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Management of Acute Clavicle Fractures

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It has been believed since the time of Hippocrates that clavicle fractures require little more than benign neglect by clinicians [1]. Although many patients who have clavicle injuries do achieve adequate healing and functional recovery without surgical interventions, good outcomes, especially with displaced fractures, are not universal. Recent literature suggests that a subset of midclavicular injuries may warrant primary surgical treatment to minimize the incidence of non-union and/or symptomatic malunion. Furthermore, certain types of clavicular injuries have been shown to result in suboptimal outcomes when managed nonoperatively. This article is based on the currently available clinical evidence on the evolving management of acute clavicle fractures.

Epidemiology

Clavicle fractures are one of the most common fractures encountered in orthopedic practice. Previous epidemiologic studies suggest that clavicle fractures represent up to 5% of all adult fractures and up to 44% of all shoulder girdle fractures [2–4]. The overall incidence of the injury was estimated to be 29 to 64 per 100 000 population per year in two large European series [5,6]. The incidence of the injury also is characterized by a bimodal age distribution with peaks under age 40 years and above age 70 years. The typical young male patient sustains a high-energy clavicle fracture secondary to a fall from height, a direct blow during a sporting event, or a motor vehicle collision (Fig. 1) [4–6]. The increased incidence in the elderly is found in both men and women and represents low-energy or insufficiency fractures caused by a fall from a standing height [3,6]. Contemporary series also report a relatively high proportion of clavicle injuries as a result of high-energy trauma or polytrauma from sports, falls, and motor vehicle collisions (Fig. 2) [4–9]. This trend probably reflects the changing demographics of the modern society with greater participation in sports and high-risk behaviors than seen many decades ago.

With respect to the incidence of different fracture types, fractures of the middle third of the clavicle are by far the most common, accounting for 69% to 81% of all clavicle fractures [2–8]. Of these, 48% to 73% are displaced fractures. The second most common type is fracture of the lateral or distal third of the clavicle, accounting for 16% to 30% of all clavicle fractures [2–8]. Of these, 10% to 52% are displaced. Less than 3% of all clavicle fractures are fractures of the medial or proximal third of the clavicle [2–8].

Applied anatomy

In human embryology, the clavicle is the first bone to ossify; its ossification begins during the fifth week of gestation [10]. It also contains the last ossification center to fuse in human body: the medial ossification center adjacent to the sternoclavicular (SC) joint fuses well past 20 years of age [10,11]. This late fusion of the medial physis explains the pathophysiology behind the physeal separation injuries seen in young adults.

Morphologically, the clavicle is a subcutaneous, S-shaped long bone with an anterior apex medially and posterior apex laterally [10,12]. It

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Fig. 1. A CT scan scout view demonstrates severe displacement of a mid-shaft fracture of the clavicle following high-speed vehicular trauma. Such displacement in a young, active individual is a relative indication for primary operative fixation.

widens at both the sternal and the acromion ends, transitioning through the narrower tubular middle third. The medial third of the clavicle has a relatively flat superior border. It articulates with the sternum through the strong capsuloligamentous attachments at the SC joint and the first rib. Attached to the medial third of the clavicle are the sternocleidomastoid, the pectoralis major, and the sternohyoid muscles. The sternocleidomastoid muscle provides the major deforming force on the medial fragment, pulling superomedially in a midshaft fracture of the clavicle [13,14]. The wide lateral third of the clavicle contains the apex of the superior bow of the clavicle. It is anchored solidly to the scapula by the acromioclavicular (AC) capsulo-ligament and the coracoclavicular (CC) ligaments—the trapezoid ligament laterally and the conoid ligament medially. Attached to the lateral third of the clavicle are the anterior fibers of the deltoid and the trapezius muscles in addition to the clavicular head of the pectoralis major muscle. The pectoralis major and the weight of the arm provide the major deforming force on the lateral fragment, pulling inferomedially and anteriorly in fractures of the middle third of the clavicle [13,14]. A thorough understanding of the osseous morphology and of the deforming forces applied to different clavicle-fracture fragments is essential for determining the appropriate therapeutic intervention and mode of fixation, as discussed later in the section on management.

Overlying the clavicle and its attached muscles are the branches of supraclavicular nerves and the platysma muscle. During a surgical exposure of the clavicle, the platysma must be divided. Just deep to it are the supraclavicular nerves branches over the medial and middle thirds of the clavicle [13,15]. The authors advocate identifying and protecting these cutaneous nerves during the surgical exposure to prevent dysesthesia after the surgery [15].

