INTRODUCTION TO CLAVICLE FRACTURES

Clavicle fractures are common injuries in young, active individuals, especially those who participate in activities or sports where high-speed falls (bicycling, motorcycles) or violent collisions (football, hockey) are frequent, and they account for approximately 2.6% of all fractures.29–32,46,112,116,122,123,126 In contrast to most fractures, Robinson 155 reported in an epidemiologic study that the annual incidence in males was highest in the under 20 age group, decreasing with each subsequent age cohort (Fig. 38-1). The incidence in females was more constant, with peaks seen in the teenager (sports, motor vehicle accidents) and the elderly (osteoporotic fractures from simple falls). The annual incidence of fractures in their Scottish population was 29 per 100,000 persons per year.155

The majority of clavicular fractures (80% to 85%) occur in the midshaft of the bone, where the typical compressive forces applied to the shoulder and the narrow cross section of the bone combine and result in bony failure.7–16,18–24,26–32,107,155,179 Distal third fractures are the next most common type (15% to 20%), and, although they can result from the same mechanisms of injury as that seen with midshaft fractures, they tend to occur in more elderly individuals from simple falls.56,153,156,157,193 Medial third fractures are the rarest (0% to 5%), perhaps due to the difficulty in accurately imaging (and identifying) them.187,189 One recent study of 57 such fractures reported that patients were typically men in their fifth decade and the usual mechanism of injury was from a motor vehicle accident.185 These authors also noted a relatively high (20%) associated mortality from concomitant head and chest injuries.
Older studies suggested that a fracture of the shaft of the clavicle, even when significantly displaced, was an essentially benign injury with an inherently good prognosis when treated nonoperatively. In a landmark 1960 study Neer reported nonunion in only three of 2,235 patients with middle third fractures of the clavicle treated by a sling or a figure-of-eight bandage. Rowe showed an overall incidence of nonunion of 0.8% in 566 clavicle fractures treated in a similar fashion. Thus, what was felt to be the most serious complication following clavicular fracture, nonunion, appeared to be extremely rare. Also, malunion of the clavicle (which occurred radiographically on a predictable basis in displaced fractures), was described as being of radiographic interest only, with little or no functional consequences. This thinking dominated the approach to clavicle fractures for decades.

More recently, there has been increasing evidence that the outcome of the nonoperatively treated (especially displaced or shortened) midshaft fracture is not as optimal as was once thought. Hill et al. were the first to use patient-oriented outcome measures to examine 66 consecutive patients with displaced midshaft clavicle fractures and they found an unsatisfactory outcome in 31%, as well as a nonunion rate of 15%. In a meta-analysis of the literature from 1975 to 2005, Zlowodzki et al. found that the nonunion rate for nonoperatively treated displaced midshaft clavicle fractures was 15.1%, exponentially higher than that previously described (Table 38-1). Other recent epidemiologic and prospective studies have supported these findings. In addition, the malunion of the clavicle has been clearly shown by multiple authors to be a distinct clinical entity with characteristic signs and symptoms that can be significantly improved by corrective osteotomy. Potential explanations for the increased complication rate seen following the nonoperative care of these fractures may be due to changing injury patterns (especially from “extreme” sports such as mountain bicycling, snowboarding, and all-terrain vehicle riding), increased expectations of the modern patient, comprehensive follow-up (including patient-oriented outcome measures) and focusing on adults (eliminating children with their inherently good prognosis and remodeling potential).

Good results with a high union rate and a low complication rate have been reported from a variety of techniques for primary fixation of displaced fractures of the clavicle, dispelling some of the pessimism that surrounded prior studies where a poor understanding of soft tissue handling, a selection bias of patients, and inadequate implants combined to produce inferior results. Zlowodzki’s systematic analysis of the current literature on clavicle fractures has helped to clarify the indications for operative treatment and has provided guidelines for the safe and effective use of various fixation techniques.

### Table 38-1

<table>
<thead>
<tr>
<th>Treatment Method</th>
<th>Percentage with Nonunion</th>
<th>Infections (Total)</th>
<th>Infections (Deep)</th>
<th>Fixation Failures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonoperative (n = 159)</td>
<td>15.1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Plating (n = 460)</td>
<td>2.2</td>
<td>4.6</td>
<td>2.4</td>
<td>2.2</td>
</tr>
<tr>
<td>Intramedullary pinning (n = 152)</td>
<td>2.0</td>
<td>6.6</td>
<td>0</td>
<td>3.9</td>
</tr>
</tbody>
</table>

review showed a relative risk reduction of 86% (from 15.1% to 2.2%) for nonunion with primary plate fixation compared to nonoperative treatment. In addition, a recent meta-analysis by McKee et al. of six randomized clinical trials of operative versus nonoperative care for displaced midshaft clavicle fractures demonstrated a reduction of nonunion and symptomatic malunion from 46/200 cases (23%) in the nonoperative group to 3/212 cases (1.4%) in the operative group (Fig. 38-2). 105

While there is increasing interest in, and enthusiasm for, primary fixation of clavicle fractures, it is vital to remember that the majority of these fractures can and should be treated nonoperatively. The current research in this area should not provoke a swing of the operative pendulum into indiscriminate fixation of all clavicle injuries. Clinical and basic science research in this field adds objective information to this topic and is directed at prompting a thoughtful assessment of each injury based on these data and each case’s individual merits such as the function and expectations of the patient, the location of the fracture, and the degree of displacement or comminution. Treatment is then based upon this assessment, the evidence-based facts now available, and a rational balance of the potential risks and benefits of surgery, rather than an extreme operative or nonoperative approach.

**Assessment of Clavicle Fractures**

**Mechanisms of Injury for Clavicle Fractures**

A direct blow on the point of the shoulder is the commonest reported mechanism of injury that produces a midshaft fracture of the clavicle. 15,107,155,179 This can occur in a number of ways, including being thrown from a vehicle or bicycle, during a sports event, from the intrusion of objects or vehicle structure during a motor vehicle accident, or falling from a height (Fig. 38-3). A recent prospective trial of over 130 completely displaced midshaft fractures of the clavicle identified motor vehicle/motorcycle accidents, bicycling accidents, skiing/snowboarding accidents, and other mechanisms as the most common causes of injury. 105

**FIGURE 38-2** A forest plot comparing the nonunion rate between nonoperative (control) and operative (experimental) groups from multiple randomized trials of clavicle fracture fixation for displaced midshaft fractures. Operative intervention results in a significantly decreased nonunion rate compared to nonoperative treatment ($p = 0.002$). The size of the squares is proportionate to the size of the study, and the diamond is the pooled data. (Adapted from: McKee RC, Whelan DB, Schimitsch EH, et al. Operative versus nonoperative care of displaced midshaft clavicular fractures: A meta-analysis of randomized clinical trials. *J Bone Joint Surg Am.* 2012;94(8):675–684, with permission.)

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>Operative Events</th>
<th>Nonoperative Events</th>
<th>Risk Ratio IV, Random, 95% CI</th>
<th>Risk Ratio IV, Random, 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Total</td>
<td>Weight</td>
<td></td>
</tr>
<tr>
<td>COTS 2007</td>
<td>2</td>
<td>16</td>
<td>49</td>
<td>0.10 [0.02, 0.41]</td>
</tr>
<tr>
<td>Judd 2009</td>
<td>1</td>
<td>28</td>
<td>1</td>
<td>0.09 [0.01, 1.57]</td>
</tr>
<tr>
<td>Smekal 2009</td>
<td>0</td>
<td>5</td>
<td>30</td>
<td>0.06 [0.00, 0.93]</td>
</tr>
<tr>
<td>Smith 2000</td>
<td>0</td>
<td>16</td>
<td>35</td>
<td>0.06 [0.00, 0.93]</td>
</tr>
<tr>
<td>Virtanen 2010</td>
<td>0</td>
<td>8</td>
<td>25</td>
<td>0.06 [0.00, 0.93]</td>
</tr>
<tr>
<td>Witzel 2007</td>
<td>0</td>
<td>3</td>
<td>33</td>
<td>0.06 [0.00, 0.93]</td>
</tr>
<tr>
<td><strong>Total (95% CI)</strong></td>
<td>212</td>
<td>200</td>
<td>100.0%</td>
<td>0.11 [0.04, 0.29]</td>
</tr>
<tr>
<td><strong>Total events</strong></td>
<td>3</td>
<td>46</td>
<td>49.0%</td>
<td>13.4% 24.0%</td>
</tr>
</tbody>
</table>

Heterogeneity: $\text{Tau}^2 = 0.00$; $\text{Chi}^2 = 3.35$, df = 4 ($p = 0.50$); $I^2 = 0$

Test for overall effect: $Z = 4.38$ ($p < 0.0001$)

**FIGURE 38-3** A: Mechanism of injury. Clavicle fractures are usually produced by a fall directly on the involved shoulder. B: Corresponding clinical photograph demonstrating posterior skin abrasion following displaced midshaft clavicle fracture.
falls or collisions, sports injuries, and falls as the most commonly involved mechanisms.\textsuperscript{15} As the shoulder girdle is subjected to compression force directed from laterally, the main strut maintaining position is the clavicle and its articulations (Fig. 38-4). As the force exceeds the capacity of this structure to withstand it, failure can occur in one of the three ways. The acromioclavicular (AC) articulation may fail, the clavicle may break, or the sternoclavicular (SC) joint may dislocate. SC injuries are rare and typically associated with more posteriorly directed blows against the medial clavicle (posterior dislocations) or posteriorly directed blows to the distal shoulder girdle (levering the proximal clavicle into an anterior dislocation).\textsuperscript{90,177} Presumably there are subtle nuances in the direction and magnitude of applied forces and local anatomy that dictate whether the failure occurs in the AC joint, or in the clavicle, and the magnitude of displacement that occurs. Most (85\%) clavicle fractures occur in the midshaft of the bone where, as can be seen in a cross section, the bone is narrowest and enveloping soft tissue structures (which may help dissipate injury force) are most scarce.\textsuperscript{29-32,153,155} It is typical to see a large abrasion or contusion on the posterior aspect of the shoulder in patients with displaced midshaft clavicular fractures, especially those who fall from bicycles, motorcycles, or other vehicles. This force vector may also contribute to the location of the injury: Midshaft fracture, distal fracture, or AC joint injury. The direction of the initial deforming force, and both gravitational and muscular forces on the clavicle are significant and result in the typical deformity seen after fracture, with the distal fragment being translated inferiorly, anteriorly, and medi-ally (shortened), and rotated anteriorly (Fig. 38-5). With recent advances in imaging techniques, there is an increasing level of information available regarding the complex three-dimensional deformity that can result from a displaced midshaft fracture of the clavicle (Fig. 38-6).\textsuperscript{152}

Simple falls from a standing height are unlikely to produce a displaced fracture in a healthy young person, but can result in injury in elderly, osteoporotic individuals: These fractures are typically seen in the distal third of the clavicle. If the mechanism of injury is trivial and does not seem commensurate with the fracture depicted, then a careful investigation for a pathologic fracture should be performed (Fig. 38-7).\textsuperscript{32,176}

**FIGURE 38-5** Muscular and gravitational forces acting on the fractured clavicle with resultant deformity. The distal fragment is translated anteriorly, medially, and inferiorly, and rotated anteriorly. This results in the scapula being protracted.
diagnostic techniques (i.e., CT scanning), the greater speed and violence of many modern sports (such as motocross and snowboarding) and the improved survivorship of patients with significant chest trauma who would have succumbed prior to the institution of comprehensive treatment of the trauma patient. In fact, several studies from Level 1 trauma centers have examined the characteristics of polytrauma patients with clavicle fractures, and have noted a high mortality rate (20% to 34%) from associated chest and head traumas. Presumably these series of critically injured patients contain survivors who live to require treatment for the complications of their clavicle fractures who may not have survived without modern trauma care.

Patients who have sustained high-energy vehicular trauma are more likely to have associated injuries to the thoracic cage, including ipsilateral rib fractures, scapular and/or glenoid fractures, proximal humeral fractures, and hemo/pneumothoraces (Fig. 38-8). In addition to simply being good medicine, identification of these injuries is important for multiple reasons. Patients may require urgent treatment directed specifically at the associated injury (i.e., tube thoracostomy for pneumothorax), their presence may influence the treatment of the clavicle fracture (i.e., an associated displaced glenoid neck fracture, the so-called “floating shoulder,” see below), or (as objective information on this entity increases) they may give an indication of the likelihood of a negative outcome for the clavicle fracture.

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**FIGURE 38-6** A: Preoperative three-dimensional CT scan of a patient with a displaced clavicle fracture and ipsilateral flail chest. This injury pattern represents a severe injury with significant instability of the entire forequarter. B: Following plate fixation of both the clavicle and multiple ipsilateral ribs, the flail segment became stable.

**FIGURE 38-7** A 45-year-old previously well woman presented to the fracture clinic with shoulder pain following an episode of minor trauma. Radiographs revealed a fracture through a lytic lesion of the clavicle. This was the presentation of what subsequent investigation revealed to be a widely disseminated metastatic adenocarcinoma of unknown source.
(malunion, nonunion) that may have implications regarding primary fixation (Fig. 38-9). There is also some evidence that multiple ipsilateral rib fractures are significant for a number of reasons: The degree of disruptive energy imparted to, and the resultant deformity and instability of, the chest and shoulder girdle may be associated with higher rates of poor outcome in the associated clavicle fracture. In addition, there is increasing interest in the primary fixation of mechanically unstable chest wall segments (or “flail chest”) as a means of improving the respiratory outcome and ventilatory care of such patients (Fig. 38-6).62,183

The clavicle can also be injured from penetrating trauma including projectiles, blasts, and sword or machete blows (Fig. 38-10). In this situation, diagnosing and treating underlying chest and/or vascular injuries is critically important, and the clavicle can be treated on its own merits.30,32,36,69,78,111,148,187 However, if a vascular repair has been performed, clavicular fixation (if possible) provides an optimally stable environment for healing.

