constructs allow for smaller, less prominent plates to be used, which are less likely to require symptomatic implant removal.

INTRODUCTION

Clavicle fractures are a common injury accounting for 2.6% to 4% of fractures.[1,2] These fractures are typically the result of a high-energy force following a fall onto the shoulder (30%); motor vehicle accidents (12.3%); and during sporting activities (30%), such as, football (16.2%) and cycling (4.1%).[1–3] Fractures to the shaft of the clavicle make up 69% of all clavicle fractures.[1] There are two common classification systems for describing midshaft clavicle fractures: the AO Foundation/Orthopaedic Trauma Association classification and the Edinburgh classification. Using the AO Foundation/Orthopaedic Trauma Association classification system the clavicle is identified by the number 15, followed by a location qualifier, 1 for medial fractures,

Department of Orthopaedic Surgery, University of Connecticut, UConn Musculoskeletal Institute, 120 Dowling Way, Farmington, CT 06032, USA
* Corresponding author.
E-mail address: coedgar@uchc.edu

Clin Sports Med 42 (2023) 677–684
https://doi.org/10.1016/j.csm.2023.06.016
sportsmed.theclinics.com

2 for shaft fractures, and 3 for lateral fractures. Additionally, a letter is added to describe fracture pattern: A for simple fractures, B for wedge fractures, and C for comminuted fractures.[1] The Edinburgh classification can also be used to describe clavicle fractures, type I fractures occur in the medial fifth of the clavicle, type II in the middle three-fifths, and type III in the lateral fifth. Again, two qualifiers are added: A for nondisplaced or less than 100% displaced and B for greater than 100% displacement and 1 or 2 for intra-articular fractures or fracture comminution.[1] These classification systems can help guide treatment based on known risk factors for worse outcomes.

Although many of these fractures are treated without surgical intervention with good outcomes, there are risks of nonunion, malunion, and persistent symptoms. There is also a greater ability to return to activity and perform overhead activities more quickly after surgical treatment, which may be a consideration when treating younger and more active individuals.[4,5] For those that are treated with surgery, there are risks including infection, symptoms from the implant, and the need for additional surgery. There has been an increased emphasis on reducing implant-associated complications with surgical management without sacrificing outcomes or failure rate. When choosing operative management, fixation with a single plate placed either superiorly or anteroinferiorly or dual plates placed orthogonally have been described. We discuss these treatment options, their outcomes, and the rationale behind them.

SURGICAL TREATMENT TECHNIQUES

There has been some debate with regards to management of clavicular fractures. Historically it has been thought that the degree of nonunion or malunion following nonoperative treatment was very low and therefore these fractures were often treated nonoperatively. More recently, however, data have shown a higher rate of nonunion and malunion than previously described. A meta-analysis by McKee and coworkers[6] reported a nonunion rate of 14.5% and a symptomatic malunion rate of 8.5% following nonoperative treatment of displaced midshaft clavicular fractures. This is in comparison with a 1.4% nonunion and 0% symptomatic malunion rate following operative treatment.[6] Operative treatment is generally considered for fractures with greater than 2 cm of shortening, greater than 2 cm of displacement, skin tenting, in combination with ipsilateral serial rib fractures, or a floating shoulder.[7] Additionally, a patient's desire to return to previous level of activity plays a role in this decision making. Higher rates of return to sport after operative treatment of clavicle fractures have been reported and operative treatment also allows a faster return to sport.[4,5]

SINGLE-PLATE FIXATION

Biomechanics

Traditionally, clavicle fixation has been completed through a single superiorly placed plate. A variety of plates have been used in the fixation of clavicular fractures including 3.5-mm reconstruction plates, 3.5-mm locking compression plates, 3.5-mm precontoured plates, 2.7-mm reconstruction plates, and 2.7-mm calcaneal plates. Overall, union rates and need for reoperation are not affected by the type of plate used.[8] There are, however, biomechanical differences among plate options. The 3.5-mm plates have higher bending stiffness when compared with 2.7-mm plates and are more likely to failure by plastic deformation.[8,9] The 2.7-mm plates, however, require more displacement before plastic deformation and fail by plate breakage.[8,9] Limited contact dynamic compression plates placed superiorly have better biomechanical stability when compared with reconstruction plates and dynamic compression plates. Iannotti

and colleagues[10] compared limited contact dynamic compression plates, dynamic compression plates, and reconstruction plates and found limited contact dynamic compression plates to have greater biomechanical stability. Because of the S-shape of the clavicle, precontoured plates have been designed to better fit this shape. Precontoured plates with locking screws created a stiffer construct, which had a higher number of cycles to failure than noncontoured locking compression plates.[11] With many different plate choices, a plate with the appropriate characteristics can be chosen based on fracture pattern and need for absolute versus relative stability.