Functionally, the clavicle acts as a strut that connects the shoulder girdle to the axial skeleton. Clinical and biomechanical studies demonstrate the importance of restoring and maintaining the normal length of this strut, and hence the attached muscle unit length, to optimize the functional recovery of the shoulder girdle following a clavicle fracture [14,16–20]. The clavicle also protects the vital neurovascular bundles coursing underneath it as well as the apex of the lung. The brachial plexus and the subclavian vessels traverse toward the axillae under the middle third of the clavicle,

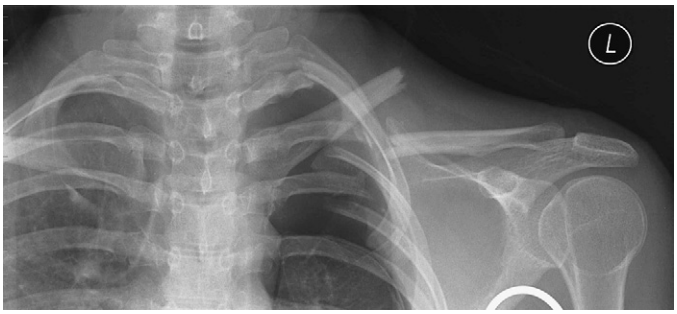

Fig. 2. Multiple rib fractures with associated pneumothorax in a patient who has a displaced mid-shaft clavicle fracture. Associated injuries are common with severely displaced clavicle fractures.

which forms the inferior border of the posterior triangle of the neck [13]. Medially, the carotid and jugular vessels are protected adjacent to the SC joint. Because of this intimate anatomic relationship between the clavicle and the neurovascular structures, a number of cases have been reported involving neurovascular compromise secondary to clavicle fractures [21–25].

The motion of the clavicle is interconnected intimately with the motion of the shoulder girdle through its articulation with the scapula. The SC joint serves as a stable medial pivot point on which the clavicle elevates and rotates, depending on the motion of the arm at the shoulder joint. Previous studies showed that, with the shoulder abduction and forward flexion, the clavicle can elevate as much as 15° to 30° and can rotate posteriorly 30° to 50° [26–29]. This close dynamic relationship between the clavicle and shoulder motion is well supported by clinical studies showing deficits in shoulder function after a clavicle malunion with shortening [14,20,26,28].

Mechanism of injury

Most clavicle fractures result from a fall or from a direct blow to the shoulder. This compressive force onto the clavicle is estimated to account for more than 85% of all clavicle fractures [5–8,29]. The middle third of the clavicle is the thinnest segment of the bone and is devoid of any protective muscular or ligamentous attachment, rendering it the weakest point of the bone; therefore clavicle fractures most commonly involve the middle third of the clavicle [2–8,29]. No studies to date have proposed any definite correlation between the mechanism of injury and the fracture location on the clavicle.

Much less common are fractures resulting from blunt or penetrating injuries directly to the clavicle. They can result from direct blows to the clavicle during sports activities, from seat belt injuries, or from ballistic injuries and are estimated to account for approximately 10% of clavicle fractures [5–8,29]. An even rarer mechanism of injury is a severe distraction injury around the shoulder girdle as seen in a scapulothoracic dissociation with distraction of the clavicle fracture site [30]. Because of the clavicle's close proximity to the neck and the chest, pathologic clavicle fractures from metastatic lung, breast, and neck cancers or previous irradiation and from primary neoplasms also have been reported without any history of trauma [31–33]. In addition, stress fractures involving the clavicle have been reported [34,35].

Classification

A number of classification systems have been devised based on the location and the complexity of the fractures involving the clavicle. These classification systems aim to facilitate description of the fracture patterns and communication among surgeons in both clinical and research settings [6,36–39].

The first widely used classification system for clavicle fractures was introduced by Allman in 1967 [36]. This scheme divided the clavicle into three equal segments: group I (fractures of the middle third of the clavicle), group II (fractures of the lateral third of the clavicle), and group III (fractures of the medial third of the clavicle). This classification is simple to use and is designated in the order of decreasing frequency of fractures but does not address fracture pattern.

In 1968, Neer [37] added three subtypes to address the fractures of the lateral third of the clavicle that seemed to behave quite differently from those involving more medial segments. Recognizing the importance of an intact CC ligament in maintaining fracture stability, he divided fractures of the lateral third of the clavicle into three subtypes: type I (intact CC ligament), type II (CC ligament torn off the medial fragment), and type III (intra-articular fractures involving the AC joint with intact CC ligament). Rockwood [38] later emphasized the significance of an intact conoid ligament by subdividing Neer type II injuries.

Craig [39] then merged and modified the Allman and Neer classification systems by further subdividing fractures of the medial and lateral thirds of the clavicle and including periosteal and epiphyseal injuries. The Craig classification describes five subtypes of fractures of the medial and lateral thirds of the clavicle: type I (undisplaced), type II (displaced), type III (intra-articular), type IV (epiphyseal separation), and type V (comminuted). Nordqvist and Petersson [5] further classified the most frequent fractures of the middle third of the clavicle (Allman group I) as undisplaced, displaced, or comminuted fractures.

The most recent classification scheme proposed by Robinson [6] in 1998 is based on 1000 consecutive clavicle fractures seen over 6 years in

Edinburgh, Scotland. In his series, Robinson redesignated the fracture types from the medial to lateral direction: type I (fractures of the medial third of the clavicle), type II (fractures of the middle third of the clavicle), and type III (fractures of the lateral third of the clavicle). Fracture patterns such as displacement, angulation, comminution and extension into the SC or AC joint were considered in the subgrouping of each type. Although complicated, this classification system revealed prognostic value based on the initial fracture patterns, and both inter- and intraobserver reliability were high among orthopedic trainees. The main limitation of these classification systems is their lack of clear prognostic and therapeutic value. Further studies are warranted to improve these deficiencies.