**Signs and Symptoms of Clavicle Fractures**

**History**

The history should delineate a number of aspects to optimize the patient’s care. In addition to the standard demographic data, the details of the mechanism of injury are important. A clavicle fracture caused by a simple low-energy fall is unlikely to be associated with other fractures or intrathoracic injuries, while a fracture that occurs as a result of severe vehicular trauma or a fall from a height should prompt a search for other injuries. In my experience, clavicle fractures that result from falls while bicycling often have multiple ipsilateral upper rib fractures. At a Level 1 trauma center, we studied 105 polytrauma patients (multiple system injury and injury severity score greater than 16) with fractures of the clavicular shaft and found a mortality rate of 32%, mainly due to associated head and chest injuries.101 This high incidence of associated head/chest injuries mandates careful clinical and radiographic investigation. The physical mechanism of injury is important: While the majority of fractures will result from a blow to the shoulder, failure of the bone can also occur from a traction-type injury. This usually occurs in an industrial or dockyard injury in which the involved arm is forcefully pulled away from the body as it is caught in machinery. It can also occur in vehicular trauma when the arm is pinned against or strikes a fixed object as the torso continues past it. This can lead to scapulothoracic dissociation, as the shoulder girdle fails in tension at the SC joint, the clavicle or the AC joint. This is evident on the radiographs when a completely displaced, distracted fracture site is seen (as opposed to the typical overlapping fracture fragments) (Fig. 38-11). The high incidence of neurologic and vascular traction injuries seen in this setting mandates further investigation (i.e., angiography), because they can be limb threatening.30,39,58,111,136,207

If the clavicular fracture has occurred with minimal trauma, one must be alert to the possibility of a pathologic fracture (Fig. 38-7). Metabolic processes that weaken bone (i.e., renal disease, hyperparathyroidism), benign or malignant tumors (i.e., myeloma, metastases), or pre-existing lesions (i.e., congenital pseudarthrosis of the clavicle) can result in pathologic fractures. In this setting, nonoperative treatment of the clavicle fracture is recommended initially, while intervention is directed toward diagnosis and treatment of the underlying condition. Once the primary diagnosis has been made and treatment initiated, the clavicle fracture is treated based on its individual aspects. Also,
Figure 38-9 A “floating shoulder” injury. This patient was injured in a motor vehicle accident. A: An anteroposterior radiograph demonstrates a displaced, shortened left clavicle fracture. B: A CT scan of the shoulder reveals a comminuted glenoid neck fracture. C: There is significant clinical deformity. D: Intraoperatively, the fracture is reduced with the aid of reduction clamps, and an anterior fixation plate is applied (E, F). Symmetry of the shoulder was restored by clavicle fixation alone, and it was not necessary to repair the glenoid fracture. G: There was an excellent clinical result with full restoration of motion and a Constant score of 95.
repetitive or unusual loads may induce a stress fracture of the clavicle, typically in bodybuilders or weightlifters.\textsuperscript{134,159,169} In the past, when treatment of all clavicular shaft fractures was consistently nonoperative, a detailed history of lifestyle, occupation, and medical conditions was usually perfunctory at best, since these factors did little to influence decision making. However, there is now increasing evidence that operative intervention is superior in carefully selected cases of displaced clavicular shaft fracture, such that additional information gleaned from the history contributes to the risk/benefit analysis regarding possible surgery. Compliant patients in the 16 to 60 age group, who have active recreational lifestyles and/or physically demanding occupations (especially those that require throwing, repetitive overhead work, or recurrent lifting) are candidates for primary operative repair if they are medically fit and have completely displaced fractures with good bone quality.\textsuperscript{15,108,140,190,209} Factors associated with noncompliance and a high rate of fixation failure, such as drug and alcohol abuse, untreated psychiatric conditions, homelessness, or uncontrolled seizure disorders are contraindications for primary operative repair of clavicle fractures.\textsuperscript{10}

**Physical Examination**

When nonoperative treatment was chosen for the vast majority of clavicle fractures, there was little emphasis placed on a careful physical examination of the shoulder girdle. However, there are a number of findings that are important in surgical decision making. There is usually swelling, bruising, and ecchymosis at the fracture site, as well as deformity with displaced fractures. Visible deformity of the shoulder girdle, best seen when the patient is standing, is an important feature to recognize. The usual position seen with a completely displaced midshaft fracture of the clavicle has been described as shoulder “ptosis,” with a droopy, medially driven, and shortened shoulder (Fig. 38-12)\textsuperscript{64,74,136,190} In addition, the shoulder translates and rotates forward: This is a deformity that can best be seen by viewing the patient from above. Due to this malposition of the shoulder girdle, inspection of the patient from behind may reveal a subtle prominence of the inferior aspect of the scapula from scapular protraction as it moves with the distal fragment.
Shortening of the clavicle should be measured clinically with a tape measure. A mark is made in the midline of the suprasternal notch and another is made at the palpable ridge of the AC joint: Measuring this length gives the difference between the involved and normal shoulder girdle. The degree of shortening at the fracture site is very important in the decision making of operative versus nonoperative care, as it has been reported in multiple studies to be of prognostic significance (greater shortening, especially more than 1.5 to 2 cm, is associated with a worse prognosis). Radiographs, especially of long oblique fractures, tend to overestimate the degree of shortening which emphasizes the importance of a proper clinical examination.

A careful neurologic and vascular examination of the involved limb is mandatory, especially if surgical intervention is contemplated. If a deficit is not noted preoperatively, then it may be incorrectly attributed to the surgery which has prognostic, medical–legal, and treatment implications.

Open Fractures

Surprisingly, given its subcutaneous nature and exposed position, open fractures of the clavicle are relatively rare. Most open fractures are associated with high-energy vehicular trauma, and recognition is important for a number of reasons: The fracture itself will require irrigation, debridement, and fixation, and there is a high incidence of associated injuries. Two large, recent series focused on open fractures of the clavicle. Taitsman et al. described 20 patients with this injury: 15 had pulmonary injuries, 13 had head injuries, 8 had scapular fractures, 11 had facial trauma, and there was a variety of other injuries. In the largest published series to date, Gottschalk et al. identified 53 open clavicle fractures from an active Level 1 trauma center over a 16-year period (roughly three cases per year, illustrating the rarity of this condition). They also reported many associated serious injuries, with the 26 patients with penetrating injuries having a high incidence of great vessel injury, while the 21 patients with blunt trauma had a 52% rate of serious head injury. They stated that an open clavicle fracture should immediately raise suspicion for a serious concomitant injury, and that a prompt and thorough evaluation should be initiated. As far as treatment of the clavicle fracture itself is concerned, no specific recommendations are available in the literature, but general principles should be followed. Prophylactic antibiotics should be administered, and in general the instability associated with such a fracture will warrant operative stabilization as promptly as the patient’s general condition permits.

Imaging and Other Diagnostic Studies for Clavicle Fractures

Simple anteroposterior (AP) radiographs are usually sufficient to establish the diagnosis of a clavicle fracture. The diagnosis may also be made from a single AP chest radiograph, which may be the only available film in an urgent trauma setting. The chest radiograph can also be used to evaluate the deformity of the involved clavicle relative to the normal side, and to look for associated skeletal injuries such as rib, glenoid, and scapular fractures. A measurement of length can be made on the chest radiograph comparing the injured to the uninjured side: Shortening of 2 cm or more represents a relative indication for primary fixation. To best delineate a clavicular fracture, as when one is determining whether operative intervention is warranted, a radiograph should be taken in the upright position (where gravity will demonstrate maximal deformity). Ideally, the radiographic beam for the AP radiograph of the clavicle should be angled 20 degrees superiorly to eliminate the overlap of the thoracic cage and show the clavicle in profile. In addition, if the torso is internally rotated a similar 20 degrees (rotating internally when standing or by bumping up the opposite side while supine), the scapula and shoulder girdle are placed parallel to the cassette for a true AP film. CT scanning of midshaft clavicular fractures is rarely performed in the clinical setting, although...
Fractures of the medial end of the clavicle are difficult to visualize with conventional radiography. This 32-year-old female equestrian sustained a medial clavicle fracture following a riding accident when her horse fell on her. The anteroposterior radiograph (A) reveals some asymmetry of the clavicles but it is difficult to define the exact nature of the injury due to the overlap of bony axial structures and the spinal column. B: A CT scan clearly demonstrates the medial fracture with a small residual medial fragment (small arrow) and posterior displacement of the shaft (big arrow). C) Impinging on the mediastinal structures. D: Plate fixation was performed, with extension of the plate onto the sternum due to the small size of the medial fragment. Once bony union has occurred (between 3 and 6 months), such a plate should be removed. (Case courtesy of Dr. Jeremy A. Hall.)
this imaging modality can demonstrate the complex three-dimensional deformity that affects the shoulder girdle with these injuries, including significant scapular angulation and protraction. It is also useful for evaluating fractures of the medial third of the clavicle and the remainder of the shoulder girdle, such as the glenoid neck in cases of a “floating shoulder.”

Lateral clavicle fractures can be well visualized with AP radiographs. Centering the radiograph on the AC joint and angling the beam in a cephalic tilt of approximately 15 degrees (the Zanca view) helps delineate the fracture well, by removing the overlap of the upper portion of the thoracic cage. To accurately delineate the degree of fracture displacement, these radiographs should be taken with the patient standing and the arm unsupported by slings, braces, or the uninjured arm. On occasion, it may be useful to obtain a stress view to determine the integrity of the coracoclavicular ligaments (as this can influence the choice of fixation): A 2.26- to 4.53 kg (5- to 10-lb) weight is suspended from the wrist of the affected arm and then radiographs are taken. CT scanning of lateral clavicle fractures is rarely required clinically; but can be useful in selected cases to determine intra-articular extension or displacement.

Fractures of the medial clavicle, especially those involving the SC joint, are notoriously difficult to accurately assess with plain radiographs. CT scanning is the radiographic procedure of choice when the anatomy of the fracture is uncertain. This investigation can help distinguish between a medial epiphyseal fracture (common in individuals up to 25 years of age) and true SC dislocations (Fig. 38-13).

### Classification of Clavicle Fractures

A number of classification schemes have been proposed for fractures of the clavicle. These have traditionally been based on the position of the fracture, with the groups originally divided by Allman into proximal (Group I), middle (Group II), and distal (Group III) third fractures. This general grouping has the advantage of corresponding to the clinical approach to these fractures of most orthopedic surgeons. Recognizing that this advantage of corresponding to the clinical approach to these distal (Group III) third fractures. This general grouping has the advantage of corresponding to the clinical approach to these fractures of most orthopedic surgeons. However, a feature of this scheme is that it reverses the traditional numbering scheme, describing medial fractures as Type I, middle third fractures as Type II, and distal third fractures as Type III. Since distal third fractures are firmly entrenched in the orthopedic lexicon as “Type II” fractures, this can lead to significant confusion. Despite this drawback, the Robinson classification is based on an extensive database that includes prospectively gathered, objective clinical data. For this reason, it is the classification I prefer to use clinically as it can help predict outcome and hence guide treatment, including the decision to operate and the fixation methods chosen. The AO/OTA Fracture and Dislocation Classification Compendium was updated in 2007 to include recent developments including a unified numbering scheme and measures to improve observer reliability (Fig. 38-15). The clavicle is designated as segment 15, and is divided into the standard medial metaphyseal, diaphyseal, and lateral metaphyseal fractures. An important difference is that the metaphyseal fractures in this scheme are not one-third of the length of the bone but are shorter segments, according to the AO “rule of squares.” For the all-important diaphysis, there are simple (15-B1), wedge (15-B2), and complex (15-B3) subtypes.

#### Outcome Measures for Clavicle Fractures

It has become apparent that outcome measures previously used for fractures in general, and clavicle fractures in particular, have not reliably demonstrated significant residual deficits following injury. Gauging success or failure based on the isolated finding of the presence or absence of union on a post-injury radiograph was shown to be inadequate by Gossard. They used patient-based questionnaires that revealed a 32% rate of patient dissatisfaction following the nonoperative treatment of displaced midshaft clavicle fractures, a significantly higher rate than expected from traditional (i.e., radiographic or surgeon-based) outcome measures. In addition, they showed that a significant proportion of patients (15%) were dissatisfied despite radiographic union, confirming the existence of symptomatic clavicular malunion for the first time in a large series. McKee et al. used
**Robinson Cortical Alignment Fracture (Type 2A)**
- Undisplaced (Type 2A1)
- Angulated (Type 2A2)

**Robinson Displaced Fractures (Type 2B)**
- Simple or single butterfly (Type 2B1)
- Segmental or comminuted (Type 2B2)

**Robinson Undisplaced Fractures (Type 1A)**
- Extra-articular (Type 1A1)
  - Neer Type I
  - Craig Type I
- Intra-articular (Type 1A2)
  - Neer Type III
  - Craig Type III

**Robinson Displaced Fractures (Type 1B)**
- Extra-articular (Type 1B1)
  - Neer Type II
  - Craig Type II, IV
- Intra-articular (Type 1B2)
  - Craig Type V

**Robinson Cortical Alignment Fracture (Type 3A)**
- Extra-articular (Type 3A1)
  - Neer Type I
  - Craig Type I
- Intra-articular (Type 3A2)
  - Neer Type III
  - Craig Type III

**Robinson Displaced Fractures (Type 3B)**
- Extra-articular (Type 3B1)
  - Neer Type II
  - Craig Type II, IV
- Intra-articular (Type 3B2)
  - Craig Type V

**Robinson Displaced Fractures (Type 3B)**
- Extra-articular (Type 3B1)
  - Neer Type II
  - Craig Type II, IV
- Intra-articular (Type 3B2)
  - Craig Type V

**FIGURE 38-14** Robinson classification scheme of clavicle fractures.
machine-based objective strength measurements on patients with clavicular malunion to demonstrate strength deficits of up to 30% that were not apparent on the traditional manual strength testing against the physicians resisting arm.

Similar findings in other areas have prompted extensive research into the evaluation of outcome. A number of modern, validated, responsive, consistent outcome measures are now available for the evaluation following shoulder girdle injuries. Most clinical research studies examining patient outcome in this anatomic area use a comprehensive set of outcome measures including a patient-oriented general health status measurement such as the SF-36 or MFA, a patient-oriented limb-specific outcome measure such as the Disabilities of the Arm, Shoulder, and Hand (DASH), a surgeon-based outcome score such as the Constant shoulder score or UCLA shoulder score, and a radiographic measure. With regard to the radiographic measurements, there is
increasing focus on standardizing technique so as to obtain consistent results. There are now data available from multiple studies on the effect of a clavicle fracture on these outcome measures that help the attending surgeon with treatment and prognosis (see below).15,85,103,143,155

Another previously unanswered yet important question regarding outcome following clavicle fracture was the length of follow-up required to determine the time of maximal recovery, or when a patient “plateaued” following injury. While most scientific journals require a minimum follow-up of 2 years for outcome studies, this can be extremely difficult to obtain in the “trauma population,” which tends to be predominantly young, male, and transient. A recent study by Schemitsch et al.164 demonstrated that outcome measures such as the DASH or Constant score do not change appreciably after 1 year in patients with midshaft clavicle fractures (Fig. 38-16). This finding has important implications. Clinically, following either operative or nonoperative treatment, patients can be told that their functional outcome is unlikely to change significantly from their status at 1 year post injury. Researchers can plan for a single year of follow-up post-intervention, with the knowledge that the expense and effort of longer monitoring is unnecessary as changes in outcome measures past this point are minimal. In addition, economists can use the 1-year data from such studies for definitive calculations of the long-term cost-effectiveness of various treatment methods.137

**PATHOANATOMY AND APPLIED ANATOMY RELATING TO CLAVICLE FRACTURES**

**Bony Anatomy of the Clavicle**

The clavicle is a relatively thin bone, widest at its medial and lateral expansions where it articulates with the sternum and acromion, respectively (Fig. 38-17). It has two distinct curves: The larger, obvious curve is in the coronal plane giving the bone its characteristic S shape (medial end convex anterior and lateral end concave anterior).107 There is also a more subtle superior curve delineated in a cadaver study by Huang et al.70 This milder superior bow had its apex laterally a mean of 37 mm from the acromial articulation, with a mean magnitude of 5 mm. The medial superior surface of the clavicle was found to be flat. This article also described the fit of a precontoured clavicular plate to 100 pairs of cadaver clavicles. The authors found that there were significant sex and racial differences in the fit of the plate from best (black male clavicles) to worst (white female clavicles). This article helps explain why intraoperatively it often

**FIGURE 38-16** Constant shoulder scores of patients following operative versus nonoperative treatment of a displaced midshaft fracture of the clavicle at 2 years are similar to 1-year scores, indicating that function plateaus after 1-year post injury. (Adapted from: Schemitsch LA, Schemitsch EH, Veillette C, et al. Function plateaus by one year in patients with surgically treated displaced midshaft clavicle fractures. *Clin Orthop Relat Res.* 2011;469(12):3351–3355, with permission.)

**FIGURE 38-17** The cross-sectional and topographic anatomy of the clavicle. The clavicle is narrowest in its midportion, explaining the high incidence of fractures in this area.
is necessary to adjust or contour even “anatomic” plates for the clavicle to achieve an optimal fit. The bone in the relatively thin diaphysis is typically hard cortical bone best suited for cortical screws, whereas the medial and lateral expansions are softer cancellous bone where larger pitch cancellous screws can be inserted without tapping.

Ligamentous Anatomy of the Clavicle

Medial
There is relatively little motion at the SC joint, and the supporting soft tissue structures are correspondingly thick. Medially the clavicle is secured to the sternum by the SC capsule, and although there are not easily demonstrable “ligaments,” the thickening of the posterior capsule has been determined to be the single most important soft tissue constraint to anterior or posterior translation of the medial clavicle. There is also an interclavicular ligament which runs from the medial end of one clavicle, gains purchase from the superior aspect of the sternum at the sternal notch, and attaches to the medial end of the contralateral clavicle. Acting as a tension wire at the base of the clavicle, this ligament helps prevent inferior angulation or translation of the clavicle. In addition, there are extremely stout ligaments that originate on the first rib and insert on the undersurface or the inferior aspect of the clavicle. A small fossa inferomedially, the rhomboid fossa, has been described as an attachment point for these ligaments, which primarily resist translation of the medial clavicle.