With the advent of precontoured plates and easier bending, anterior plating has become a popular option because of many purported benefits. When compared with superiorly placed plates, anterior plates experienced less stress when exposed to axial compression and torsion forces.[12,13] Although this is true, anteroinferiorly placed plates were found to fail at a lower load by plate bending.[13] Gilde and colleagues[14] compared reconstruction and dynamic compression 2.7-mm plates placed anteroinferiorly and found that reconstruction plates failed more often. Many single-plate options with acceptable biomechanical properties exist taking into consideration location and type of plate used.

Clinical Outcomes

Overall, single-plate fixation, either superiorly or anteroinferiorly, results in good patient-reported outcomes.[15–18] Clavicle fracture fixation with a single plate demonstrates high union rates, with anterior plating having a slightly higher union rate than superior plating.[17,19,20] Single plating is, however, associated with complications that can require reoperation including symptomatic hardware because of the thick plates frequently used and the thin soft tissue coverage, nonunion, deep infection, wound dehiscence, and broken hardware.[18,21–23] There are many studies looking at implant removal after single-plate fixation of clavicular fractures. Reports of implant removal rates vary from 37% to 61% and 7.7% to 67% in anteroinferior plating and superior plating, respectively.[17,18,20,24] Although the data show that there is a high number of patients who require implant removal, there are some data to suggest patients who undergo anteroinferior plating have less symptoms as a result of their plate.[24,25] With a similar surgical approach, operative time for anterior and superior plating is similar, around 60 $\pm$ 20 minutes.[26,27] A meta-analysis did show anteroinferior plating may reduce blood loss, operation time, and union time.[28]

Single plating, superiorly and anteroinferiorly, allow individuals to return to high levels of activity. In a study of cyclists with clavicular fractures treated with anteroinferior plates, all cyclists returned to sport, with competitive cyclists returning at an average of 10 days and recreational cyclists at an average of 2 to 3 weeks.[29] Similarly, 94% of athletes with clavicular fractures treated with a superiorly placed precontoured locking plate returned to sport at their preinjury level.[30] This study did find a wider range of time to return to activity of 5 to 180 days.[30]

DUAL-PLATE FIXATION

Orthogonal Plating

Biomechanics

Although clavicle fractures can be treated with one plate, placed superiorly or anteriorly, this plate is often larger and therefore is prominent, which can lead to implant complications and even implant removal as discussed previously. This is most appropriate when the fracture "keys" in and stability is imparted by fracture anatomy (**Fig. 1**). Additionally, this plate predominantly resists force in only one direction. The use of two

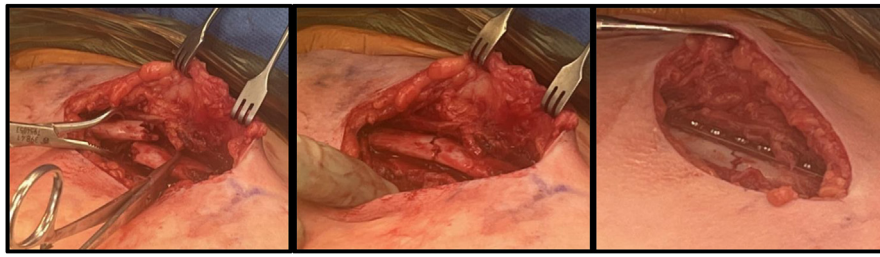

Fig. 1. Left simple clavicle fracture with stable fracture pattern, treated with 2.7-mm superior plate.

small plates, placed orthogonally, addresses rotational and pullout forces as an inferior displacement force from gravity and shoulder gridle activation is initiated (Fig. 2). Smaller plates are less prominent and therefore less commonly cause irritation and with two orthogonally placed plates, there is better resistance to deforming forces.

Although a 2.7-mm or 3.5-mm plate is used for single plating, dual-plate constructs can be made up of smaller plates, such as a 2.4-mm plate superiorly and a 2.7-mm plate anteriorly. In cases with larger patients or more significant comminution an anterior 3.5-mm plate is placed after length is established with a smaller superior plate (Fig. 3). Acceptable results have even been seen with plates of 2.4 mm and 2.0 mm.[31] As with single plating, reconstruction, locking compression, and nonlocking plates have all been used in dual-plate constructs.