Clinical evaluation

Most patients have a history of a direct fall onto the shoulder [4–6,8,29]. Because of its subcutaneous nature, the initial diagnosis of a clavicle fracture usually is readily apparent. In the context of a high-energy trauma or in a multiply injured patient, however, identifying associated injuries is much more challenging and is of great importance. Multiple studies have shown associated rib, scapular, intrathoracic, and neurovascular injuries, particularly to subclavian vessels and brachial plexus, in high-energy clavicle fractures [3,9,21–25].

On physical examination, inspection of the injured clavicle often reveals a tender, bony protuberance under the skin, ecchymosis, and swelling at the fracture site. Prolonged skin tenting may lead to skin necrosis and a secondarily open fracture. The ipsilateral shoulder may demonstrate a typical droop or ptosis with associated scapular anterior rotation or winging and a shortened clavicle [14,20,26]. A sizable and/or expanding hematoma around the fracture site may indicate an injury to the subclavian vessels that necessitates an inspection for a local bruit, diminished or absent distal pulses, and asymmetrical blood pressure measurements in the arms. A thorough neurologic examination is mandatory.

Radiologic evaluation

For an isolated clavicle injury, routine radiograph starts with a full-length antero-posterior view of the clavicle, which includes the SC and AC joints as well as the shoulder girdle. A 45° cephalic tilt view of the clavicle helps delineate further the degree of displacement and comminution at the fracture site and profiles the clavicle superior to the thorax. Particularly in high-energy or polytraumatic injuries, a careful radiologic assessment of the shoulder girdle is essential to rule out any associated scapular or glenoid fractures [40]. In this scenario, a routine anteroposterior chest radiograph also is necessary to screen for associated rib fractures or intrathoracic injuries such as pneumothorax or hemothorax. An axillary view may become particularly useful in identifying subtle injuries to the lateral third of the clavicle. The serendipity view is a 40° cephalic tilt view coned over the SC joints that allows comparison of the bilateral SC joints to evaluate fractures and/or dislocations involving the medial third of the clavicle.

CT scanning is of little diagnostic value in an acute clavicle injury, except to rule out neurovascular and visceral injuries in the selected setting of an associated intra-articular glenoid fracture or a significantly displaced fracture-dislocation at the SC joint. It is more useful in evaluating the delayed union or non-union of a clavicle fracture. A CT angiogram or standard angiogram can be valuable in the setting of a distal vascular deficit following a clavicle fracture.

Management

The aim of clavicle fracture treatment is to reconstitute the clavicle as a rigid strut for the shoulder girdle to allow painless motion and strength around the shoulder while avoiding symptomatic non-union or malunion. Whenever possible, the least invasive means to accomplish this in each patient in a timely fashion should be the goal. In general, nonoperative treatment is preferred, and operative fixation for clavicle fracture have been reserved for open fractures, impending open fractures, associated neurovascular injuries, post-neurovascular repairs, floating shoulders, scapulothoracic dissociations, and fractures with polytrauma. Steady improvements in surgical technique and implant technology combined with the emergence of both objective and patient-based outcome studies with higher levels of evidence have challenged the notion that a good outcome can be obtained universally without operative management, however. The following sections present an evidence-based

review of the literature regarding management of clavicle fractures and floating shoulders.

Fractures of the medial third of the clavicle

The medial third is the least commonly injured segment of the clavicle; less than 3% of all clavicle fractures involved this segment [2–8]. More recently, over a 5-year period at their tertiary trauma center, Throckmorton and colleagues [41] found the incidence of injuries to the medial third of the clavicle to be as high as 9.3% of all clavicle fractures. The key findings in this retrospective review of 57 fractures of the medial third of the clavicle highlighted the unique clinical features associated with these injuries. The major cause of injuries to the medial third of the clavicle was high-energy trauma: 84% of the patients were involved in motor vehicle collisions, and 90% had multisystem trauma. These fractures are difficult to visualize on plain radiographs and are best delineated with a CT scan (Fig. 3). This trend is consistent with the findings in the series by Postacchini and colleagues [4]. Associated intrathoracic injuries such as pneumo/hemothorax and lung contusions, as well as head and neck injuries, were found frequently. Overall, 93% of the patients were treated nonoperatively.

A number of authors have advocated nonoperative treatment of fractures of the medial third of the clavicle [3,11,15,36,39,41–43]. Given the relative paucity of these injuries, the literature on this topic is dominated by retrospective reviews with small sample sizes and by case reports. Moreover, confounding factors such as severe neurovascular or visceral injuries in polytrauma scenarios complicate the analysis of overall clinical outcome with or without operative treatment. Nevertheless, with the current level of evidence, nonoperative treatment with a period of immobilization is standard for most injuries of the medial third of the clavicle.

Fig. 3. Medial fractures of the clavicle are difficult to see on plain radiographs. CT scanning is the preferred imaging study for these injuries.

