The clavicle is one of the most commonly fractured bones encountered by the orthopaedic surgeon. Clavicle fractures represent up to 12% of all fractures and between 44% and 66% of the fractures about the shoulder.\textsuperscript{1,2} Due to its inherent anatomy, the midshaft is the most common location for these fractures accounting for approximately two-thirds of cases.\textsuperscript{2,3} Historically, the treatment of these fractures has been conservative. In fact, Hippocrates noted that the physician would not be sorry for the neglect of these patients. Nonoperative management is based on the high rate of union noted by investigators reporting on large series of patients.\textsuperscript{4,5} However, recent reports have noted lower union rates for displaced midshaft fractures treated nonoperatively and questioned the sequelae of subsequent malunion in fractures that do go on to heal.\textsuperscript{6-9} Therefore, interest in the operative management of midshaft clavicle fractures is growing and includes a recent evidence-based analysis.\textsuperscript{10} The current review will focus on the anatomy and evaluation of midshaft clavicle fractures and discuss the role of both operative and nonoperative management.

Surgical Anatomy and Biomechanics

The clavicle is the first bone to ossify during the fifth week of gestation and is the last to fuse.\textsuperscript{11} The sternal end fuses in the early third decade. Details of the osseous anatomy become particularly important when planning operative management. Medially, the clavicle is convex forward, while laterally it is concave forward. The bone flattens out both medially and laterally at the sternoclavicular and acromioclavicular joints. There is a central zone of transition where the clavicle is more tubular. This central area is subjected to the highest bending and torsional forces, making it vulnerable to fracture.\textsuperscript{12}

Medially the clavicle is supported by strong capsular ligaments. Interclavicular ligaments run across the sternoclavicular joint acting as static stabilizers, preventing downward displacement of the clavicle. Laterally, the clavicle attaches to the scapula via the coracoclavicular ligaments and acromioclavicular ligaments. The coracoclavicular ligaments consist of the trapezoid ligament laterally and conoid ligament medially. The strong posterosuperior portion of the acromioclavicular ligaments prevent anteroposterior (AP) clavicular translation.\textsuperscript{13}

The muscular attachments to the clavicle become important when considering displacement patterns of fractures. Medially, the pectoralis major and sternohyoid have their...
origins. Superomedially, the sternocleidomastoid has its origin while running toward the inferior base of the skull. When the clavicle is fractured, the origin of the sternocleidomastoid acts as an insertion and the medial segment displaces accordingly. Anterolaterally, the deltoid has part of its origin on the clavicle, while the trapezius has part of its insertion posterosuperiorly. The trapezius pulls distal fracture fragments posteromedially and the fascial interval between the deltoid and trapezius is exploited during the surgical dissection.

The clavicle is intimately located near the brachial plexus and subclavian vessels. The middle third is the inferior boarder of the posterior triangle of the neck. Knowledge of this anatomy is essential when planning surgical dissection and hardware placement.

The clavicle functions as a strut in the sagittal plane, stabilizing the glenohumeral joint and providing a stable center of rotation for the shoulder. In the coronal plane, the clavicle performs a suspensory function. The shoulder girdle effectively hangs from the clavicle by the coracoclavicular ligament. This has been described as being similar to a “sign post,” whose arm, the clavicle, is dynamically stabilized by the trapezius.

**Patient Evaluation**

An understanding of the mechanism of injury is essential in ruling out associated injuries. A clavicle fracture can result from both indirect and direct trauma. A fall onto the shoulder is the most common mechanism. A fall onto an outstretched hand is an indirect mechanism that may lead to fracture as well. Less common causes of fracture may include pathologic fractures following a radical neck dissection or stress fractures in laborers. Due to its subcutaneous position, open fractures of the clavicle are possible and every polytrauma patient should be examined thoroughly.

Associated injuries should be evaluated and treated accordingly. Rib injuries occur concomitantly 3% of the time, and a pneumothorax should be ruled out by chest radiograph if suspected. A neurovascular exam of the effected extremity should be performed and findings noted to document the integrity of the brachial plexus and axillary arterial tributaries.