Lateral
The coracoclavicular ligaments are the trapezoid (more lateral) and conoid (more medial) which are stout ligaments that arise from the base of the coracoid and insert onto the small osseous ridge of the inferior clavicle (trapezoid) and the clavicular conoid tubercle (conoid). These ligaments are very strong and provide the primary resistance to superior displacement of the lateral clavicle. Their integrity, or lack thereof, plays an important role in the decision making and fixation selection in the treatment of displaced lateral third clavicle fractures. Clavicle fractures in this location will often have an avulsed inferior fragment to which these ligaments are attached, especially in younger individuals. Inclusion of these fragments in surgical fixation selection enhances the stability of the operative repair. The capsule of the AC joint is thickened superiorly and is primarily responsible for resisting AP displacement of the joint. It is important to repair this structure, which is usually reflected surgically as part of the deep myofascial layer, when operating on the lateral end of the clavicle. If one is inserting a hook plate for fixation of a very distal fracture, a small defect can be made in the posterolateral aspect of the capsule for insertion of the hook portion into the posterior subacromial space.

Muscular Anatomy of the Clavicle

The clavicle is not as important as the scapula in terms of muscle origin, but still serves as the attachment site of several large muscles. Medially, the pectoralis major muscle originates from the clavicular shaft anteroinferiorly, and the sternoclavicular origin. The clavicular fragment is elevated by the unopposed pull of the pectoralis major muscle and fascia envelope the medial 60% of the clavicle while the lateral 40% is covered by the deltoid muscle and its fascia. Posterosuperiorly, the trapezius muscle attaches to the clavicle.

Neurovascular Anatomy of the Clavicle

The supraclavicular nerves originate from cervical roots C3 and C4 and exit from a common trunk behind the posterior border of the sternocleidomastoid muscle. There are typically three major branches (anterior, middle, and posterior) that cross the clavicle superficially from medial to lateral, and are at risk during surgical approaches. If they are divided, an area of numbness is typically felt inferior to the surgical incision, although this tends to improve with time. A more difficult problem can be the development of a painful neuroma in the scar...
which, although rare, can negatively affect an otherwise good surgical outcome. For this reason, some authorities recommend identification and protection of these nerves during operative repair. More vital neurovascular structures lie inferior to the clavicle. The subclavian vein runs directly below the subclavius muscle and above the first rib, where it is readily accessible (for central venous access) and vulnerable (to inadvertent injury). More posteriorly lie the subclavian artery and the brachial plexus, separated from the vein and clavicle by the additional layer of the scalenus anterior muscle medially. The plexus is closest to the clavicle in its midportion, where the greatest care needs to be taken in not violating the subclavicular space with drills, screws, or instruments. A recent study by Sinha et al. used reconstructed three-dimensional CT arteriograms of the head, neck, and shoulder to better define the relationship between these vascular structures and the clavicle. Their goal was to define “safe zones,” in terms of distance and direction, for potential drill penetration during plate and screw fixation of the clavicle. They divided the clavicle into medial, middle, and distal thirds, and found that the subclavian vessels were closest at the medial end, with the vein directly apposed to the posterior cortex of the medial clavicle in some cases. In the middle third, the artery and vein were a mean of 17 and 13 mm from the clavicle, respectively, at an approximate angle of 60 degrees to the horizontal (i.e., the vessels were posterior-inferior to the clavicle, Figs. 38-19 and 38-20). Laterally, the distances were greater, with the artery and vein a mean of 63 and 76 mm, respectively, form the clavicle. Using these findings, the authors made a number of recommendations regarding surgical technique: Extreme caution must be used when manipulating medial clavicular fracture fragments, and superior plating may be safer than anterior plating in this area. Also, they felt that anterior plating had less potential for vessel injury from drill or screw penetration, as compared to superior plating, in the more common middle third fractures. They felt the risk of iatrogenic vessel injury was much less in the fixation of distal third fractures. Despite the proximity of these vital structures, iatrogenic injury is surprisingly rare in clavicle fracture fixation (see below).

**CLAVICLE FRACTURE TREATMENT OPTIONS**

A recent review article focusing on evidence-based medicine outlined treatment approaches to displaced midshaft fractures of the clavicle. This resource summarizes the available objective evidence about recommendations for the optimal treatment of these injuries (Table 38-2). The grades of recommendation are as follows.

- **Grade A:** Good evidence (high-quality prospective, randomized clinical trials (RCTs) with consistent findings) recommending for or against intervention
- **Grade B:** Fair evidence (lesser quality RCTs, prospective comparative studies, case-control series) recommending for or against intervention
- **Grade C:** Poor-quality evidence (case series or expert opinions) recommending for or against intervention
- **Grade I:** There is insufficient or conflicting evidence not allowing a recommendation for or against intervention

While there is an abundance of manuscripts detailing the treatment of clavicle fractures, most tend to be retrospective reviews, although there are an increasing number of prospective and/or randomized trials being published. My personal recommendations for treatment must be considered in light of the evidence available in Tables 38-1 and 38-2.
Nonoperative Treatment of Clavicle Fractures

The earliest reported attempt at closed reduction of a displaced midshaft fracture of the clavicle was recorded in the “Edwin Smith” papyrus dating from the 30th century BC. Hippocrates described the typical deformity resulting from this injury, and emphasized the importance of trying to correct it. It is usually possible to obtain an improvement in position of the fracture fragments by placing the patient supine, with a roll or sandbag behind the shoulder blades to let the anterior displacement and rotation of the distal fragment correct with gravity, followed by superior translation and support of the affected arm. Unfortunately, it is difficult or impossible to maintain the reduction achieved. For this reason, over the millennia that followed the traditional treatment of displaced midshaft clavicle fractures, there have been hundreds of descriptions of different devices designed to maintain the reduction, including splints, body jackets, casts, braces, slings, swathes, and wraps. At the present time, there is no convincing evidence that any of these devices reliably maintains the fracture reduction or improves clinical, radiographic, or functional outcomes. For many years the standard of care in North America was the “figure-of-eight” bandage: Andersen et al. examined its utility in a prospective, randomized, controlled clinical trial comparing it to a simple sling in 60 patients. They could demonstrate no functional or radiographic difference between the two groups, and in general the patients preferred the sling (2/27 dissatisfied with the sling compared to 9/34 dissatisfied with the figure-of-eight bandage, p = 0.09).

In a retrospective review of 140 patients treated nonoperatively, Stanley and Norris did not find any difference between a standard sling and a figure-of-eight bandage, a finding confirmed by other authors. Also, a figure-of-eight bandage that is over-tightened can result in a temporary lower trunk brachial plexus palsy and for this reason my practice, if nonoperative care is selected, is to apply a simple, conventional sling with a padded neckpiece, and no attempt at reduction is made.

Outcomes—Nonoperative Treatment

Traditionally, clavicle fractures have been treated nonoperatively but recent studies have shown that the union rate for displaced midshaft fractures of the clavicle may not be as favorable as previously described. In a prospective series of 868 patients with clavicle fractures treated nonoperatively, Robinson et al. reported a significantly higher nonunion rate (21%) in displaced comminuted midshaft fractures. An analysis of this paper by Brinker et al. suggested a nonunion rate varying between 20% and 33% for displaced comminuted fractures in males. Hill et al. studied 66 consecutive displaced midshaft clavicle fractures and found a 15% nonunion rate and a 31% rate of patient dissatisfaction with nonoperative care. Based on their data, they concluded that displacement of the fracture fragments of greater than 2 cm was associated with an unsatisfactory result. A meta-analysis of studies of clavicle fractures from 1975 to 2005 revealed that displaced midshaft clavicle fractures treated nonoperatively had a nonunion rate of 15.1%. This meta-analysis also showed that primary plate fixation was, contrary to prevailing opinion, a safe and reliable procedure. Nowak et al. examined the late sequelae in 208 adult patients with clavicle fractures at 10 years post injury. Interestingly, 96 (46%) still had symptoms despite the fact that only 15 (7%) had an established nonunion. McKee et al. reported on a series of patients who has nonoperative treatment of a displaced midshaft clavicle fracture a mean of over 4 years earlier. Objective muscle strength testing revealed significant strength deficits, especially of shoulder abduction and flexion which help explain some of the patient dissatisfaction seen despite bony union.

While it is unclear why such a dramatic difference exists in outcome between previous reports on clavicle fractures and contemporary studies, one possibility may be the inclusion of children in the older reports, which, due their inherent healing abilities and remodeling potential, may artificially improve the overall results. Also, patient-oriented outcome measures, as used by Hill et al. and McKee et al. have been shown to reveal functional deficits in the upper extremity that have not been detected traditionally. A focus on radiographic outcomes would not reveal such problems. Patient expectations and injury patterns are changing. Several studies that examined clavicular shaft fractures in polytrauma patients found that the presence of a clavicle fracture was associated with a 20% to 30% mortality rate (mainly from concomitant chest and head injuries), and that survivors displayed a significant level of residual disability in the involved
Operative Treatment of Clavicle Fractures

Indications/Contraindications

There are numerous large series that describe relatively good results following nonoperative treatment of clavicle fractures, and it is my opinion that the majority of clavicle fractures can, and should, be treated in this fashion. However, there are serious deficiencies in these papers including the inclusion of children (who have an intrinsically good result and remodeling potential), large numbers of patients lost to follow-up, and radiographic and/or surgeon-based outcomes that are insensitive to residual deficits. Recent evidence from prospective and randomized clinical trials has suggested that there is a subset of individuals who benefit from primary operative care (Fig. 38-21). Operative repair in this setting should be reserved for medically well, physically active patients who stand to benefit from the most from a rapid restoration of normal anatomy and stable fixation. There are multiple potential indications for primary operative fixation, outlined in Table 38-4. The majority of modern prospective studies examining the potential benefits of primary clavicle fracture fixation have been in adult patients, with 16 years of age the typical (arbitrary) lowest age of inclusion. Thus, it is unclear if adolescent patients, in general, would benefit from operative repair to a similar degree as adult patients. However, adolescent patients can develop symptomatic malunion following nonoperative treatment of displaced midshaft fractures of the clavicle, although nonunion remains rare as one would expect. Vander Have et al. performed a retrospective study on 43 adolescent patients (mean age: 15.4 years) with displaced midshaft clavicle fractures, 17 of whom underwent primary plate fixation, and 25 of whom were treated nonoperatively. They found that complications in the plate group were minor, and a more rapid return to function with a shorter time to union resulted. Five patients in the nonoperative group, with a mean of 26 mm of shortening, developed a symptomatic malunion, with four patients choosing corrective osteotomy. It is clear that some adolescent patients with significantly displaced midshaft clavicle fractures have suboptimal results following closed

TABLE 38-3 Cosmesis Following Operative Versus Nonoperative Care of Clavicular Fractures

<table>
<thead>
<tr>
<th>Complaint</th>
<th>Operative (n = 62)</th>
<th>Nonoperative (n = 49)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Droopy&quot; shoulder</td>
<td>0</td>
<td>10</td>
<td>0.001</td>
</tr>
<tr>
<td>Bump/Asymmetry</td>
<td>0</td>
<td>22</td>
<td>0.001</td>
</tr>
<tr>
<td>Scar</td>
<td>3</td>
<td>0</td>
<td>0.253</td>
</tr>
<tr>
<td>Sensitive/painful fracture site</td>
<td>9</td>
<td>10</td>
<td>0.891</td>
</tr>
<tr>
<td>Hardware irritation/prominence</td>
<td>11</td>
<td>0</td>
<td>0.001</td>
</tr>
<tr>
<td>Incisional numbness</td>
<td>18</td>
<td>0</td>
<td>0.001</td>
</tr>
<tr>
<td>Satisfied with appearance of shoulder</td>
<td>52</td>
<td>26</td>
<td>0.001</td>
</tr>
</tbody>
</table>

shoulder. Thus, there is a surviving patient population (with clavicle fractures) that has an intrinsically worse prognosis where long-term sequelae may be more common.

Although it is not typically an orthopedic priority, cosmesis is important to patients, and an unsightly scar has been a traditional deterrent to operative treatment of clavicular fractures. However, to a body image conscious patient (predominantly young, male population), a droopy shoulder is also of significant cosmetic concern. In a recent RCT comparing operative and nonoperative treatments, despite the incidence of hardware prominence and incisional complications (numbness, sensitivity) in the operative group, more patients in this group answered "yes" to the question "Are you satisfied with the appearance of your shoulder?" than in the nonoperative group (52/62 vs. 26/49, p = 0.001, Table 38-3). This study also showed superior surgeon-based (Constant score) and patient-based (DASH) upper extremity outcomes.

In contradistinction to older case series, recent studies on the primary plate fixation of acute midshaft clavicle fractures have reported high success rates with union rates ranging from 94% to 100% and low rates of infection and surgical complications. A recent meta-analysis of plate fixation for 460 displaced fractures revealed a nonunion rate of only 2.2%. With improved implants, prophylactic antibiotics, and better soft tissue handling one can conclude that plate fixation is reliable and reproducible.

Operative Treatment of Clavicle Fractures

TABLE 38-4 Relative Indications for Primary Fixation of Midshaft Clavicle Fractures

<table>
<thead>
<tr>
<th>Fracture-Specific</th>
<th>Patient Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Displacement &gt;2 cm</td>
<td>1. Polytrauma with requirement for early upper extremity weight-bearing/arm use</td>
</tr>
<tr>
<td>2. Shortening &gt;2 cm</td>
<td>2. Patient motivation for rapid return of function (e.g., elite sports or the self-employed professional)</td>
</tr>
<tr>
<td>3. Increasing comminution (&gt;3 fragments)</td>
<td></td>
</tr>
<tr>
<td>4. Segmental fractures</td>
<td></td>
</tr>
<tr>
<td>5. Open fractures</td>
<td></td>
</tr>
<tr>
<td>6. Impending open fractures with soft tissue compromise</td>
<td></td>
</tr>
<tr>
<td>7. Obvious clinical deformity (usually associated with 1 and 2 above)</td>
<td></td>
</tr>
<tr>
<td>8. Scapular malposition and winging on initial examination</td>
<td></td>
</tr>
<tr>
<td>Associated Injuries</td>
<td></td>
</tr>
<tr>
<td>1. Vascular injury requiring repair</td>
<td></td>
</tr>
<tr>
<td>2. Progressive neurologic deficit</td>
<td></td>
</tr>
<tr>
<td>3. Ipsilateral upper extremity injuries/fractures</td>
<td></td>
</tr>
<tr>
<td>4. Multiple ipsilateral upper rib fractures</td>
<td></td>
</tr>
<tr>
<td>5. &quot;Floating shoulder”</td>
<td></td>
</tr>
<tr>
<td>6. Bilateral clavicle fractures</td>
<td></td>
</tr>
</tbody>
</table>
treatment, and that plate fixation is a safe and reliable fixation method with a low complication rate in this group. Prospective, randomized studies of operative versus nonoperative treatment in this specific group are required to determine the exact role, if any, for primary operative repair of these fractures. At present, the consensus is that operative intervention should be reserved for older, larger adolescents with severely displaced fractures.

### External Fixation

There are reports in the literature of various techniques of external fixation for clavicle fractures. This method takes advantage of the intrinsic healing ability of the clavicle and allows restoration of length and translation without the scarring or morbidity of a surgical approach. In addition, there is no retained hardware at the conclusion of treatment. Schuind reported on a series of 20 patients treated with external fixation for clavicular injuries, many of whom had local soft tissue compromise; union occurred in all. Tomic et al. described the treatment of 12 patients with nonunion of the clavicular shaft by application of a modified Ilizarov device. Union was achieved in 11 of 12 patients with an increase in the mean Constant score from 30 preoperatively to 69 postoperatively.