In selected clinical settings, however, operative treatments have been described and recommended [44–49]. Particularly in pediatric and adolescent patients, retrosternal SC dislocations or medial epiphyseal separations threatening the neck or the mediastinal contents often have been treated operatively [45–47]. In case reports, bipolar clavicle fractures, rare segmental fractures involving both the medial and lateral thirds of the clavicle, also have been deemed quite unstable and have been treated operatively with plates or screw fixation [48,49].

Fractures of the middle third of the clavicle

Fractures of the middle third of the clavicle are the most common type of clavicle fracture. The traditional view of nonoperative treatment of this type of fracture, irrespective of fracture characteristics or patient demographics, has been influenced principally by Neer's [50] series in 1960. In his review of 2235 patients who had nonoperatively treated fractures of the middle third of the clavicle, the non-union rate was 0.13%, compared with 4.6% in 45 patients treated operatively. A smaller review by Rowe [3] validated the notion, with non-union rates of 0.8% in patients treated nonoperatively and 3.7% in patients who received operative treatment. Given these findings, nonoperative treatment was recommended.

More than 200 different methods of immobilization, bracing, or sling treatments have been devised for the nonoperative treatment of displaced fractures of the clavicle. The number of treatments attests to the extreme difficulty of achieving and maintaining reduction [2,51]. Much of the effort spent in developing different ways of immobilizing the injured clavicle has been made against the near impossibility of maintaining the reduction and the impracticality of patient compliance [13,52–54]. As expected, no single superior method of immobilization has been found in any series [13,53–55]. A randomized study comparing a figure-of-eight brace versus a sling conducted by Andersen and colleagues [55] showed that there were no statistically

significant functional or radiographic differences between the two groups. The brace was ineffective in restoring the bony alignment, and patients experienced difficulty tolerating the brace, clearly favoring the sling treatment. Moreover, there is no consensus on the optimal duration of immobilization or on the rehabilitation protocol for these injuries. Recommended periods of immobilization vary from 2 to 6 weeks, individualized to the patient's comfort level [13,53–56]. In addition, most authors recommend avoiding contact sports or heavy lifting for 4 to 6 months from the initial injury. Although good clinical outcomes can be achieved following nonoperative treatment, even after significant radiographic malunion, the rate of unsatisfactory outcomes increases with increasing fracture displacement [2,3,50,54,55,57]. The basic treatment protocol of immobilization as tolerated for 2 to 6 weeks followed by an individualized shoulder rehabilitation program as needed is an effective treatment modality for non- or minimally displaced fractures of the middle third of the clavicle.

A number of modern studies reporting a significant number of dissatisfied patients have emerged [7,53,58–61], challenging three facets of conventional wisdom concerning clavicle fractures: that the non-union rate is less than 1% with nonoperative treatment, that malunions cause functional deficit, and that operative treatment offers lower rates of non-union, symptomatic malunion and greater functional improvement in selected patients. Hill and colleagues [53] were one of the first groups to report a much higher-than-expected non-union rate following nonoperative treatment of fractures of the middle third of the clavicle. They reviewed 52 displaced clavicle fractures and found a non-union rate of 15% and a patient dissatisfaction rate of 31%, whereas in the older studies had lower rates of non-union [3,50]. Additionally, the study found that clavicle shortening of more than 2 cm was associated with lower patient satisfaction. Wick and colleagues [57], reviewing 33 delayed unions in fractures of the middle third of the clavicle, also found that more than 90% of them had more than 2 cm of shortening. A large, prospective observational study by Robinson and colleagues [7] analyzing 581 consecutive fractures of the middle third of the clavicle found an overall non-union rate of 4.5% at 6 months; the rate escalated to more than 20% in the subgroup that had displaced and comminuted fractures. The study also identified independent risk factors for non-union, which included 100% displacement, fracture comminution, advanced age, and female gender. In their prospective study, Nowak and colleagues [58] also reported a non-union rate of 7% and similar risk factors for non-union. A recent systematic review of 2144 clavicle fractures validated these findings with a non-union rate of 15.1% in nonoperatively treated displaced fractures of the middle third of the clavicle [59]. Clearly, the rate of non-union with nonoperative treatment is not as low as previously estimated. Demographic differences between the older and the contemporary studies may play a significant role in the observed increase in non-union rates. As mentioned earlier, an increasing proportion of clavicle injuries reported in contemporary studies are caused by high-energy trauma or polytrauma [4–7,9,57,58]. These injuries are more likely to produce fracture patterns of increasing comminution and displacement, which are reported risk factors for non-union and poor outcomes [7,53,57–59].

As previously discussed, nonoperative treatment is quite ineffective in obtaining and maintaining an anatomic reduction of displaced clavicle fractures, so that radiographic malunion is ubiquitous. Clinical features such as shoulder weakness and easy fatigability with ptosis and/or scapular winging and thoracic outlet syndrome have been noted in the past [14,17,18,60,61]. This presentation is secondary to the typical displacement of the lateral (distal) fragment with inferior and medial translation and anterior rotation [14]. More recent studies estimated symptomatic malunion rates to be as high as 18% to 35% in nonoperatively treated patients [52,58,61]. An association between significant shortening ($>$ 15–20 mm) of the clavicle and symptomatic malunion also has been reported in other studies [20,53,56,61]. In many established cases, restoration of the clavicle length by a corrective osteotomy improved patient-based outcome scores after symptomatic malunion [14,16–18]. To date, however, only two studies have showed statistically and clinically significant deficits in shoulder strength from clavicle shortening greater than 15 mm [20,62].