Multiple radiographic views have been recommended for clavicle fractures. The injuries are often discovered during a routine chest radiograph. The chest film may be evaluated and associated clavicular shortening grossly assessed. A clavicular AP view is shot with the beam directed 15° to 30° cephalad to avoid the mediastinal contents. An apical oblique image is obtained by angling the shoulder 45° toward the beam and 20° cephalad. Due to the S-shape structure of the clavicle, the apical oblique may provide an assessment of clavicular length. Advanced imaging studies such as a computed tomography (CT) scan are reserved for cases of possible nonunion or fractures at the medial or lateral ends. Furthermore, a CT scan may be indicated in the presence of an associated scapular neck fracture to help assess displacement. Currently, there is no role for magnetic resonance imaging (MRI) in the management of these injuries.

**Nonoperative Management**

Historically, nonoperative management has been the mainstay of treatment for midshaft clavicle fractures in adults. Investigators have cited high union rates and low associated functional deficits as a basis for such management. In 1960, Neer reported on 2,235 clavicle fractures and showed a nonunion rate of only 0.13%. In 1968, Rowe reported on 566 clavicle fractures and found a nonunion rate of only 0.8%. However, a critique of these studies may be that the pediatric population was included in the study groups. It is also notable that modern day functional assessments of outcome were not available in either study.

In 1997, Hill and colleagues demonstrated a much higher nonunion rate of 15% in a study group of displaced midshaft clavicle fractures. In addition, these investigators reported 30% of the nonunion patients in this study had a poor functional result. The conclusion of this retrospective study was that an initial fracture shortening of greater than 2 cm was associated with nonunion and a high percentage of those patients went on to a poor result.

Overall, the literature is clear that the majority of adults with midshaft clavicle fractures will heal their injuries. Initial immobilization in either a sling or a figure-of-eight bandage remains the norm. The patient should remain immobilized until pain allows discontinuation, typically at 2 to 4 weeks. Active motion may be initiated at that time, with light duty allowed for laborers at 6 weeks. A return to contact sport may be allowed by 3 months if the radiographs and examination allow.

Anderson and associates performed a randomized study evaluating a sling versus a figure-of-eight bandage to treat clavicle fractures. The sling was maintained until pain allowed and the figure-of-eight bandage was worn for 3 weeks. The investigators reported on a cohort of 61 patients that followed-up from the initial study group of 79. They found no difference in union rate or time to union. There was a significant increase in dissatisfaction in the patients treated in a figure-of-eight bandage. However, the reader must note that the follow-up period was 3 months in the study, and no functional outcome scores were used to evaluate treatment. In their retrospective review of 140 midclavicular fractures, Stanley and Norris also noted no difference in the radiographic outcome when comparing the sling versus figure-of-eight treatment. Once again, this was a short-term radiographic outcome study lacking functional outcome scores.

Nonoperative treatment of midclavicular fractures in adults will likely result in a malunion with various degrees of angular, rotatory, and translational deformity (Fig. 1). The clavicle will typically lie shortened with the lateral fragment...
posterior to the medial fragment.\textsuperscript{21} The effect of subsequent malunion and the possible sequelae have been the subjects of recent study.

As stated previously, Hill and coworkers had a greater than 30\% dissatisfaction rate in 52 malunited clavicle fractures.\textsuperscript{7} Thirty-seven percent of the patients had difficulty with overhead activities and 25\% required the use of an analgesic for pain at an average follow-up of 38 months. When using the contralateral clavicle as a comparison, another study found a 25\% dissatisfaction rate in shortened clavicle fractures. The investigators defined a threshold of acceptable shortening to be 18 mm in males and 14 mm in females.\textsuperscript{22} Muscular dysfunction has recently been demonstrated in shortened malunions of the clavicle as well.\textsuperscript{23} In 2006, McKee and colleagues reported on the functional outcome of healed displaced midshaft clavicle fractures.\textsuperscript{8} The investigators reported on the results of 30 healed displaced clavicle fractures at an average of 55 months. In this study, Constant and DASH outcome measures were utilized as was objective strength testing of the affected shoulder.\textsuperscript{24,25} The range of motion of the injured shoulder was similar to the contralateral side. However, the injured shoulder had strength and endurance scores 60\% to 80\% in various planes of motion when compared to the opposite side. The Constant and DASH scores were significantly worse than for contralateral shoulder, signifying a relative disability in the malunited clavicle fractures.