In a biomechanical study of clavicular osteotomies by Golish et al. comparing 3.5-mm compression plates to 3.8- or 4.5-mm IM pins showed that the plated constructs were superior in resisting displacement in a number of different testing modes (maximal load, cyclical

### Intramedullary Pinning

Preoperative Planning. Intramedullary (IM) pinning of fractures of the shaft of the clavicle has several advantages. These are similar to the benefits seen with IM fixation of long bone fractures in other areas, although this technique had not been as consistently successful in the clavicle as series in the femur or tibia have reported. Advantages include a smaller, more cosmetic skin incision, less soft tissue stripping at the fracture site, decreased hardware prominence following fixation, technically straightforward hardware removal, and a possibly lower incidence of refracture or fracture at the end of the implant. Recently, modifications to the technique have included a radiographically guided completely “closed” technique. Since, at the present time, there is no consistently reliable way to “lock” an IM clavicle pin, complications include those common to all unlocked IM devices, namely failure to control axial length and rotation, especially with increasing fracture comminution and decreasing intrinsic fracture stability. In addition, a biomechanical study of clavicular osteotomies by Golish et al. comparing 3.5-mm compression plates to 3.8- or 4.5-mm IM pins showed that the plated constructs were superior in resisting displacement in a number of different testing modes (maximal load, cyclical

### Table 38-5

**External Fixation of Clavicle Fractures: Preoperative Planning Checklist**

<table>
<thead>
<tr>
<th>OR table</th>
<th>Radiolucent table</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position</td>
<td>Semisitting with small pad between scapulae</td>
</tr>
<tr>
<td>Fluoroscopy location</td>
<td>C-arm is placed ipsilateral and enters from the side</td>
</tr>
<tr>
<td>Equipment</td>
<td>External or ring fixator of surgeon’s choice</td>
</tr>
<tr>
<td>Special considerations</td>
<td>This is a complex technique requiring a subspecialty skill level and is not well tolerated by some patients</td>
</tr>
</tbody>
</table>
stress) compared to both IM pin constructs. Therefore, based on clinical and biomechanical evidence, at the present time this technique is, in general, reserved for simple fracture patterns (transverse and short oblique fractures) (Table 38-6).

**Patient Positioning.** The technique includes positioning the patient in a semisitting position on a radiolucent table, with an image intensifier on the ipsilateral side. By rotating the image 45 degrees caudal and 45 degrees cephalad orthogonal views of the clavicle can be obtained. A small pad is placed between the scapulae to allow the shoulder to “fall back,” aiding in reduction, as the typical clavicle fracture deformity results in protraction of the shoulder girdle. The arm may be free-draped if a difficult reduction is anticipated (i.e., as with significant shortening), but in general this is not necessary. The head is turned to the opposite side and taped in place.

**Surgical Approach/Technique.** A small incision is then made over the posterior-lateral corner of the clavicle 2 to 3 cm medial to the AC joint (Fig. 38-22). The posterior clavicle at this point is identified and the breach passed with a drill consistent with the planned fixation device. A reduction of the fracture is then performed, either through a small open incision or, as experience increases, in a completely closed fashion using a percutaneous reduction clamp on the medial fragment and a “joystick” in the distal fragment. Alternatively, the fixation device can be inserted using a “retrograde” technique where it is passed out from the fracture site through the lateral fragment. The fracture is then reduced and the IM device is inserted into the medial fragment under direct vision. It is important to accurately reduce length and rotation, although the latter can be quite difficult if done closed and no visual clues from the fracture configuration are available. A small incision may be necessary to reduce vertically oriented comminuted fragments and “tease” them back into alignment. Following this, the canal is drilled to the appropriate size to accept the planned IM device. Options include headed pins, partially threaded pins or screws, cannulated screws, and smooth wires. Although some series report favorable results with smooth wires, the North American experience with small diameter smooth pin fixation includes breakage and migration and is, in general, dismal. Smooth wires are contraindicated for fracture fixation about the shoulder in general and the clavicle in particular. It is important not to distract the fracture site with the fixation device, which can occur as the pin is inserted into the unyielding opposite cortex as the S-shaped clavicle comes into contact with the end of the straight pin. If this occurs, the pin must be withdrawn slightly or a shorter pin is used. The head of the pin or screw can be left prominent to facilitate early removal through a small posterior incision, or can be left flush with the bone to decrease soft tissue irritation (Fig. 38-23).

**TABLE 38-6 Intramedullary Fixation of Clavicle Fractures: Preoperative Planning Checklist**

<table>
<thead>
<tr>
<th>OR table</th>
<th>Radiolucent table</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position</td>
<td>Semisitting with small pad between scapulae</td>
</tr>
<tr>
<td>Fluoroscopy location</td>
<td>C-arm is placed ipsilateral, and enters from the side</td>
</tr>
<tr>
<td>Equipment</td>
<td>Intramedullary pins, reamers, inserters, and any attachment guides or jigs</td>
</tr>
<tr>
<td>Special considerations</td>
<td>At present, this technique is reserved for simple fractures such as transverse or short oblique patterns without significant comminution</td>
</tr>
</tbody>
</table>

**Figure 38-22** Intramedullary fixation with a headed, distally threaded pin (modified Hagie pin). (**A**) Retrograde drilling of the distal fragment, (**B**) reduction and fixation of the fracture, (**C**) addition of bone graft or bone graft substitute.
A comminuted, displaced, midshaft fracture of the clavicle.

Photograph showing the operative set-up with the image intensifier in place.

A small incision is made and the fracture reduced in an open fashion followed by retrograde insertion of the pin.

Postoperative radiograph revealing reduction of the fracture.

Skin irritation over prominent pin.

Radiograph demonstrating bony union.

Follow-up radiograph following uneventful union and pin removal. (Case courtesy of, and copyright by, Dr. David Ring.)
Postoperative Protocol. Some authors advocate leaving the pin in a prominent position subcutaneously for easy access in the clinic at the time of early (7 to 8 weeks postoperative) hardware removal. This step depends on the type of fixation device used and the philosophy of the treating surgeon. The incisions are closed in a fashion similar to that used for plate fixation, although they are typically smaller. If the surgeon is confident with the stability of the repair, early motion is instituted similar to that performed following plate fixation.

Potential Pitfalls and Preventative Measures

Outcome. While there are many theoretical advantages to IM fixation, it would appear that the results of this method with currently available implants are more unpredictable than the results reported for plate fixation. Biomechanically, IM devices appear to be inferior in resisting displacement when compared to plate fixation. Two clinical studies comparing IM fixation to nonoperative treatment failed to show any advantage in the IM fixation group. Grassi et al. described a high complication rate with IM fixation including eight infections, three “refractures,” two delayed unions and two nonunions with hardware failure in 40 patients. Judd et al., in a randomized trial, failed to show an advantage of IM fixation over nonoperative care in 57 patients, with nearly half the operative group losing some degree of reduction. A recent study by Strauss et al. described a complication rate of 50%, (including three cases of skin necrosis) in 16 patients treated with Hagie pin fixation. They recommended against the continued use of this device. A meta-analysis by Złowodzki et al. did not reveal any significant differences between plate and IM fixation, although this analysis was hampered by the lack of any direct comparative studies. Conversely, Chuang et al. described 100% union with no significant complications in a group of 34 patients with an acute midshaft fractures of the clavicle treated with an IM cannulated screw. Also, these studies examine the clinical outcomes of implants that, in general, are essentially unlocked, have poor rotational or axial control, and are not suitable for unstable or comminuted fractures. Newer devices are now available that have the potential to improve on traditional IM implants with locking capability (Fig. 38-24). Further studies will elucidate if their theoretical advantages are borne out in clinical practice. See also “Controversies: Method of Fixation,” below.

Open Reduction and Plate Fixation

Preoperative Planning. While this section will describe the author’s technique of operative repair of a midshaft clavicle fracture, it is important to remember that the majority of midshaft fractures can be treated nonoperatively. A careful physical examination (see above) is mandatory to rule out other injuries, which may influence the anesthetic choice (i.e., an ipsilateral pneumothorax), or the surgery itself (compromised skin or deficient soft tissue, neurovascular injury). The skin in this area is typically bruised, with extensive swelling, following a displaced midshaft fracture. Since the difficulty of reduction and fixation does not increase until approximately 2 weeks following injury, it may be prudent to delay operative intervention (as one would in other areas) until the soft tissue in the vicinity of the planned surgical approach is more robust. Radiographs of the injured clavicle are usually sufficient. The surgeon should observe the severity of the displacement, the number of fracture fragments, and the location of the main fracture line (Fig. 38-25). There is often a vertically oriented anterosuperior fragment, which may benefit from lag screw fixation and minifragment screws should be available as this fragment may be quite narrow. Also, the number of screws that potentially can be placed into the distal fragment can be determined preoperatively, so that the appropriate size of plate can be available. Older series describing fixation of clavicle fractures have described poor results when inadequate fixation such as
cerclage wires alone or plates of inadequate size or length are used (Figs. 38-26 and 38-27). A fixation set that includes plates which are precontoured, or “anatomic,” to fit the S shape of the clavicle is ideal. Although these plates may require some intraoperative adjustments, they typically save significant time associated with the extensive contouring required to make a straight plate fit the bone. They help to decrease the soft tissue irritation that occurs when the end of a straight plate protrudes past the end of the bone as the clavicle curves away.

Currently, there are two common surgical approaches applicable to the fixation of clavicle fractures, each with its own advantages and disadvantages. They are as follows.

Anteroinferior. Several groups have published large series on the advantages of anteroinferior plating of acute clavicle fractures. Advantages of this technique include an easier screw trajectory with less likelihood of serious neurovascular injury with inadvertent overpenetration of the drill (although

**FIGURE 38-25** A: Anteroposterior radiograph of a displaced midshaft clavicle fracture. Note the difference in diameter of the proximal and distal fragments at the fracture site, suggesting that a significant degree of rotation has occurred. B: Intraoperative photograph of a displaced fracture, (C) reduced anatomically with small fragment reduction forceps. D: Postoperative radiograph after open reduction and internal fixation with an anterior to posterior lag screw followed by fixation with an anatomic plate.
the incidence of iatrogenic nerve injury is very low), and the ability to insert longer screws in the wider AP dimension of the clavicle, and decreased hardware prominence. It is also technically easier to contour a small-fragment compression plate along the anterior border as opposed to the superior surface. However, the advent of precontoured plates has largely negated this particular advantage. Collinge et al. reported on the use of this technique in 58 patients and described 1 fixation failure, 1 nonunion, 3 infections, and only 2 hardware removals. Potential disadvantages of this technique include the lack of general familiarity with the approach, and that the plate tends to obscure the fracture site radiographically. Also, although there remains some controversy on the matter, biomechanical studies have in general shown that the most advantageous position for plate placement is the superior surface.

Anterosuperior. Anterosuperior plating can reasonably be considered the most popular operative method for fixation of the clavicle. Its advantages include a general familiarity with this approach in most surgeons’ hands, the ability to extend it simply to both the medial and lateral ends of the clavicle, and the benefit of clear radiographic views of the clavicle postoperatively. Its disadvantages include the trajectory of screw placement (from superior to inferior) that can be difficult, and inadvertent “plunging” with the drill can place the underlying lung and neurovascular structures at risk. Also, the clavicle is fairly narrow in its superoinferior dimension, and typically the length of screws inserted range from 14 to 16 mm in females to 16 to 18 mm in males (Table 38-7).

Patient Positioning. The patient is positioned in the “beach-chair” semisitting position on a regular operating room (OR) table with an attached foot piece to support the legs. It has not been routinely necessary to use special tables or positioners. The head is placed on a round support and, if general anesthesia is to be used, the endotracheal tube is taped to the opposite side. The arm does not need to be free-draped for isolated injuries and is usually padded and strapped to the patients’ side. It is helpful to place a small pad behind the involved shoulder to elevate it and then check to ensure that the anticipated superior drill trajectory is free from obstruction. This is less of a concern if an anterior-inferior plate application is chosen.

Surgical Approach (Anterosuperior). A superior approach and plating is my preferred technique because of its simplicity, the well-proven clinical record of superior plate application, and several biomechanical studies that have suggested that the optimal location for plate placement is superior.

![Figure 38-26](image)

**Figure 38-26** Cerclage wiring in isolation is inadequate to control the deforming forces at the site of a displaced clavicle fracture. It results in all of the risks of surgical intervention with few of the benefits, and is to be avoided.

![Figure 38-27](image)

**Figure 38-27** Anteroposterior radiograph of a 35-year-old man who weighed over 200 pounds (200 lb), whose clavicle nonunion was fixed with a 3.5-mm pelvic reconstruction plate. Early mechanical failure occurred through deformation of the plate. This type of plate may be suitable for smaller, low-demand individuals but has a higher failure rate when used in larger, more physically active patients, especially given the current availability of stronger, precontoured plates.

### TABLE 38-7 Open Reduction and Plate Fixation of Clavicle Fractures: Preoperative Planning Checklist

<table>
<thead>
<tr>
<th>OR table</th>
<th>A regular or radiolucent table may be used at the surgeon’s discretion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position</td>
<td>Semisitting with small pad between scapulae—this aids in reduction of the fracture</td>
</tr>
<tr>
<td>Fluoroscopy location</td>
<td>Fluoroscopy is not mandatory, and is used at the discretion of the surgeon if a difficult reduction is anticipated. If used, the C-arm is placed ipsilaterally, and enters from the side</td>
</tr>
<tr>
<td>Equipment</td>
<td>Precontoured plates, small fragment fixation set, drill</td>
</tr>
<tr>
<td>Special considerations</td>
<td>Most fractures are amenable to plate fixation, and this procedure is within the skill set of most orthopedic surgeons</td>
</tr>
</tbody>
</table>
It is possible that anterior-inferior plating leads to less plate irritation than placement of the plate on the superior surface of the clavicle. In the one direct comparison (nonrandomized) between the two techniques, Lim et al. reported a significantly better pain visual analog scale for patients in the anterior/inferior fixation group \( p = 0.05 \). This finding awaits confirmation from further studies.

An oblique skin incision is made centered superiorly over the fracture site. The subcutaneous tissue and platysma muscle are kept together as one layer and extensively mobilized, especially proximally and distally. As experience with the technique increases, a smaller incision using “minimally invasive” principles can be employed. Care is taken to identify, isolate, and protect any visible, larger branches of the suprACLavicular nerves; smaller ones may need to be divided. It is usually wise to warn patients that they may experience some numbness inferior to the incision which will typically improve with time. The myofascial layer over the clavicle is incised and elevated in one continuous layer. Therefore, at the conclusion of the procedure, fracture site and plate coverage are enhanced by having two soft tissue layers (skin/subcutaneous tissue, myofascial layer) to close. Care is taken to preserve the soft tissue attachments to any major fragments, especially the vertically oriented fragment of the anterosuperior clavicle that is often seen. It is not necessary to completely denude these fragments in order to reduce them.

**Technique.** The main fracture line and major fragments are clearly identified and cleaned of debris and hematoma, and a fixation strategy is formulated. If there is a free fragment of sufficient size to be structurally important (one-third of the clavicle circumference or greater), it can be reduced to the proximal or distal clavicle that it arose from and fixed with a lag screw, simplifying the fracture to a simple pattern (Fig. 38-28). The proximal and distal fragments are then reduced with the aid of reduction forceps; they can be held temporarily with a K-wire or, ideally, with a lag screw. A precontoured plate of sufficient length is then applied to the superior surface. If a lag screw has been placed, it is usually sufficient to secure the fracture with three bicortical screws (six cortices) both proximally and distally. If it is not possible to place a lag screw, then four screws should be inserted both proximally and distally. If the main fracture line is of a stable configuration, compression holes can be used to apply compression. If the fracture is comminuted or of an unstable pattern, then the plate should be applied in a “neutral” mode. Care must be taken not to violate the subclavicular space and the vital structures therein. If there is any concern intraoperatively about violation of the pleural space, a Valsalva maneuver should be performed to identify any leakage of air.