The non-union rate associated with operative treatment had been based on two widely cited older studies by Neer [50] and Rowe [3] (Fig. 4). Numerous recent retrospective series of operative fixation for acute fractures of the middle third of the clavicle reported pooled non-union rates well below 5%, however [63–73]. A recent systematic

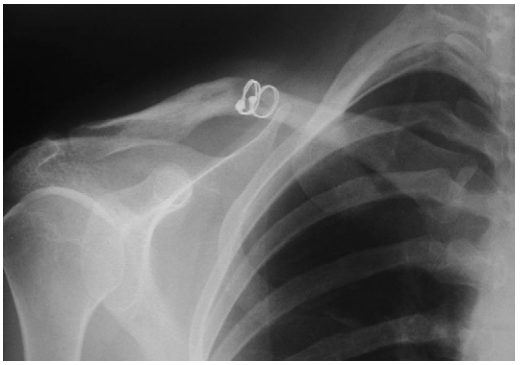

Fig. 4. In the past, operative treatment of clavicle fractures was plagued by inadequate fixation with high rates of delayed and non-union. Cerclage wiring alone is inherently unstable in the treatment of these injuries.

review of 460 displaced fractures of the middle third of the clavicle treated by plating had an overall non-union rate of 2.2% compared with a non-union rate of 15.1% in 159 similar fractures treated nonoperatively [59]. Similarly, a recent multicenter, randomized clinical trial by the Canadian Orthopaedic Trauma Society [52] comparing plate fixation versus sling treatment of displaced fractures of the middle third of the clavicle showed a significantly lower rate of non-union and symptomatic malunion in the surgical group. The trial also revealed that both surgeon-based and patient-based scores were significantly improved at all points of follow-up in the operated group. Improved surgical technique and implant designs and the judicious use of prophylactic antibiotics have contributed to improved overall surgical outcomes.

Primarily, two widely accepted methods of fixation—plate fixation or intramedullary pinning—are used in the operative treatment of fractures of the middle third of the clavicle. Any decision to treat fractures of the middle third of the clavicle operatively rather than nonoperatively must prompt a careful consideration of the advantages and the disadvantages of the treatment options. After carefully considering the risk factors for non-union and symptomatic malunion likely to cause functional impairments in an appropriate surgical candidate, one must take into consideration the possible complications inherent in operative treatment. These complications include deep or superficial wound infection, hardware-related irritation, hardware failure or migration, and poor cosmesis of a surgical scar. The data reported in more recent clinical series show a universal decline in the rate of these complications, probably resulting from improved surgical technique and implant technology [63–74]. The timing of the chosen surgical intervention also may be an issue, because a recent retrospective study by Potter and colleagues [75] demonstrated a subtle decline in shoulder endurance strength and outcome measures with delayed plate fixation of clavicle malunion or non-union when compared with early fixation.

For plate fixation, dynamic compression plates, pelvic reconstruction plates, and anatomic precontoured plates have been used [12,63–69]. Although their low profile may lead to less skin irritation, semitubular plates and mini-plates were found to be mechanically too weak for rigid fixation and are not recommended [63,76,77]. Rigid plate fixation allows compression across the main fracture line combined with the use of interfragmentary compression screws as necessary. Plate fixation has superior biomechanical strength that offers excellent rotational and length control and allows early weight bearing on the limb. The main disadvantages are the long skin incision and tissue dissection around the fracture, the hardware prominence which may require plate removal, and possible refracture after the plate removal. As experience with precontoured "anatomic" plates and surgical technique increases, minimally invasive soft tissue handling can result in dramatic decreases in incision size. At present, there is no well-designed prospective study directly comparing clinical outcomes with different plate types. Intramedullary fixation with various devices including Kirschner wires, pins, rods, and screws also has been used widely [70–74]. Intramedullary fixation offers the advantages of being a soft tissue friendly and a minimally invasive or percutaneous procedure with the potential for improved cosmesis. The main disadvantages of this method of fixation (common to all "unlocked" intramedullary devices) are its inferior axial and rotational stability in nontransverse and comminuted fractures. Also, there have been reports of catastrophic migration of these implants—specifically smooth pins—elsewhere in the body [78–80]. Again, no comparative studies evaluating different types of intramedullary devices or of plates versus intramedullary fixation are available. Clearly, these voids in higher-level evidence regarding the operative treatment of fractures of the middle third of the clavicle need to be filled through future studies.