The recent malunion literature is countered by the 17-year follow-up reported by Nordqvist and associates, which concluded that acceptable results can be expected with nonoperative management.\textsuperscript{26} The study investigators reported on 225 midshaft clavicle fractures treated nonoperatively and reported outcomes as good, fair, or poor, based on pain or functional deficit. There were 185 good results in such a classification. It has been noted that, although the majority of patients with nondisplaced fractures had a good result, the percentage decreased to 83\% of those with displaced two-part fractures and 73\% of those with displacement and comminution.\textsuperscript{27}

\textbf{Operative Management}

The options for surgical management include external fixation, intramedullary fixation, and osteosynthesis with a plate and screws. The technique used depends on surgeon preference and the “personality” of the fracture. Patient positioning is either supine or beach chair. Supine positioning can help to facilitate intramedullary screw placement and provide easier access for the image machine. We prefer the beach chair position with a folded towel underneath the ipsilateral scapula when using plate and screw techniques. Incisions are typically placed along Langer's lines, and thick skin flaps are developed to aid in covering a plate. Supraclavicular nerves should be identified and preserved in order to avoid the development of painful neuromas (Fig. 2).

\textbf{Figure 1} Injury radiograph (A) and 6-month follow-up radiograph (B), demonstrating an anticipated malunion of a displaced midshaft clavicle fracture.

\textbf{Figure 2} Intraoperative view demonstrating the preservation of supraclavicular nerves during the superior plating of a clavicle fracture.
External fixation is effective in the setting of open fractures and has been reported for use in nonunions. Furthermore, external fixation may be considered in certain open fractures or fractures with vascular injury to allow access to the neurovascular anatomy. When external fixation is utilized, typically 3.0 mm half pins are used. The medial pins should be placed in an anterior to posterior direction to avoid the apex of the lung. The lateral pins are then placed in a superior to inferior direction. Schuind and coworkers reported the healing of 20 out of 20 clavicular nonunions treated in such a manner.

The advocates of intramedullary fixation cite the ease of the procedure, the limited exposure involved, and satisfactory rates of healing. The technique is variable and may involve the use of K-wires, threaded screws, Knowles pins, Hagie pins, or elastic titanium nails. Intramedullary fixation typically should be avoided in the setting of fracture comminution where a plate will better maintain clavicular length.

Only a small skin incision is needed for intramedullary fixation. The clavicle’s medial and lateral ends are prepared sequentially with drill bits until a good fit is obtained. The appropriate sized pin is then placed in a retrograde fashion. The pin will exit the lateral fragment under the skin posteromedial to the acromioclavicular joint. A small stab incision can then be made to pull the pin back prior to advancing into the medial fragment. Reduction forceps are used to hold the fracture in place while this is performed.

Historically, excellent healing rates have been observed using intramedullary fixation. Neviaser in 1975 reported a 100% healing rate using Knowles pins. In 1981, Zenni and colleagues reported on a mix of intramedullary fixation techniques, but had a 100% healing rate. The investigators, however, did note one instance of wire breakage and one refracture following hardware removal. More recently Chu and associates reported on the healing of 77 of 78 clavicle fractures treated with a Knowles pin. Elastic titanium nails were used by Jubel and coworkers to treat 58 acute midshaft clavicle fractures, and only one nonunion was encountered.