In general, surgical intervention is selected for only young active patients with high-quality bone, and for this reason screw purchase is usually excellent, especially in the cortical area. Although there has been increasing interest in the use of locking plate technology in this area, there have been few reports on this technique in the clavicle. Celestre et al. reported that a superiorly placed locking plate was biomechanically superior to a conventional compression plate, although there is little clinical information regarding locking plate use at the present time. One small retrospective series described their use in recalcitrant clavicular nonunions: All 11 fractures eventually healed. I have not found that locking plates are routinely necessary for the fixation of clavicle fractures, and I have no experience with them. Following fixation, it is important to close both soft tissue layers with interrupted, nonabsorbable sutures. Postoperative radiographs are taken in the recovery room.

**Postoperative Care.** The surgery can typically be done on an outpatient basis. Postoperatively, the arm is placed in a standard sling for comfort and gentle pendulum exercises are allowed, and the patient is seen in the fracture clinic at 10 to 14 days postoperatively. The wound is checked and radiographs are taken. The sling is discontinued, and unrestricted range-of-motion exercises are allowed, but no strengthening, resisted exercises, or sporting activities are allowed. At 6 weeks postoperatively, radiographs are taken to ensure bony union. If they are acceptable, the patient is allowed to begin resisted and strengthening activities. If delayed union is evident, then more aggressive activities are avoided. It is generally advised

**FIGURE 38-28** A: A displaced midshaft fracture of the clavicle in a 16-year-old boy, with abrasion and tenting of the skin, approximately 2.5-cm shortening, and an obvious clinical deformity. B: The intervening fragments were fixed with a lag screw followed by plate fixation. Prompt anatomic healing occurred, as might be expected in an adolescent.
that contact (football, hockey) and/or unpredictable (mountain biking, snowboarding) sports be avoided for 12 weeks postoperatively. However, compliance in this predominately young, male population is variable and many individuals return to such activities earlier than recommended.

The clavicle has relatively poor soft tissue coverage, and hardware prominence following plate fixation is a clinical concern. Previously, prior to the advent of plates specifically designed for the clavicle, it was often necessary to contour a straight compression plate to fit the bone by twisting it on its long axis so that it faced the bone as the underlying clavicle curved away from it. In addition to making screw placement difficult, this led to undue prominence of the ends of the plate and a high incidence of subsequent plate removal. With the current availability of stronger, curved, low-profile plates, symptomatic prominence of the plates is much lower and routine plate removal is not typically required.

**Outcome—Plate Fixation.** Older reports described a high rate of complications and hardware failure with primary plate fixation of the clavicle. However, with the development of improved implants, prophylactic antibiotics, and better soft tissue handling and techniques plate fixation has become a reliable and reproducible technique which can reasonably be considered the gold standard at the present time (see also “Controversies: Method of Fixation,” below). Recent studies on the primary plate fixation of acute midshaft clavicle fractures have reported high success rates with union from 94% to 100%. Infection and surgical complication rates are low, under 10%, and functional outcome is superior to nonoperative treatment. A meta-analysis of plate fixation for 460 displaced fractures revealed a nonunion rate of only 2.2%. In the most recently published randomized trial comparing operative versus nonoperative treatment, Virtanen et al. reported union of all 28 fractures in the plate fixation group, with a low complication rate. In the largest similar trial reported to date, the union rate in the plate fixation group was reported to be over 95%, with the commonest complication being hardware irritation and the requirement for plate removal. While plating remains the most popular method of clavicle fixation, the position of plate placement is controversial, with some authorities recommending plate placement on the superior surface of the clavicle, while others recommend the anterior/inferior surface. At the present time, there is no published direct comparison between the two techniques. What is apparent is that plate fixation, for a selected subgroup of individuals with completely displaced fractures of the midshaft clavicle, is a safe, reproducible, and reliable technique with a union rate of 95% and a low complication rate.

**Potential Pitfalls and Preventative Measures—Operative Treatment**

- Patient selection is critical: Operative intervention is reserved for young, healthy, physically active patients with good bone quality and completely displaced fractures (typically with visible deformity) who stand to benefit most from operative fixation with an intrinsically low complication rate (Fig. 38-29).
- Noncompliance and substance abuse (be it alcohol, illicit drugs, or prescription narcotics) are contraindications to surgical intervention. No clavicular fixation is strong enough to withstand an unprotected fall down stairs or a physical altercation in the immediate postoperative period. The rates of hardware failure, nonunion, and reoperation are significantly higher in such individuals.
- It is critical to develop, protect, and securely close the two soft tissue layers. The superficial layer is the skin and subcutaneous tissue and the deep layer is the deltotrapezial myofascial layer. This helps protect against deep infection and ensures plate coverage if there is a superficial infection.
- Comminuted fragments, especially the often seen vertically displaced anterior-superior fragment, should be gently “teased” back into position, maintaining its soft tissue attachments. They can be secured with mini- or small-fragment screws. Reduction is important but not at the cost of denuding all of the soft tissue attachment (Fig. 38-30).
- While typically it is not necessary to dissect in the subclavicular space to place protective retractors, it is very important not to “plunge” into this area with drills or taps. If a lung injury is suspected intraoperatively, the wound is filled with saline and the anesthetist performs a Valsalva maneuver. The presence of air escape indicates pleural injury and should prompt a chest radiograph and consultation for pleural drainage (catheter or chest tube).
- A plate of size and strength commensurate with the patients' size and compliance should be used. In general, 3.5-mm compression plates or precontoured plates are ideal, especially for larger individuals (>150 lb) or those who will rehabilitate aggressively.
- IM fixation is reserved for simple fracture patterns (transverse and short oblique fractures).
Reduce the risk of refracture by avoiding routine plate removal. If required, wait a minimum of 2 years following fracture union before performing hardware removal (Table 38-8).

**Plate or Hook Plate Fixation of Displaced Fractures of the Lateral Clavicle**

**Preoperative Planning.** A careful examination of the skin over the lateral clavicle and planned operative site is important. As with midshaft fractures, temporizing until the soft tissue status improves may be prudent. The major technical challenges in these injuries are purchase in the distal fragment and resisting the primary displacing forces, which draw the proximal fragment superiorly and the distal fragment (secured by the AC and coracoclavicular ligaments to the coracoid and scapula) inferiorly.\(^4,23,42,77,83,130\) In addition, the cancellous bone of the distal fragment may be inferior in quality to that of the shaft, and there may be unrecognized comminution. The treating surgeon should template the fracture preoperatively to determine the number of screws that will have purchase in the distal fragment. There are a number of precontoured “anatomic” plates available for this purpose. If it is anticipated that there will be insufficient distal purchase then alternative fixation strategies are necessary.

**Figure 38-30**

- **A:** Anteroposterior radiograph with 20-degree cephalad tilt demonstrating a completely displaced midshaft clavicle fracture with shortening. There are often vertically oriented fracture fragments that arise from the anterosuperior surface of the clavicle at the site of displaced midshaft fractures, giving many fractures a “Z” pattern. If possible, they should be gently teased back into place and fixed with small or minifragment screws, followed by plate fixation. It is important not to denude the fragment when attempting to fix it. Reduction is performed by reducing the vertical intercalated fragment to the distal fragment and securing it with a 2.7-mm lag screw. The distal assembly is then reduced to the proximal fragment with the aid of two towel clip reduction forceps, followed by plate fixation with a precontoured plate.
- **B:** Postoperative radiograph revealing restoration of length and anatomic reduction.

**Table 38-8 Potential Pitfalls and Prevention—Operative Treatment**

<table>
<thead>
<tr>
<th>Pitfall</th>
<th>Prevention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor patient selection</td>
<td>Young, active patients with displaced fractures benefit from primary fixation: Poor bone quality, medical comorbidities, and noncompliance negatively affect outcome. Substance abusers have a dramatically higher complication and reoperation rate. Nonoperative care is preferred in these individuals</td>
</tr>
<tr>
<td>Deep wound infection with exposed hardware</td>
<td>A two layer closure, consisting of a deep myofascial layer and a superficial skin/subcutaneous tissue layer, will help decrease or eliminate this potential complication</td>
</tr>
<tr>
<td>Plate breakage</td>
<td>Use a strong plate consistent with the size, demands, and compliance of the patient. Most precontoured plates approach the biomechanical strength of a compression plate. Avoid 3.5-mm reconstruction type plates, especially in larger individuals</td>
</tr>
<tr>
<td>Hardware irritation</td>
<td>Use a precontoured plate, especially in an individual of smaller stature</td>
</tr>
<tr>
<td>Loss of reduction and shortening</td>
<td>Avoid unlocked or small diameter intramedullary devices in complex or comminuted fracture patterns. Obtain lag screw fixation if possible, and a minimum of six cortices on either side of the fracture site, when using plate and screw fixation</td>
</tr>
<tr>
<td>Nonunion after operative fixation</td>
<td>Avoid excessive soft tissue stripping at the fracture site. Small comminuted fragments should be teased into the best position possible and secured with screws or suture. Soft tissue attachments are preserved</td>
</tr>
</tbody>
</table>
need to be considered. These can include augmenting fixation into the coracoid process or achieving purchase to or under the acromion. In this instance the use of a hook plate (a pre-contoured plate with a projection or “hook” that is inserted posteriorly in the subacromial space) can be extremely useful, especially with very distal fractures.51,56,98

**Patient Positioning.** Patients are positioned in the “beach-chair” or semisitting position, similar to the position used for midshaft fractures. A small pad or bump is placed behind the involved shoulder to elevate it into the Surgical field. The head is placed on a round support and rotated out of the way of the operative field. Recently, frames and supports designed to give greater exposure of the shoulder (i.e., for shoulder arthroscopy) have become popular. This type of operative set-up can also be used, and may facilitate intraoperative radiography. It is not usually necessary to free-drape the involved arm, although this can be done if there is any difficulty anticipated with the reduction (i.e., if the fracture is severely displaced or greater than 2 to 3 weeks old).

**Surgical Approach.** The surgical approach is similar to that used for superior plating of the clavicle. A skin incision placed directly superiorly over the distal clavicle, extending approximately 1 cm past the AC joint is made. The skin and subcutaneous layer is developed, and the deltotrapezial myofascial layer is incised directly over the distal clavicle and reflected anteriorly and posteriorly. The AC joint is identified. This can be done by inserting an 18-gauge needle into the joint from the superior aspect, and an arthrotomy can be avoided. It is possible to use an anterior/inferior approach for plate fixation of distal clavicle fractures although in my experience this involves a significant amount of detachment of the deltoid and it is not possible to convert easily to coracoclavicular screw augmentation or hook plate fixation.204

**Technique.** The fracture site is identified and cleaned of debris and hematoma. The fracture is reduced and it may be held with either a K-wire or a lag screw. Elevating the distal fragment to meet the proximal fragment may aid in reduction. If the main fracture line is in the coronal plane, it may be possible to lag the fracture from anterior to posterior through a small anterior stab incision separate from the primary incision. Once the fracture is reduced and provisionally stabilized, the optimal type of plate is chosen. Anatomic plates that fit the distal clavicle are now available, and placing four bicortical, fully threaded, cancellous screws in the distal fragment should be the goal (Fig. 38-31). Following fixation, the surgeon must judge whether the number and quality of distal fragment screws are sufficient to provide stability until union occurs. If fixation is judged to be inadequate, there are several options at this point. Since the primary deforming force at the fracture site is superior displacement of the proximal fragment, it is possible to augment fixation by securing the proximal fragment to the coracoid with a longer screw inserted through one of the plate holes (Fig. 38-32). This screw, typically 30 to 40 mm long, helps secure the proximal fragment to the coracoid and prevents this superior displacement. Since there is some intrinsic motion between the clavicle and the coracoid and scapula, with time this screw either loosens or it may break, but it will give 6 to 8 weeks of stability to secure fracture healing before doing so. Alternatively, it may be necessary to augment fixation by using a hook plate with fixation under the acromion to prevent superior migration of the proximal fragment. This technique is selected when there is insufficient bony purchase in the distal fragment with conventional screws.53,56,98 This may be readily apparent during preoperative planning (Fig. 38-33), or may only be realized intraoperatively. The advantage of subacromial fixation is that conventional plating can be rapidly converted to this technique intraoperatively. The AC joint is identified,

**FIGURE 38-31** Anteroposterior radiograph of a displaced distal clavicle fracture in a 38-year-old physician following a fall off a mountain bike at high speed (A). Although the fracture was closed, there was significant bruising and swelling over the shoulder. The degree of displacement of this fracture suggests a high likelihood that of delayed union or nonunion would result with nonoperative treatment. After the soft tissue swelling had subsided 10 days post injury, operative fixation was performed with a plate specifically designed for the distal clavicle, allowing for the placement of four screws in the small distal fragment (B). The fracture healed uneventfully and the patient was able to return to work within a week of the surgery. A final follow-up radiograph (C) following hardware removal for local soft tissue irritation, a common problem in this area, shows solid union.
and the posterior edge of the distal clavicle is dissected free. An entrance into the subacromial space is then made with a pair of heavy curved scissors that will create the path of the “hook” extension of the plate. It is important that this space is made posteriorly, so that there will be no impingement of the rotator cuff in the critically tight anterior subacromial space. Once this path has been created, the hook is placed in it and the plate reduced to the shaft of the clavicle. Several different hook depths and lengths are currently available for this plate, and trial reductions can be performed to determine the optimal plate type. Alternatively, the plate can be “walked down” onto the clavicular shaft by sequential placement of the screws from distal to proximal. This can be a very effective technique of fracture reduction as this maneuver “levers” the distal fragment to the proximal fragment. On occasion, it may be necessary to contour the shaft of the plate to prevent over-reduction of the fracture; however, if excessive contouring appears to be required, a more likely explanation is that the fracture is not reduced and that there is residual superior angulation. It is possible to securely repair even very distal fractures (that are essentially AC joint fracture-dislocations) with this technique. Minimal, if any, purchase is required in the distal fragment.

**FIGURE 38-32** A: It is possible to augment fixation in distal clavicle fractures with poor-quality bone or a very small distal fragment by placing a screw through the plate into the coracoid process, which helps resist the forces that displace the fracture (superior displacement of the proximal fragment, inferior displacement of the distal fragment). Since there is 10 to 15 degrees of rotational motion between the clavicle and the coracoid, this fixation will eventually loosen (as it has in this case) or break (B). However, typically it provides augmented fixation for 6 to 8 weeks postoperatively, which is usually enough for the fracture to heal.

**FIGURE 38-33** A: Anteroposterior radiograph of a very distal clavicle fracture in a 22-year-old female pedestrian struck by a street car. The fracture was open with significant soft tissue damage, near transection of the superior deltoid and trapezius, and severe instability of the shoulder girdle. It can be anticipated that conventional plating may be inadequate given the small size of the distal fragment and the associated shoulder girdle instability. B: The radiograph following irrigation and debridement, hook plate fixation, and deltoid/trapezial muscle repair. Early motion was initiated and an excellent result ensued.
Unlike static fixation across the AC joint which is doomed to loosening or fatigue failure, hook plate fixation allows some motion between the bone. A cadaver study revealed that this technique most closely reflected the biomechanics of the native AC joint, namely secure enough to provide reliable fixation yet physiologically flexible. Following fixation, the wound is thoroughly irrigated and a two-layer closure similar to that for midshaft fractures is performed.

Postoperative Care. The arm is placed in a sling and the patient is allowed early active motion in the form of pendulum exercises. At 10 to 14 days postoperatively the wound is checked and the stitches are removed. The sling is then discarded and full range-of-motion exercises are instituted; sling protection can be extended if the quality of fixation is questionable. At 6 to 8 weeks, if radiographs are favorable, resisted and strengthening exercises are instituted. Return to full contact or unpredictable sports (i.e., mountain biking) is usually discouraged until 12 weeks postoperatively. While hardware removal is typically optional for those with conventional plates, it can be anticipated that a high percentage of individuals with hook plate fixation will require plate removal to regain terminal shoulder flexion and abduction (see Hardware Removal). This is usually performed at a minimum of 6 months postoperatively.