Operative technique

Currently, the senior author's preferred operative treatment for displaced fractures of the middle third of the clavicle is rigid fixation using anatomically precontoured 3.5-mm dynamic compression plates combined with interfragmentary compression screws as needed (Figs. 5 and 6). Operative treatment is recommended for patients who have traditional indications (eg, open fractures, neurovascular compromise) and for young, active individuals who have completely displaced fractures, obvious deformity, and shortening of 1.5 to 2.0 cm or greater displacement. A detailed surgical technique has been published recently and is similar to that used for fractures of the lateral third of the clavicle [81]. The plate usually is placed on the superior aspect of the clavicle, because this placement has been shown to be the most advantageous biomechanically. As familiarity with the technique improves, smaller skin incisions, extensive mobilization of subcutaneous tissue, and other minimally invasive techniques can be used to decrease soft tissue stripping and dissection. Whenever possible, branches of the supraclavicular nerves are identified, mobilized, and protected. A minimum of three bicortical screws are used distal and proximal to the fracture; a lag screw is placed whenever possible. Smaller fracture fragments (including a fairly consistent vertically oriented anterior cortical fragment) are "teased" into position without stripping all their soft tissue. They can be fixed with small or mini-fragment screws or sutured into place. Because this procedure typically is reserved for young, active patients, bone quality rarely is an issue, and the authors have not found locking plates to be required or useful in this setting. It is important to perform a two-layer closure of the soft tissue to maximize local resistance to infection and to minimize the potential for hardware irritation. The myofascial layer is sutured with #1 absorbable suture, followed by #2-0 subcutaneous sutures and clips for the skin. The patient wears a simple sling for comfort and can begin range-of-motion exercises immediately. The use of the sling is discontinued at 10 to 14 days, and strengthening exercises are initiated at 6 weeks. Full-contact activities usually are restricted for 12 weeks, but patient compliance with this restriction is highly variable.

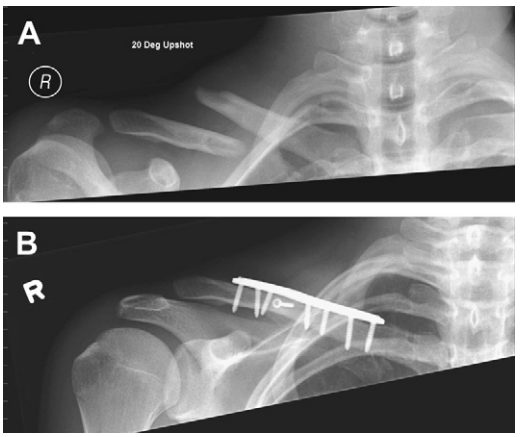

Fig. 5. (*A*) A displaced mid-shaft clavicle fracture with significant shortening. This degree of shortening is an indication for primary operative fixation in a healthy, young, active individual. (*B*) After fixation with an anatomic clavicle plate, solid bony union in an anatomic position was achieved, with rapid restoration of normal shoulder function.

Fractures of the lateral third of the clavicle

Most fractures of the lateral third of the clavicle (especially fractures that are non- or minimally displaced) can be treated successfully with a period of immobilization. A certain proportion of the fractures involving the lateral third of the clavicle are significantly displaced, however, and are at high risk for delayed or non-union. In Neer's [50] original series of clavicle fractures, he observed the unusually high rate of non-union in displaced fractures of the lateral third of the clavicle. The fractures he later classified as type II, in which the fracture occurs medial to the CC ligaments and hence is detached from the displaced medial fragment, had a particularly high rate of delayed union or non-union [37]. In type II fractures, which are much less common than the undisplaced type I injury, he recommended operative stabilization. Later series reported similar rates of non-union ranging from 22% to 33%, and several authors recommended operative treatment of displaced fractures of the lateral third of the clavicle [82–88]. Three contemporary studies have reported estimated non-union rates ranging from 22% to 37% for these injuries treated nonoperatively, validating the findings of previous studies [7,89,90]. Interestingly, two of these studies also found that a large proportion of the non-united fractures were asymptomatic, usually in elderly, sedentary individuals [89,90]. The

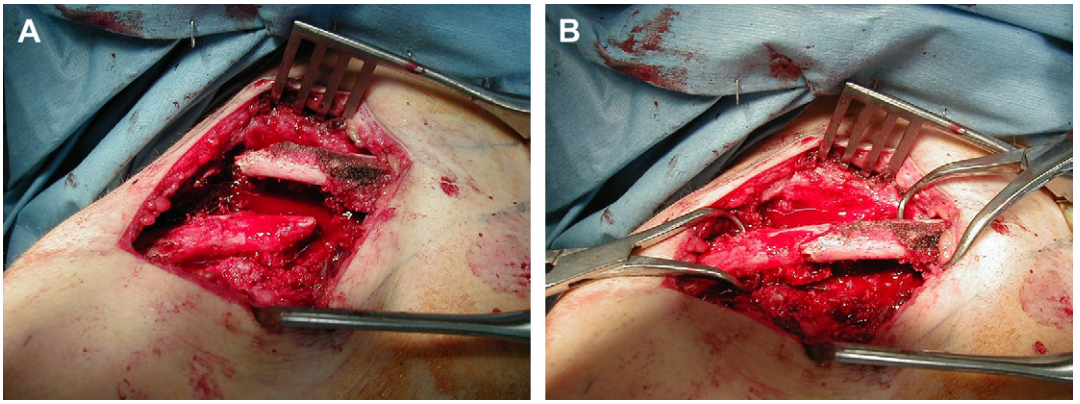

Fig. 6. (*A*) Intraoperatively, the fracture site is exposed and debrided. (*B*) Reduction is performed with the aid of reduction forceps or towel clips. Typically, little force is required for reduction, and it rarely is necessary to free drape the arm.