With these excellent healing rates have come concerns about associated complications. In a retrospective comparison study, Grassi and colleagues had a 35% complication rate with intramedullary fixation. The majority of complications were superficial infections. However, delayed union, nonunion, and refractures occurred as well.
In a recent study, Strauss and associates reported on the complications associated with the use of intramedullary pins for the treatment of midshaft clavicle fractures. The investigators found that while the ultimate union rate was 100% and shoulder range of motion was largely preserved, there was a 50% complication rate. As with the previously mentioned study, most complications were related to superficial skin breakdown.

Plate osteosynthesis carries the benefit of more rigid fixation, the ability for cortical compression, and more rotational control of the fracture. Plating options include small fragment implants, such as 3.5 mm LDC plates and 3.5 mm reconstruction plates. Furthermore, mini fragment fixation such as 2.7 mm plates and screws or smaller may also be utilized in small or thin patients, or both, as well as in extensively comminuted fractures. Pre-contoured plates with locking and nonlocking options are available as well (Fig. 3). A compression plating technique can be used for transverse or short oblique fractures. Long oblique or comminuted fractures should be amenable to neutralization plating with lag screws. Autogenous bone grafting may be considered in the setting of highly comminuted fractures.

Plates are applied in a superior or anteroinferior position across the midclavicle. The wide anterior to posterior expanses of the clavicle allow ample room for a superior plate to be applied. The dissection for superior plating may also avoid the neurovascular structures beneath the clavicle. In a 2002 study, Iannotti and coworkers found the superior position to have more axial and rotational rigidity. Anteroinferior plating on the other hand has four major advantages. First, it allows for a longer length of screws in the anterior to posterior direction. Second, there is a decreased risk to neurovascular injury when plunging with the drill bit. Third, hardware should be less prominent as opposed to the superior plate which would lie just beneath the subcutaneous tissue. Lastly, an anteroinferior plate will theoretically buttress the lateral fragment and prevent inferior displacement (Fig. 4).

In 1999, Shen and colleagues reported their results of plating for displaced midclavicular fractures. The investigators routinely plated all displaced fractures presenting to their institution. The study cohort included 232 fractures that underwent a mixture of plating techniques dependent on the fracture characteristics. The union rate was 97% with a single deep infection and four superficial infections. Patients were followed-up with a phone interview documenting any residual symptoms and their overall satisfaction rate. No patients had a perceived deformity or deficit in strength or range of motion, and the satisfaction rate with the procedure was 94%.

More recently, a multicenter randomized clinical trial comparing nonoperative treatment with plate fixation of displaced midshaft clavicle fractures was performed. One hundred eleven of the 132 patients randomized completed the one year follow-up. There were 62 patients in the plate group and 49 patients in the sling group. Outcome measures included radiographic union, Constant shoulder scores, DASH scores, and an overall satisfaction survey. The mean time to union was significantly improved in the operative group as was the nonunion rate (3% vs 15%). The Constant scores were significantly superior in the operative group at all time points utilized in the study. The DASH scores were also significantly superior in the operative group. The investigators’ conclusion supported plating of displaced fractures and cited the significance of the patient-based outcomes used in their study. However, these results may be influenced by the fact that outcomes were not further stratified according to the patient’s healing status. Simply stated, the poor outcomes of the nonunion patients in the nonoperative group may have led to the overall difference in comparing the two groups.

**Conclusion**

Clavicle fractures continue to be a common injury encountered by the orthopaedic surgeon and have received much attention recently. Overall, the union rate of minimally displaced fractures treated nonoperatively is acceptable. The management of the displaced midshaft clavicle fractures remains somewhat controversial as patient-based outcome measures have revealed the possible sequelae of clavicular malunion. Currently, there is momentum growing toward the operative management of displaced midclavicular fractures. While nonoperative care remains the standard for the majority of minimally displaced clavicle fractures, there may be a subset of patients with significant displacement who benefit from surgical intervention.

**Disclosure Statement**

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**References**