Potential Pitfalls and Preventative Measures

- The rate of delayed union and nonunion for completely displaced distal clavicle fractures treated nonoperatively is approximately 40%.
- Even minimally displaced fractures may take an excessive period of time to heal, or may develop a fibrous union. However, without displacement, they are often not symptomatic enough to warrant surgical intervention.
- The technical challenge faced during operative treatment of distal clavicle fractures is the fixation of the distal fragment; the surgeon should be prepared to deal with unexpected comminution or poor screw purchase in the distal fragment using anatomic plates, coracoclavicular fixation, or hook plates.
- Hook plate fixation is an effective alternative to conventional plate fixation when faced with inadequate distal purchase. To avoid subacromial impingement, the hook should be placed posteriorly.
- A high percentage of patients treated with hook plate fixation will require plate removal to regain full range of shoulder motion.
- Rigid transacromial fixation has a high rate of loosening and fatigue failure due to the intrinsic motion at the AC joint and is therefore not routinely recommended.

Outcomes. There are a number of studies that define the outcome of nonoperatively treated fractures of the distal clavicle. The largest and most comprehensive is by Robinson et al. who examined a cohort of 127 nonoperatively treated patients with follow-up of 101 these individuals. The mean Constant score was 93 points, although this excluded 14 patients (14%) with symptoms severe enough to warrant delayed surgical intervention. Interestingly, although 21 patients (21%) had a radiographic nonunion, they were minimally symptomatic and their outcome scores (Constant, SF-36) were no different than those in patients with uneventful union. They concluded that nonoperative treatment achieved good results in middle-aged and elderly patients, with only a small percentage (14%) requiring delayed surgery. These results were mirrored by Rokito et al. who compared 14 patients treated operatively for displaced distal third fractures with 16 nonoperatively treated patients and found no difference in ASES, Constant, or UCLA shoulder scores despite the fact that 7 (of 16) patients in the nonoperative group developed a radiographic nonunion. In a systematic review of 425 patients (21 studies), Oh et al. described a nonunion rate of 33% in the 60 patients treated nonoperatively, but noted that little functional deficit occurred. It is clear from these studies that although the nonunion rate is relatively high following the nonoperative treatment of displaced distal clavicle fractures, functional deficit (especially in middle-aged and elderly patients) is minimal and conservative care should, at present, be considered acceptable in most cases. The same study by Oh et al. described the outcome following various surgical interventions in 365 patients, and recommended that coracoclavicular fixation was preferred due to its low complication rate (4.8%) compared to hook plate fixation (40.7%) or K-wire tension banding (20.0%). IM fixation was also associated with a low complication rate (2.4%) but the number of cases amenable to this type of fixation is limited. In direct comparisons of surgical techniques, Tan et al. reported equivalent union rates between hook plate fixation and small fragment T plate fixation (100%), but that more patients in the hook plate group had residual shoulder pain that required hardware removal (15/23, 74%) for relief. Klein et al. compared early versus late distal clavicle fracture repair with hook plate fixation (22 patients) and superior locked plate application (16 patients). They found a high rate of success (union in 36/38 patients), but that fractures repaired early (<4 weeks) had better outcomes than the delayed group (ASES score 78 vs. 65), with a lower complication rate (7% early vs. 36% delayed). Unfortunately, there are few prospective or randomized trials examining distal clavicle fractures. In the absence of high-quality evidence, we must rely on available information that would suggest that the majority of these injuries should be treated nonoperatively initially, especially in middle-aged or elderly individuals. Operative intervention is reserved for severely displaced fractures, high-demand patients, or for failures of nonoperative care: In these cases a variety of methods (hook plate repair, coracoclavicular fixation, tension-band wiring, etc.) can have a high degree of success.

Medial Clavicle Fractures

There are very few reports on medial fractures of the clavicle, a rare entity. Low et al. reported the successful treatment of five cases of completely displaced medial clavicle fractures using internal fixation (plates and/or screws). They stressed the importance of preoperative imaging as this area is difficult to visualize with plain radiographs. In a similar series, this
was emphasized by Oe et al., who reported on 10 cases of medial clavicular fracture. The medial clavicular epiphysis is the last long bone epiphysis to fuse in the body, and may persist in patients until 25 to 30 years of age. Therefore, medial clavicular fractures are often epiphyseal fracture-subluxations or fracture-dislocations. This can be defined by the preoperative CT scan. There is little in the way of evidence-based medicine to dictate treatment, with the majority of information on this entity contained in small retrospective case series. Fractures that are significantly displaced may warrant operative repair, especially if there is posterior displacement. The primary technical difficulty with these injuries is the fixation in the medial fragment. The surgical approach is similar to that made to the shaft. It is important to remember that the subclavian vessels are in close proximity to the bone medially. Following identification, debridement, and reduction of the fracture, it can be temporarily held reduced with K-wires. Definitive plate fixation can then be performed in a variety of ways. If the medial fragment is large enough, then standard plate and screw fixation can be performed; a plate with an expanded end section (as in a distal clavicle plate from the contralateral side) may augment multiple screw purchase. There is a significant expansion of the medial clavicle (Fig. 38-17) and this allows for placement of longer (22 to 24 mm) cancellous screws. If there is insufficient purchase, than the plate can be extended across the joint onto the sternum. This construct will eventually loosen due to motion at the SC joint, but will typically stabilize the fracture long enough (3 months) for union to occur, at which point the plate should be removed. Rarely, fixation with a hook plate intratransternally or retrosternally may be required. This is a highly specialized technique and cardiovascular support should be available in the event of inadvertent injury to the vascular structures found retrosternally. Fixation of the fracture using smooth wires or pins alone is contraindicated, due to the potential for migration and visceral injury.

Management of the “Floating Shoulder”

The combination of ipsilateral fractures of the clavicle and scapular neck has traditionally been called the “floating shoulder,” which has been considered to be an unstable injury that may require operative fixation. In fact, this injury pattern can be considered to be a subgroup of the “double disruption of the superior shoulder suspensory complex (SSSC),” a concept introduced by Goss. This describes the bone and soft tissue circle, or ring, of the glenoid, coracoid process, coracoclavicular ligaments, clavicle (especially its distal part), AC joint, and acromion. This complex is extremely important biomechanically, as it maintains the anatomic relationship between the upper extremity and the axial skeleton. The clavicle is the only bony connection between the two, and the scapula is suspended from it by the coracoclavicular and AC ligaments. Thus, any injury that disrupts this ring at two or more locations is considered inherently unstable and one whose cumulative effect may be greater than the sum of its individual constituents. Long-term functional problems have been reported following significantly displaced injuries of this nature, including shoulder weakness and stiffness, impingement syndrome, neurovascular compression, and pain. Such injuries have been considered relative indications for operative intervention (Fig. 38-9). Combined scapular (or glenoid) neck and clavicle fractures are the commonest type of double disruptions of the SSSC, and there remains considerable controversy over optimal treatment.

A study by Leung and Lam described good or excellent results in 14 of 15 patients with this injury pattern following fixation of both the clavicle and glenoid fractures. However, Herscovici et al. described excellent results in seven of nine patients who had their floating shoulder treated with reduction and fixation of the clavicular fracture only. These findings were confirmed in a study by Rikli et al. who performed clavicle fixation is isolation in 11 patients with combined clavicle and glenoid fractures. They described an average final Constant score in the operated shoulders of 95% of the unaffected side. These studies support the concept, in selected cases, of clavicular fracture reduction and fixation alone. It is postulated that reduction of the clavicle helps to reduce and stabilize the glenoid fracture, eliminating the requirement for operative fixation of the glenoid. This is an important point, since open reduction and internal fixation of the glenoid can be a difficult and complex procedure with a high complication rate, especially if the surgeon lacks experience in this anatomic area.

There are also reports that support nonoperative management of this injury. Ramos et al. described the results of nonoperative treatment in 16 patients with ipsilateral fractures of the clavicle and glenoid. Eleven patients had a complete recovery to near-normal status, although one had a significant malunion of the glenoid neck and three had significant shoulder asymmetry. Edwards et al. reported good results (“pleased” or “satisfied”) in 16 of 20 patients with floating shoulder injuries treated nonoperatively. There were four patients who were “dissatisfied” or “unhappy” with their outcome. While the outcome assessment of these patients was suboptimal it would appear that nonoperative treatment may be considered, especially for minimally displaced fractures. Interestingly, two of the four patients with poor results had severely displaced clavicular fractures. In a clinical study, Williams et al. evaluated 9 of 11 patients with a floating shoulder treated nonoperatively and found five excellent, one good, and three fair results. They found that the worse clinical results were strongly associated with 3 cm or more of medial displacement of the glenoid, and recommended nonoperative care for lesser amounts of glenoid displacement. Similarly, van Nort et al. performed a questionnaire review including 31 of 35 floating shoulder patients treated nonoperatively and found that only 3 required late operative reconstruction for clavicular malunion or nonunion. They found that results in the nonoperative group (a mean Constant score 76) deteriorated with increasing degrees of glenoid displacement. Interestingly, they also found that three of the four patients who had their clavicle fracture fixed primarily had a poor result due to scapular malunion. They believed that this failure...
of indirect glenoid reduction following clavicular reduction and fixation was due to associated ligamentous injuries that caused a dissociation of the two structures.

There is some limited biomechanical evidence to support the intuitive clinical finding that increasing degrees of fracture displacement in floating shoulder injuries corresponds to poorer results if left unreduced. Williams et al. performed a cadaver biomechanical study by establishing a scapular neck fracture and investigating the effect of an ipsilateral clavicle fracture, a coracoacromial ligament injury, and an AC ligament injury. They found that substantial instability (lack of resistance to a medially directed force) only occurred after associated ligamentous disruption. Although there are limitations to this study (such as the uniaxial direction of the applied deforming force), it remains one of the only biomechanical studies on this topic.

Unfortunately, given the variable and sporadic nature of this injury, there is a paucity of prospective, randomized, or comparative trials upon which to base treatment recommendations. What is clear is that earlier recommendations for routine operative fixation for all floating shoulder injuries were too liberal, and that poor results occur regularly with badly displaced fractures that are treated nonoperatively. In addition, the aggressiveness of treatment must be commensurate with the risk of intervention and the expected functional demands of the patient. Thus, an operative approach may be indicated in a young healthy individual who works overhead for a living whereas the same fracture pattern may be treated nonoperatively in an elderly, low-demand patient with multiple medical comorbidities. Further research in this area may help identify currently unknown factors that may predict outcome and hence guide treatment. Currently, standard operative indications include the following:

1. A clavicle fracture that warrants, in isolation, fixation
2. Glenoid displacement of greater than 2.5 to 3 cm
3. Displaced intra-articular glenoid fracture extension
4. Patient-associated indications (i.e., polytrauma with a requirement for early upper extremity weight bearing)
5. Severe glenoid angulation, retroversion, or anteversion >40 degrees (Goss Type II)
6. Documented ipsilateral coracoacromial and/or AC ligament disruption or its equivalent (coracoid fracture, i.e., AC joint disruption)

If operative intervention is chosen, then anatomic reduction and internal fixation of the clavicle is typically performed first, and the shoulder then reimaged. If there is indirect reduction of the glenoid such that its alignment is within acceptable parameters, then no further intervention is required apart from close follow-up. If the glenoid remains in an “unacceptable” position, then fixation of the glenoid neck, typically performed through a posterior approach, is indicated (see “Fractures of the Scapula, Chapter 39”). Also, Oh et al. reported the failure of isolated clavicle fixation in two cases of floating shoulder. If this method is chosen in this setting, the clavicle may experience greater loads than with isolated fractures, and the size and length of the fixation device selected should be commensurate with these anticipated loads (Table 38-9).

### Table 38-9 Management of Expected Adverse Outcomes and Unexpected Complications

<table>
<thead>
<tr>
<th>Clavicle Fractures Common Complications</th>
<th>Prevention</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infection</td>
<td>Careful technique, short operative times, prophylactic antibiotics</td>
<td>Irrigation, debridement, local and intravenous antibiotics, maintain fixation if stable, remove if loose</td>
</tr>
<tr>
<td>Nonunion</td>
<td>Primary fixation reduces nonunion rate in selected cases</td>
<td>Plate or IM pin fixation, add iliac crest bone graft or osteoinductive bone substitute if atrophic</td>
</tr>
<tr>
<td>Malunion</td>
<td>Primary fixation reduces symptomatic malunion rate in selected cases</td>
<td>Corrective osteotomy and plate fixation</td>
</tr>
<tr>
<td>Neurovascular injury</td>
<td>Careful technique to avoid iatrogenic injury (see text)</td>
<td>Treatment of established injury difficult, and usually expectant. Prevention is the key (see text)</td>
</tr>
<tr>
<td>Hardware failure</td>
<td>Use a plate strong enough for size, activity level, and compliance of patient. Precontoured plates ideal, 3.5-mm reconstruction plates should be avoided</td>
<td>If fracture site stable and not displaced, it may heal with observation. Most cases will require revision ORIF with stronger plate, ± iliac crest bone graft to promote healing</td>
</tr>
<tr>
<td>Hardware prominence</td>
<td>Use a precontoured plate, especially in smaller individuals</td>
<td>Hardware removal, minimum 2 years post implantation</td>
</tr>
<tr>
<td>Refracture</td>
<td>Avoid plate removal, if necessary, for 2 years after fixation</td>
<td>If minimally displaced, may heal with nonoperative Rx. If displaced or unstable, repeat ORIF indicated</td>
</tr>
<tr>
<td>Scapular winging</td>
<td>Due to residual clavicular malposition (malunion, nonunion), Primary fixation lessens incidence</td>
<td>Corrective clavicular surgery with plate or IM pin may be indicated if symptoms severe</td>
</tr>
</tbody>
</table>
MANAGEMENT OF EXPECTED ADVERSE OUTCOMES AND UNEXPECTED COMPLICATIONS IN CLAVICLE FRACTURES

Infection in Clavicle Fractures

Infection had traditionally been one of the most feared complications following fixation of displaced clavicular fractures, and earlier series described an unacceptably high rate of deep infection. However, significant improvements have been made in a number of areas that are well recognized to decrease infection, including perioperative antibiotics, selective operative timing with regard to soft tissue conditions, better soft tissue handling, two-layer soft tissue closure, and fixation which is superior biomechanically. In a recent meta-analysis that examined operative series from 1975 to 2005, Zlowodzki et al. reported a superficial infection rate of 4.4%, and a deep infection rate of only 2.2%; these figures are significantly improved compared to earlier studies. When infection does occur, if it is superficial, then it is usually possible to temporize with local wound care and systemic antibiotics until fracture union has occurred. At that point, plate removal, debridement, and thorough irrigation have a high success rate in infection eradication.

Deep infection with unstable implanted hardware is a more complex problem. If it appears that there is progressive bone formation, then temporizing until union occurs followed by hardware removal and debridement may be successful. If there is no obvious progress toward union, then operative intervention is indicated. Hardware removal followed by radical debridement of infected bone and dead or devitalized tissue and subsequent irrigation is performed. At this point there are several options. If the patient is healthy without comorbidities (as is usually the case) and the infecting organism is a sensitive one, then immediate reconstruction with plating, bone grafting, and local antibiotics may be warranted. Alternatively, especially with polymicrobial infections or resistant organisms (i.e., methicillin-resistant Staphylococcus aureus), local antibiotic impregnated polymethylmethacrylate cement beads, or an antibiotic impregnated bone substitute are implanted into any residual dead space following debridement, and systemic antibiotics are administered until clinical and hematologic markers indicate the infection has been eradicated. Delayed reconstruction can then be performed. If there is a significant soft tissue deficiency, then the assistance of a plastic surgeon who can perform soft tissue coverage, typically with a rotational pectoralis major flap, is ideal.