long-term (mean, 15 years) follow-up study by Nordqvist and colleagues [89] reviewing 110 fractures of the lateral third of the clavicle treated nonoperatively showed that eight of the their non-union cases had no significant deficits based on patient-based outcome measures. In Robinson's [90] series of 101 patients who had nonoperatively treated fractures of the lateral third of the clavicle, there were no statistically significant differences in Constant and Short Form-36 scores between those with and without non-union or between those with and without delayed operative fixation. Twenty-one of the 32 cases of non-union (66%) also were deemed by the patients to be asymptomatic enough to avoid delayed surgical treatment at an average follow-up of 6.2 years. Still to be determined through prospective prognostic studies are possible radiologic and/or clinical risk factors for symptomatic non-union to help guide timely, active treatment.

There are no prospective studies comparing operative versus nonoperative treatment for fractures of the lateral third of the clavicle. In terms of methods of fixation, the orthopedic literature is dominated by small case series based on an array of different technical variations using wires, screws, pins, and plates [37,83,84,86,87,91–100]. These methods include open and arthroscopic combinations of transacromial stabilization using Kirschner wires, tension banding, transacromial screws or pins, plates, CC screw fixation, CC ligament reconstruction or repair, and subcoracoid "slings." Only one study directly compared two different methods of operative fixation: Flinkkila and colleagues [93] retrospectively compared Kirschner wire fixation versus hook plating and showed the use of the transacromial wire to be fraught with complications such as infections, wire breakage, and wire migration. These complications previously had been reported [101]. Interest in the use of the hook plate (with a smooth, subacromial extension of the plate to maintain position of the distal clavicular fragment) to treat these injuries has increased recently because the plate's stable anatomic and biomechanical properties allow early shoulder mobilization and weight bearing. The high incidence of subacromial impingement and shoulder stiffness often necessitates removal of the plate, however [91–93]. Resection of the distal clavicle has little role in the setting of an acute fracture; however, intra-articular fractures (Neer type III) involving the AC joint eventually may cause a posttraumatic arthritis of the joint that is amenable to such intervention [102].

In summary, most fractures of the lateral third of the clavicle should be treated nonoperatively. Even though non-union does occur frequently with displaced (Neer type II) fractures of the lateral third of the clavicle, recent clinical studies suggest that many non-unions in elderly, sedentary individuals are asymptomatic. Given the current paucity of high-level therapeutic evidence regarding these injuries, operative treatment should be individualized and reserved for young, active patients (especially those engaged in throwing or overhead activity) who have completely displaced fractures of the distal clavicle. Further prospective studies are needed to optimize the approach and treatment modalities for managing fractures of the lateral third of the clavicle.

Operative technique

Currently, the senior author's treatment of choice for displaced fractures of the lateral third of the clavicle is to employ rigid fixation using either anatomically precontoured distal clavicular plates or hook plates.

The patient is placed in the beach-chair position with the head secured on a headrest. The shoulder is prepped and draped to include the SC joint; the authors do not free drape the arm routinely. The AC joint and the fracture site are palpated to determine the center of the skin incision. An oblique skin incision is made over the fracture on the superior border of the clavicle and is extended across the AC joint. A single, thick layer of subcutaneous tissue flap is raised, exposing the underlying myofascial layer. This layer then is divided sharply down to the clavicle and is elevated off the bone as a single layer to cover the plate later. The fracture site then is exposed and inspected. After the fracture hematoma and interposed soft tissue are debrided, bone-holding forceps are used for anatomic reduction of the fracture. If a low-profile "anatomic" plate is used for fixation, the plate first can be fixed provisionally to the medial-clavicle fragment to aid in reduction. Anatomic distal clavicle plates offer extra holes for screws in the cancellous bone of the distal clavicle to enhance distal fixation (Fig. 7). It rarely is necessary to cross the AC joint for fixation: if required, unicortical screws can be used to avoid impinging on the subacromial space. If a hook plate is used, a cautery is used to create an opening posterior to the AC joint to pass the hook underneath the acromion before setting the plate down onto the reduced clavicle. One must be careful not to cauterize deep into the subacromial space, because doing so may damage the rotator cuff muscles and cause excessive bleeding from the subacromial bursa. Screws are inserted into the plate, taking care not to violate the subclavicular space. In selected cases, with a very small distal fragment, hook plate fixation can be supplemented with the modified Weaver-Dunn procedure. This procedure involves mobilization of a wafer of bone along with the coracoacromial ligament from the acromion. The bony wafer is attached into or onto the distal end of the clavicle with a nonabsorbable suture (Fig. 8).

Once the internal fixation is complete, the wound is irrigated thoroughly and is closed in two layers. Closure of the deeper myofascial layer is very important to cover the plate and minimize problems with prominent hardware later. The incision then is infiltrated with 0.5% bupivacaine solution for postoperative pain control, and the arm is placed into a sling.