Overall, no significant difference in construct stiffness has been reported when comparing dual plating to single plating for clavicular fracture fixation.[32–35] Additionally, no difference in load to failure has been noted.[33,35] Dual-plate fixation may even create a construct that is superior to single plating. Dual-plate constructs have been shown to be stiffer when exposed to bending forces in the superior and anterior direction and axial forces.[36–38] This stronger construct leads to lesser degree of fracture displacement after repeated cycling.[37]

Clinical Outcomes

Dual plating has favorable outcomes that are comparable with single plating. Similarly to clavicle fracture fixation with a single plate, dual plating has very high union rates despite the need for increased soft tissue exposure for two plates.[22,31,39–41] Although dual plating uses smaller plates, studies have shown no difference in maintenance of reduction.[31,42] In contrast to single plating, dual plating does have more favorable outcomes with regard to complications, reoperations, and implant removal. Studies have shown rates of implant removal between 0% and 15%.[21,22,31,41–43] A low number of complications, such as peri-incisional numbness, superior plate prominence, and

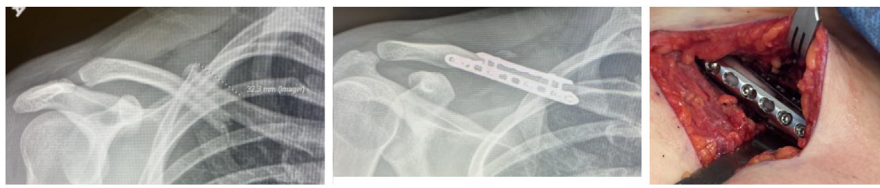

Fig. 2. Left clavicle fracture with dual-plate fixation; 2.4-mm superior plate, 2.7-mm anterior plate.

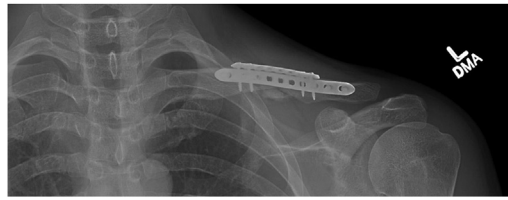

Fig. 3. Left clavicle fracture with dual-plate fixation; 2.4-mm superior plate, 3.5-mm anterior plate with comminution.

infection, have been noted with dual plating with few of these requiring reoperation.[22,40] With smaller, less prominent plates, the rate of implant removal is lower with dual plating when compared with single plating.[41,42] As may be expected, operative time is longer with dual plating than with single plating. A study by Lee and colleagues[44] reported an average operative time of 174 minutes for dual plating and 119 minutes for single plating.

SUMMARY

For clavicle fractures that indicate surgical management because of fracture or patient characteristics, plating is the method of choice for fixation. A single plate may be placed superiorly or anteriorly or two plates may be used. When a single plate is used it is often a larger, 3.5-mm plate. These plates demonstrate the ability to create strong constructs that resist deforming forces. With low levels of nonunion and good patient-reported outcomes this may seem like a great option for fixation. However, these plates are often prominent because of their size and superficial location. Single plates are often associated with symptoms that require implant removal, with reported rates of up to 67%. Dual plating is an alternative option that maintains similar or even improved construct stability, which allows for high levels of fracture union while allowing smaller plates to be used. The use of smaller plates in turn decreases the frequency and severity of symptoms experienced because of prominent implant position.

CLINICS CARE POINTS

- Clavicle fractures should be treated operatively when there is greater than 2 cm of shortening, greater than 2 cm of displacement, skin tenting, ipsilateral rib fractures, or in the presence of a floating shoulder. Operative management should also be highly considered in active, athletic individuals wishing to return to a high level of activity.
- When choosing between single and dual plating, fracture pattern, patient activity level, patient size, and patient expectations should all be taken into consideration.
- Because prominent hardware is a common problem, patients must be counseled regarding this before surgery.
- Single and dual plating for clavicle fracture provide biomechanically stable constructs with overall good clinical outcomes.

DISCLOSURES

L.M. Tamburini has no disclosures. B.C. Mayo has no disclosures. C. Edgar is a paid consultant for Mitek; is a Board member for MTF; and a full list of disclosures is found on the AAOS Web site.

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