Nonunion in Clavicle Fractures

Traditionally, the rate of nonunion of the clavicle has been described as being less than 1% of all fractures. This was based on two sentinel studies, one by Neer in 1960 that described 3 nonunions in 2235 patients, and one by Rowe in 1968 in which only 4 of 566 patients developed nonunion after a fracture of the clavicle. More recently, however, the nonunion rate following closed treatment of completely displaced midshaft fractures of the clavicle has been described as being exponentially higher, in the 15% to 20% range. The reason for this difference is unclear but probably includes more complete follow-up in recent studies, the exclusion of children (with their inherently good natural history), changing mechanisms of injury (mountain biking, all-terrain vehicles, parachuting), and the modern patients’ intolerance of prolonged immobilization. In addition, several prospective population-based studies have been helpful in elucidating factors associated with the development of nonunion (Fig. 38-21). Robinson et al. identified increasing age, female sex, fracture displacement, and comminution as risk factors for nonunion in midshaft fractures. Lateral third fractures had higher nonunion rates as patient age and fracture displacement increased. Nowak et al. prospectively followed 208 patients with radiographically verified clavicle fractures and, 9 to 10 years post injury, found that 96% (46%) still had sequelae. They identified no bony contact between the fracture fragments as the strongest predictor for sequelae. Nonunion occurred in 15 patients (7%). Zlowodzki et al. performed a meta-analysis of all series of displaced midshaft fractures from 1975 to 2005 and identified 22 published manuscripts. They found that, for the specific entity of completely displaced midshaft fractures of the clavicle, the nonunion rate with nonoperative treatment was 15.1%, while the nonunion rate following operative treatment was 2.2%. This represents a relative risk reduction (for nonunion) of 86% (95% CI 71% to 93%). This meta-analysis, in addition to recent prospective studies examining primary operative fixation of clavicle fractures, definitively terminated the postulation that primary fixation was associated with a higher, not lower, nonunion rate (Table 38-1). This observation was based on early operative studies with poor patient selection, inadequate fixation (Figs. 38-26 and 38-27) and inferior soft tissue management. Undoubtedly there are other factors that contribute to the incidence of nonunion (i.e., associated fractures, soft tissue interposition, rotation at the fracture site) that have yet to be clarified. Therefore, at the present time, factors associated with the development of nonunion include complete fracture displacement (no contact between the main proximal and distal fragments), shortening of greater than 2 cm, advanced age, more severe trauma (both in terms of mechanism of injury and associated fractures), and refracture. Primary operative fixation however is not associated with a higher nonunion rate.

Nonunion is defined as the lack of radiographic healing at 6 months post injury (Fig. 38-34). While a significant percentage of distal nonunions may be asymptomatic, especially in the elderly, the majority of midshaft nonunions in young active individuals will be symptomatic enough to require treatment.

FIGURE 38-34. An atrophic nonunion of the clavicle. The degree of bone loss demonstrated in this case suggests that an intercalary graft may be required to restore length and obtain union.
A variety of methods have been described for the treatment of an established clavicular nonunion that is symptomatic enough to warrant operative intervention.\textsuperscript{11,12,30,32,33,40,50,75,76,94} Successful nonunion repair usually decreases pain and improves function. Described methods range from noninvasive techniques such as electrical stimulation and low-intensity ultrasound to minimally invasive techniques (isolated bone grafting, screw fixation) to formal open reduction and internal fixation with iliac crest bone grafting. Apart from isolated case reports, or cases described in larger series of standard treatments, there is very little objective evidence to support the use of electrical stimulation or ultrasound in this area.\textsuperscript{13,30,32} In rare cases where there is minimal deformity or shortening, a stable hypertrophic nonunion with good soft tissue coverage and no infection, and a biologically favorable host (i.e., no smoking or diabetes), such techniques may occasionally be successful in promoting union. However, the majority will require mechanical stabilization and biologic stimulation.

There are two main techniques used to achieve union, plate fixation, and IM screw or pin fixation. The gold standard treatment against which other methods must be compared is open reduction and internal fixation with a compression plate and iliac crest bone graft. Reported success rates with this technique are high if appropriate size and length plates are used. Manske and Szabo (20/21 healed), Eskola et al. (20/22 healed), Jupiter and Lefert (16/19 healed), Boyer and Axelrod (7/7 healed), Olsen et al. (16/17 healed), and Bradbury et al. (31/32 healed) all describe excellent results with a low complication rate.\textsuperscript{11,12,50,75,94,133} It is important to note that the forces generated by deformity correction and the longer healing time will mean that the operative construct for a nonunion will require greater stability for a longer period of time than that for an acute fracture. Multiple authors stress that short four-hole plates, weak 1/3 tubular plates, or even 3.5-mm pelvic reconstruction plates (often under a local anesthetic) are proposed benefits compared to formal open reduction and internal fixation with a compression plate and IM fixation is required to define their respective roles in this setting.

Severe bone loss and/or poor bone quality, typically associated with multiple failed operative procedures and infection, can complicate the reconstruction of recalcitrant clavicular nonunions. The final treatment option in such circumstances is clavicular excision, or claviculectomy (either partial or total).\textsuperscript{30,32,202} Considering the important strut effect of the clavicle for upper extremity function, and the availability of modern treatment options, this must be considered a salvage procedure. While reasonable results with retention of a full range of motion and relief of pain have been described in selected cases with severe preoperative pathology, a significant decrease in strength (especially overhead) and a loss of shoulder girdle stability typically result.

My preferred surgical treatment for a midshaft nonunion of the clavicle is open reduction and internal fixation with a precontoured anatomic clavicular plate with the addition of an iliac crest bone graft or an osteoinductive bone graft substitute. Patient positioning and draping is similar to that used for the fixation of acute midshaft fractures, with the exception of having an iliac crest bone graft site prepared (typically the contralateral side) if bone grafting is anticipated (see below). The surgical approach is similar to that used for a fracture, taking care to reflect and preserve the myofascial layer for later closure, and the superior surface of the clavicle at the nonunion site is identified. The ends of the nonunion are identified, and judicious soft tissue dissection is performed around them to allow correction of deformity. This usually involves bringing the distal fragment out to length and translating it superiorly and posteriorly. The distal fragment is often rotated anteriorly, and derotating it brings the flat superior surface directly superiorly, facilitating plate placement on the superior surface. The sclerotic ends of the proximal and distal fragments are identified and a rongeur is used to clear them back to bleeding bone. It is rarely necessary to resect excessive bone to do this. The medullary canals are then re-established with a drill to allow the free egress of osteoprogenitor cells to the nonunion site. Reduction forces are then placed on the proximal and distal fragments and a reduction is performed. Remembering that there is a slight apex superior bow to the native clavicle, excess superior callus is rongeured away to allow the plate to fit on the superior surface of the clavicle. Any excess callus removed in the approach, debridement or deformity correction is saved, morcelized and inserted into the fracture site at the conclusion of the procedure. If possible, the nonunion is then fixed with an anterior to posterior small- or minifragment lag screw (Fig. 38-35). The chance of success of this helpful step can be increased by recognizing the orientation of the nonunion line during the approach and debridement. Lag screw fixation helps hold the reduction while the plate is applied and also increases the construct stability. If this is not possible than a 2-mm K-wire can be inserted to hold the reduction while a precontoured clavicle plate is applied to the superior surface. I typically use an eight-hole plate. This allows for one or even two empty holes at the nonunion site (often necessary due to
bony configuration or lag screw interference) while providing for three bicortical screws both proximal and distal, which I consider to be the absolute minimum for fixation. If the nonunion is transverse in nature the first screws on each side are inserted in a compression mode, and tightened after the provisional K-wire has been removed. Although they are available, I have not found it routinely necessary to use locking screws or plates in the clavicle.

If the nonunion is hypertrophic (the minority) then the morcellized autograft from the local bone is applied to the nonunion site and a standard closure, as for a fracture case, is performed. Thorough irrigation and hemostasis is achieved before closure, and drains are not used.

If the nonunion is atrophic, then either morcellized autograft from the iliac crest or an osteoinductive bone substitute, such as a bone morphogenetic protein, is packed in and around the nonunion site. Bone substitutes with little osteoinductive capability, such as calcium phosphates or sulfates, allograft, or demineralized bone, are to be avoided. A structural or intercalary graft may be required in certain cases where there has been excessive loss of length or failed previous surgery. Shortening can often be determined preoperatively by comparing the length of the clavicle radiographically to the measured clinical length. If there appears to be significant bone loss then an intercalary graft, as per the technique of Jupiter and Ring, can be employed. Postoperative care is similar to that following malunion reconstruction or acute fracture fixation.

**Malunion in Clavicle Fractures**

Traditionally, it was believed that malunion of the clavicle (which was ubiquitous with displaced fractures) was of radiographic interest only, and success in the clinical setting was defined as fracture union. However, more recently, a number of investigators have described a fairly consistent pattern of patient symptomatology (with orthopedic, neurologic, “functional,” and cosmetic features) following malunion of displaced midshaft fractures of the clavicle. While all of the factors that contribute to the development of this condition are unclear; it is typically diagnosed in young, active patients with significant degrees of shortening at the malunion site (Fig. 38-36). As could be reasonably anticipated, shortening of the shoulder girdle (with the typical inferior displacement and anterior rotation of the distal fragment) results in a variety of biomechanical and anatomic abnormalities that translate...
directly into patient complaints. Orthopedically, shortening of the muscle-tendon units that traverse the malunion site results in a sense of weakness and rapid fatigability, with a loss of endurance strength. It has been previously shown that there are significant, objective, deficits in maximal strength and endurance (especially of abduction) following the healing of displaced midshaft fractures of the clavicle treated nonoperatively (Fig. 38-37).99,172 Narrowing and displacement of the thoracic outlet (the inferior border of which is the clavicle) result in numbness and paraesthesias, usually in the C8 to T1 nerve root distribution, exacerbated by provocative overhead activities. Due to their deformity, patients complain of the appearance of their shoulder and difficulty with backpacks, hiking packs, military gear, and shoulder straps: This has been termed a deficit in “functional cosmesis.” Patients with this condition also complain of upper back pain and periscapular aching, especially with repetitive activity. There is objective evidence that the displacement of the distal fragment (to which the scapula is attached) results in malalignment of the scapulothoracic joint and a form of scapular winging; this produces periscapular muscle spasm and fatigue pain.64,146

It would appear that the predominant risk factor for the development of this condition is shortening at the malunion site. Gossard69 found that shortening of 2 cm or more was associated with poor functional outcome and a high rate of patient dissatisfaction. McKee et al.103 described a series of 15 patients with a symptomatic clavicular malunion who had a mean amount of shortening of 2.9 cm and Bosch et al.9 described an “extension osteotomy” in 4 patients with shortening of 0.9 to 2.2 cm. In a retrospective study, Eskola et al.19 reported on 83 patients with displaced fractures and found that shortening of 1.2 cm or more was associated with increased pain at final follow-up. However, this point remains controversial. In retrospective reviews, Nordqvist et al.124 (225 midshaft clavicle fractures) and Oroko et al.135 (41 midshaft clavicle fractures) could not demonstrate a relationship between shortening and a poor outcome. It is probable that length is just one component of a complex three-dimensional deformity that, combined with the intrinsic variability of human response to skeletal injury, explains why some individuals with a malunion function well and others determinedly seek operative correction. For patients with a symptomatic malunion who have failed a course of physiotherapy for muscle strengthening, the options are to accept the disability or have a corrective osteotomy.

Operative intervention is reserved for patients with signs and symptoms of malunion that are specific to the condition and sufficiently severe to warrant surgery. A vague and generalized ache about the shoulder (especially in a patient with medical–legal or compensation issues) and a radiographic malunion is not necessarily an indication for surgery. Patients selected for surgery are typically young, active, and healthy with good bone stock. The primary goal of surgery is to correct the deformity, and preoperative planning is important (Fig. 38-38). Careful measurement both clinically and radiographically defines the degree of length to be restored. A posteroanterior thorax or chest radiograph that includes both clavicles has been shown to be a reliable way of comparing length to the opposite (normal) clavicle.172 Inferior displacement and anterior rotation of the distal fragment is corrected by having the plate applied to the superior surface flush both medially and laterally; some contouring of the plate may be required in the anterosuperior plane as there is a slight caudal bow to the clavicle.

Patient positioning and the surgical approach are similar to those used for acute fracture fixation or nonunion repair.102 The exception is that in certain cases it is prudent to have an iliac crest bone graft site prepared (see below). In general, it has not been routinely necessary to insert an intercalary graft to restore length. It is usually possible to identify the position of the

![Figure 38-37](image-url)
Figure 38-38 A: Anteroposterior radiograph of a symptomatic clavicle malunion with 2.5 cm of shortening. B: The corresponding clinical photograph showing the measurement of clavicular length from the sternal notch to the acromioclavicular joint. C: An intraoperative photograph of the malunion site demonstrating the typical displacement of the distal fragment with medial, inferior, and anterior translation. This also demonstrates the abundant local bone which is usually present at the malunion site. While it is difficult to appreciate, there is anterior rotation of the distal fragment as well. D: An intraoperative photograph following osteotomy of the malunion, recreating the original fracture line and rongeuring of excess callus (which will be used to graft the osteotomy site), and distracting the fragments to their correct length and position. It is typically not necessary to perform an intercalary bone graft, as there is rarely absolute bone loss, and the original proximal and distal fragments can be re-established using a combination of a microsagittal saw and osteotomes. E: An intraoperative photograph following reduction and plate fixation using an anatomic precontoured plate. F: An anteroposterior radiograph following union. The patient’s preoperative symptoms resolved fully.
proximal and distal fragments in most patients. The malunion site is cleared, and a mark is made in the bone proximally and distally and the length is measured. This enables the surgeon to calculate how much length has been gained by remeasuring the distance between the two marks at the conclusion of the osteotomy. Next, the osteotomy to recreate the original fracture and proximal and distal fragments is made with a combination of a microsagittal saw and osteotomes. Care is taken not to violate the subclavicular space. Following the osteotomy, the proximal and distal fragments are grasped with a reduction forceps and gently distracted to the desired position. It is not routinely necessary to free-drape the arm for traction. For difficult cases, a minidistractor can be used to correct length and maintain position while fixation is applied. Care must be taken not to overdistract the fragments as neurologic injury may result. 151 Depending on the configuration of the bone ends, after the osteotomy is performed it is often possible to fashion an interdigitating or step cut contour to improve intrinsic stability and increase the bony surface area for healing. The medullary canals are re-established with a drill, and the osteotomy is temporarily secured with a K-wire. It is then measured for correction of deformity and length. On occasion, an absolute bone deficit may be encountered, such that reduction of the fragments does not restore length. Options at this point include accepting some shortening or using an intercalary graft. This situation can be anticipated preoperatively when the measured clinical shortening (i.e., 3 cm) is significantly greater than the degree of shortening seen on the radiograph of the involved clavicle. Once deformity correction is confirmed, definitive fixation is performed. There are several precontoured “anatomic” plates designed for clavicular fixation that are ideal for this purpose. 70 If a lag screw can be placed across the osteotomy then three additional screws both proximally and distally are usually sufficient. If not, four screws proximally and distally are recommended. Additional local bone can be morcellized and added to the osteotomy site. Wound closure and postoperative care are the same as that for acute fracture fixation or nonunion repair.

Neurovascular Injury in Clavicle Fractures

Despite the proximity of the brachial plexus and subclavian vessels, neurovascular injury is surprisingly rare, given the number of severely displaced clavicular shaft fractures seen in practice. 6,10,18,22,34,36,55,69,147,131,161

In general, neurovascular injuries associated with clavicle fractures can be divided into three groups: Acute injuries, delayed injuries, and iatrogenic injuries.

Acute Injuries

A careful vascular and neurologic examination is critical with any clavicular injury, especially those associated with high-energy trauma. If the signs of vascular injury are present, an angiogram is indicated. In addition to being diagnostic, with the refinement of interventional techniques such as embolization and stenting, the procedure can also be therapeutic (Fig. 38-39). While direct impalement of bony fragments can occur, most neurovascular injuries occur from excessive traction, which in its most severe form is termed scapulothoracic dissociation. The unique feature of these injuries is that the associated clavicular fracture is typically distracted, rather than shortened. This can be a limb or life-threatening injury. A study by Ebraheim et al. reported 3 deaths in 15 patients, and Zelle et al. described 3 deaths and 6 amputations in 22 patients in their series from a major European trauma center. 90,107 If limb salvage is to be performed, shoulder girdle stabilization (typically plate fixation of the clavicle fracture) is indicated to create an optimal healing environment for the soft tissue structures.