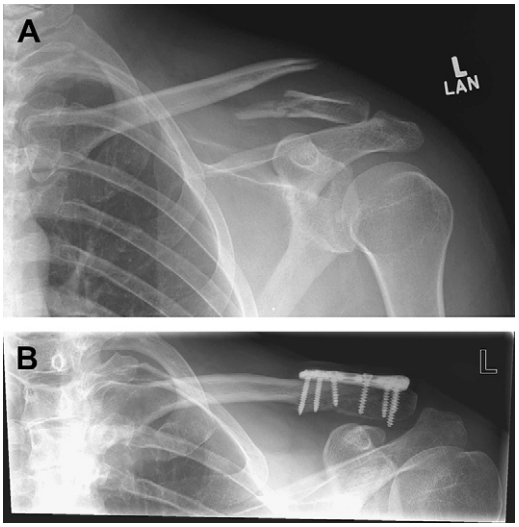

Fig. 7. (*A*) A displaced fracture of the lateral third of the clavicle after a cycling accident in a young, active individual. (*B*) Plate fixation resulted in rapid union in an anatomic position.

Postoperatively, the arm stays in the sling on a full-time basis for 2 weeks followed by active assistive range-of-motion exercises in the scapular plane of motion. Full active range-of-motion exercises are begun at 4 weeks followed by strengthening of the shoulder girdle at 6 to 8 weeks. Return to sports can be considered 3 months after surgery.

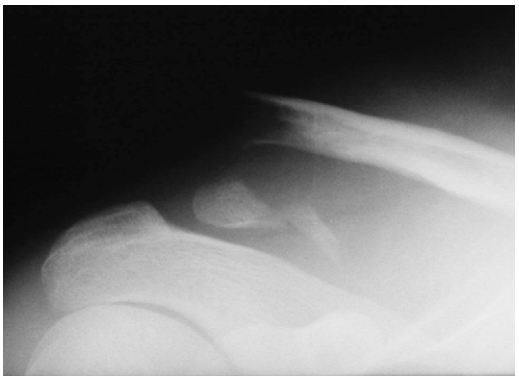

Fig. 8. A very distal fracture with little potential purchase in the distal fragment is a relative indication to augment fixation with a hook plate or coracoclavicular screw if operative intervention is chosen.

Floating shoulder

Floating shoulder is a rare injury pattern consisting of ipsilateral clavicle and glenoid neck fractures. This injury initially was considered inherently unstable, because the glenoid loses both osseous and ligamentous contact with the scapula and the clavicle. The perceived concern was that the weight of the arm and the pull of the muscles around the shoulder girdle continue to displace the glenohumeral joint inferiorly as well as anteromedially. In a cadaver study, Williams and colleagues [103] performed sequential osseous and ligamentous sectioning around the AC joint and found that fractures of the clavicle and the scapula must be accompanied by ligament disruptions to result in a floating shoulder.

Given the combined injuries to the stabilizers of the shoulder suspensory complex, early reports recommended operative management to restore stability to the shoulder girdle [104,105]. The authors reported good to excellent outcomes in most patients who had operative fixation of the clavicle and/or the glenoid. Edwards and colleagues [106] reported a retrospective review of 20 patients treated nonoperatively for floating shoulders. Nineteen of the 20 patients reported good to excellent results, especially when fracture displacement was less than 5 mm. Further studies retrospectively comparing operative and nonoperative treatment groups showed no significant differences between the two groups in radiologic or functional outcome measures [107–109]. The authors' general consensus was that operative fixation could be considered for significantly displaced fractures but that an individualized approach to treatment was more important.

To date, all the studies regarding treatment of floating shoulders are retrospective reviews limited by small patient numbers and surgeons' bias. Because of the rarity of this injury pattern, it will be challenging to generate enough number of cases to compare therapy modalities in a prospective manner. For now, the authors recommend the moderate approach of treating each injury individually and managing operatively any symptomatic or grossly unstable injury patterns based on radiographs and clinical examinations.

Summary

Clavicle fractures are one of the most common upper extremity injuries encountered in orthopedic practice. In most cases, rare fractures involving the medial third of the clavicle are treated adequately with a period of immobilization, particularly in an isolated setting. Given the incidence of associated injuries, a careful diagnostic evaluation is important. There is increasing evidence supporting primary operative fixation of completely displaced mid-shaft fractures of the clavicle, especially in young, active patients who have visible deformity or shortening of 1.5 to 2.0 cm or more. Although a number of fixation methods are available, none has been proven to be definitively superior to the others. At present, an anatomic, precontoured compression plate placed on the superior aspect of the bone through a minimally invasive approach is the authors' preferred operative treatment. Completely displaced fractures of the lateral third of the clavicle respond well to nonoperative treatment but have a high rate of delayed and non-union. This failure to achieve union may produce minimal symptomatology in older, sedentary individuals; primary operative repair should be considered in younger individuals, especially those who perform overhead activities regularly. A floating shoulder is a rare clinical entity that has been treated both operatively and nonoperatively with good clinical outcomes in the past. Therapy recommendations cannot be made with the current level of evidence, and thus treatment must be individualized, usually based on the degree of displacement: greater deformity and a higher activity levels are indications for more aggressive primary treatment. Further well-designed prospective and randomized, controlled trials are needed to provide further insights into the evolving management of this common orthopedic injury.

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