Delayed Injuries

Delayed injuries tend to occur due to encroachment upon the thoracic outlet, either from displacement of the borders (i.e., from clavicular displacement due to malunion or nonunion), or encroachment from inferior clavicular callus formation. This phenomenon can be especially severe in patients with a concomitant head injury (Fig. 38-40). In the case reports describing this entity, debridement of local callus with realignment and fixation of the clavicle injury is indicated. 36,47,147 The timing of this intervention is controversial, but in general it should be performed as promptly as the patient’s general condition allows. The commonest reason for brachial plexus irritation following clavicular fracture is the chronic thoracic outlet syndrome (TOS) that results from clavicular malunion (see above). In this setting, operative treatment should be directed toward re-establishing the preinjury dimensions of the thoracic outlet through a corrective clavicular osteotomy. 7,9,21,103

Simply removing the “bump” around the fracture site, or conventional treatments for TOS such as first rib resection have a high failure rate. This is due to the fact that the fundamental anatomical problem is the change in position, orientation, and contour of the thoracic outlet from the displacement of the distal clavicular segment, rather than from local impingement of callus or normal structures (i.e., the first rib). Connolly and Ganjianpour 26 reported the case of a patient with TOS following a clavicular malunion that was treated with first rib resection to no avail, while corrective clavicular osteotomy resulted in prompt resolution of symptoms. Mc Tee et al. 101 reported resolution of TOS symptoms in 16 patients who underwent corrective clavicular osteotomy to treat a malunion. Chronic encroachment upon the thoracic outlet leading to TOS is probably the commonest form of neurovascular “injury” following displaced clavicular fractures.

Iatrogenic Injury

Despite the proximity of the brachial plexus, catastrophic injury from intraoperative penetration by drills or taps is very rare. Shackford and Connolly 168 reported a case of subclavian pseudoaneurysm formation with distal embolization from
A severely displaced midshaft fracture of the clavicle in a fall from a standing height. She also had a partial brachial plexus injury and a partial laceration of the subclavian artery with pseudoaneurysm formation (arrow), demonstrated on the preoperative angiogram (B). The patient was treated with immediate stenting of the resultant pseudoaneurysm, followed by plate fixation of the fracture with a 3.5-mm limited contact dynamic compression plate (C). The indications for fixation included reducing the severe displacement and creating an optimal environment for neurologic and vascular healing. Uneventful bony and soft tissue healing ensued (D).

screw penetration after plate fixation of a clavicular nonunion, and Casselman18 described a similar case. Iatrogenic injury can occur, but is thought to occur in specific situations where distraction can occur. Ring and Holovacs151 described three cases of brachial plexus palsy after IM fixation of clavicle fractures. They postulated that the distraction of the fracture site (a prerequisite for reduction and pin insertion) and the delayed presentation (patients were diagnosed several weeks after their injury) led to a traction injury of the brachial plexus. Fortunately, all three palsies recovered completely with nonoperative care. It would appear that distraction of a shortened clavicular fracture, especially one that presents or is treated some weeks or months following initial injury, creates a risk for a traction-type injury to the adjacent brachial plexus. Overdistraction at the fracture site or any violation of the subclavicular space is to be avoided during operative repair of clavicular injuries. Fortunately, with the information presently available, these injuries are usually transient in nature and a full recovery with time can usually be expected.

**Hardware Failure in Clavicle Fractures**

This complication occurs when the stress placed upon the implant exceeds its biomechanical strength, typically due to early overuse from noncompliance, implant/patient size mismatch, or delayed union or nonunion. This complication can be prevented by proper surgical technique (i.e., avoiding extensive soft tissue stripping, stable fixation) and the use of implants commensurate with the patient's size and compliance (i.e., avoiding the use of 3.5-mm pelvic reconstruction plates). These technical details are described in “Plate Fixation” (above). The incidence of hardware...
failure should decrease as improved implants (in terms of strength, materials and contour) become available.

**Hardware Prominence in Clavicle Fractures**

Local irritation from prominent hardware remains a clinical concern following the operative treatment of clavicle fractures, given its relatively scanty soft tissue coverage. The incidence of hardware removal ranges from less than 5% to essentially 100% in some series (i.e., where pin removal is a planned second stage of the procedure). The use of bulky, straight plates in thin or small individuals is associated with greater degrees of local irritation. It is probable that the incidence of plate removal can be minimized by using a precontoured plate. In addition, proponents of anterior-inferior plating suggest that this technique results in less prominence and irritation, although this remains to be proven. With regard to plate fixation in general, it is clear that routine plate removal is not recommended or desirable in the majority of cases following ORIF. Asymptomatic plates can and should be left in situ with a low rate of long-term complications, similar to retained plates in other areas in the upper extremity such as the forearm or humerus. Plates that provoke local irritation sufficient to warrant operative intervention should be removed only after 2 years have elapsed since fracture union to minimize the risk of refracture (as in the forearm). Collision athletes should have their plates removed at the end of a season to further decrease refracture risk. Anecdotally, many patients who have symptomatology at 1 year and desire plate removal find that by 2 years post injury the symptoms have ameliorated to the point where intervention is not desired.

FIGURE 38-40 The initial anteroposterior radiograph of a 46-year-old polytrauma patient with a head injury demonstrates a displaced clavicle fracture (A). The anteroposterior radiograph at 6 weeks post injury reveals abundant callus formation around the fracture (B). The patient had increasing neuralgic pain in the associated upper extremity with progressive objective muscle weakness in the hand. The involved hand (C, arrow) had signs of venous obstruction with swelling, loss of skin wrinkle definition, and violaceous discoloration. A CT scan confirmed obstruction of the thoracic outlet due to a combination of severe shortening and displacement of the fracture site and exuberant callus formation (D). This patient was treated with operative corrective of the deformity, complete resection of the supraclavicular callus, and judicious resection of infraclavicular callus followed by plate fixation. A prompt resolution of symptoms, complete neurologic recovery, and uncomplicated fracture union ensued (E).
IM devices will have a lower removal rate, although that is certainly one of their theoretical advantages.

**Refracture in Clavicle Fractures**

True refracture after healing of a fracture of a clavicle is surprisingly rare. It has been my experience that many individuals who have claimed to have sustained multiple fractures of the clavicle have in fact a nonunion of their initial fracture that has never healed completely. Recurrent episodes of trauma prompt medical attention, and new radiographs are misinterpreted as showing a “refracture.” The few cases that are reported describe a higher nonunion rate following “refracture.” Regardless of the exact etiology, patients with this condition should be counseled about the high rate of unsatisfactory outcome and that they may benefit from fixation.15,30,32

Given the increasing popularity of operative fixation of displaced clavicle fractures, and the patient population involved, it is not surprising that fractures at the end of a plate used for fixation of a prior clavicle fracture are being encountered. This typically happens from recurrent high-energy trauma. Large prospective series are not available and recommendations are based on only a few cases. In general, a fracture in the upper extremity that occurs at the end of a stable implanted diaphyseal plate has a poor natural history and a high chance of delayed union or nonunion. It is my experience that these fractures, if displaced, generally require repeat fixation. Attempts should be made to fix the fracture and span the area of bone previously repaired (Fig. 38-41). If the fracture is minimally displaced, a trial of nonoperative care with the arm at rest in a sling is reasonable.

**Scapular Winging in Clavicle Fractures**

Scapular winging has a variety of etiologies, and there are a number of case reports describing this condition following the nonoperative treatment of displaced midshaft fractures of the clavicle. Rasyid et al.146 reported two cases of winging of the scapula, one from a “neglected” fracture of the clavicle with 2-cm of shortening. A recent paper by Ristevski et al.152 examined 18 patients with symptomatic clavicular malunion and evidence of scapular winging clinically (Fig. 38-42) The authors performed CT scanning of all patients and were the first to be able to describe and quantify a consistent pattern of scapular malalignment. The patients had a mean clavicular shortening of 2.1 cm, and the acromion was found to translate with the distal clavicular fragment medially, inferiorly, and anteriorly. The average acromial translation was 2.4 cm. The posterior aspects of the clavula were found to translate less (superior angle, 1 cm; inferior angle, 0.6 cm). This gives the typical clinical appearance of a shortened, protracted shoulder seen in clavicle malunion or nonunion (Fig. 38-43). The main function of the clavicle is as a strut to position the scapula in its correct location. Since the scapula is the base upon which the arm and hand function, a malunion or nonunion of the clavicle alters the position of the scapula such that the mechanical advantage of the associated muscles is affected. The negative mechanical effects of this shoulder position are well documented, with a mean decrease in rotational strength ranging from 13% to 24% in one study.175 While it is difficult to prove a direct link between scapular malalignment and poor outcome following nonoperative treatment of displaced fractures of the clavicle, it is hypothesized that the early fatigability, weakness, spasm, and pain from the shoulder girdle musculature may be related to scapular malposition.

While the relationship between scapular malalignment and outcome may be unclear at present it may help explain some of the variability in outcome seen with clavicle fractures. While we use the measurement of clavicular shortening as a surrogate for overall displacement, it is clear that significant degrees of scapular malposition (and inherent symptomatology) can result from translation and rotation of the distal clavicular fragment and scapula with minimal “shortening” seen on standard radiographs. Prospective studies to analyze the degree of scapular malalignment in the acute setting of a clavicle fracture would help determine whether a correlation exists between this malalignment and outcome, and could aid in surgical decision making.
Artists rendition of typical deformity and resulting scapular malposition following clavicular malunion or nonunion. It is this malposition that results in clinical evidence of scapular winging and resultant symptomatology.

**A:** Anterior view of inferior scapular translation.

**B:** Side view demonstrating scapular protraction.

**C:** Superior view showing anterior translation.


**Figure 38-43** A clinical photograph of scapular winging of the left shoulder associated with a midshaft clavicle malunion with 3-cm shortening. There is a characteristic protrusion of the inferior angle of the scapula, produced as the scapula rotates and translates anteriorly with the distal clavicular fragment.
at present. For example, while most studies use the magnitude of shortening when defining fracture displacement, this alone is a relatively simplistic linear measurement of what is typically a complex three-dimensional deformity. Since most of the major muscle groups of the shoulder have a scapular origin it may be that the final position of the scapula relative to the trunk and upper arm (which is difficult to measure, see Scapular Winging) may be the dominant factor in determining prognosis. 64 While the prognostic index published by Robinson et al.154 is a dramatic advance in providing objective information and facilitating our ability to predict outcome, there are still significant improvements that can be made so that intervention can be selected specifically for those patients for whom the risk/benefit ratio of surgery is favorable. It is also clear that patient noncompliance, especially when associated with substance abuse, is a clear contraindication for surgery. Bostman et al., 10 in a study of 103 consecutive adults with acute, displaced midshaft fractures of the clavicle, stated that “Patient noncompliance with the postoperative regimen could be suspected to have a major cause of the failures.”

**AUTHOR’S PREFERRED METHOD OF TREATMENT FOR CLAVICLE FRACTURES**

The above figure describes the author’s preferred method of treatment of clavicle fractures (Fig. 38-44).

**CONTROVERSIES AND FUTURE DIRECTIONS IN CLAVICLE FRACTURES**

**Patient Selection for Operative Intervention for Clavicle Fractures**

Recent studies have made it clear that there is a subset of patients, especially those with shortened, displaced fractures who would benefit from primary operative repair of clavicular injuries.13,68,154 However, these early interventions are not without risk and consume significant health care resources. In addition, there are patients who would seem to have prognostic factors for a poor outcome following a clavicular fracture (i.e., displacement of greater than 2 cm) and yet heal promptly (albeit in a “displaced” position) with minimal symptomatology and full function of the involved shoulder. While some of the explanation for this is undoubtedly due to the inherent variability of patient response to musculoskeletal injury, there may be other factors that are not clearly define or understood.

**Method of Fixation for Clavicle Fractures**

There has been increasing interest in direct comparative studies examining the outcome of various IM nails versus plates for displaced fractures of the midshaft clavicle. This includes
two prospective randomized trials, two retrospective comparative studies, and one meta-analysis. In a prospective study, Ferran et al.35 randomized 32 patients to Rockwood pin fixation (17 patients) or small fragment compression plate fixation (15 patients) and found 100% union in both groups with no difference in Constant scores at final follow-up (pin group mean score 92, plate group mean score 89, p = 0.365). They concluded that both techniques were effective, although there was a high rate of hardware removal (100% of pins and 53% of plates), and their study could be criticized for its small numbers. Lee et al. performed a similar study (Knowles pins vs. plate fixation) in 62 patients over the age of 50 years, and although there was no difference in functional outcome (Constant score 85 in the pin group vs. 84 in the plate group), there were fewer complications, decreased OR time and hospital stays, and less symptomatic hardware in the pin group. Klewen et al.81 performed a retrospective review of 40 patients treated operatively for completely displaced, simple pattern (transverse or wedge type) midshaft fractures of the clavicle and were able to follow up 18 treated with Rockwood pins and 14 treated with plates. They reported five complications in the pin group and five adverse events in the plate group with no documented differences in functional outcome, and concluded that pinning was a suitable option for simple pattern fractures. Chen et al.25 reported on 141 patients treated with flexible titanium elastic nails (TENs, 57 patients) or small fragment pelvic reconstruction plates (plate, 84 patients). They reported no significant difference between the two groups with regard to complications, although the TEN group had shorter operative times and less blood loss than the plate group, with better DASH scores (mean 8 point difference) early at 6 months. There was no difference at 2 years, with excellent DASH and Constant scores (mean 96 in both groups) in both groups. They concluded that TEN fixation was an excellent option but it should be stressed that they restricted its use to simple fracture patterns in a group of patients typically much smaller than the North American population. At the present time, TEN nailing has not been widely reported in the North American literature, and caution must be used in its application. Duan et al.27 conducted a meta-analysis of these studies and concluded that the evidence failed to show a difference in treatment effects between plating and IM pin fixation, although there were more hardware complications with plating. They also stress that more high-quality, multicenter comparative studies are required for firm conclusions to be made.

**Timing of Surgical Intervention for Clavicle Fractures**

Conventional thinking has been that nonoperative treatment is appropriate for most if not all fractures of the clavicle, even severely displaced injuries, with the assumption that the reconstructive repair of those that developed nonunion or symptomatic malunion would produce results similar to that of primary operative repair of the original fracture. Since these injuries are nonarticular, and the reported “success” rate of reconstruction is high, this approach seems to have inherent merit. However, there is recent evidence that while operative reconstruction of malunion or nonunion is a reliable procedure, with increasing refinement of outcome measures and objective muscle strength testing it is apparent that there are residual deficits compared to what primary operative repair can provide. Potter et al.145 examined a cohort of 15 patients who had undergone late reconstruction with plate fixation for clavicular nonunion or malunion (“delayed group”) at a mean of 63 months post injury and compared them to a similar cohort of 15 patients who had primary plate fixation of a clavicle fracture a mean of 0.5 months after injury (“acute group”). The groups were similar in age, sex, original fracture characteristics, and mechanism of injury. They found that there were subtle but significant differences between the two groups with regard to shoulder scores (Constant score 89 in the delayed group, and 95 in the acute group, p = 0.02), and the delayed group demonstrated inferior endurance strength in the involved shoulder. They concluded that while late reconstruction is a reliable and reproducible procedure, there were subtle decreases in outcome compared to acute fixation, and they recommended that this information be used in decision making when counseling patients with displaced midshaft fractures of the clavicle. Rosenberg et al.158 reported similar results in a group of 13 patients who had late reconstruction for clavicular malunion and nonunion. While osseous healing occurred in all cases there was a mean 20-point deficit in Constant score (61 vs. 81, p = 0.01) in the affected shoulders. The authors felt that “last functional impairment” was possible even with objective success. With time, substantial adaptive changes (muscle atrophy, soft tissue contracture, bone loss) occur in the shoulder girdle of individuals with clavicular malunion or nonunion that will compromise the outcome of late reconstructive surgery to some degree when compared to the results of primary fixation. This is useful, objective information to use when evaluating the risk/benefit ratio of early operative intervention.

**Clavicle Fracture Summary**

There are now available a number of high-quality, prospective, and randomized studies that define the role of primary operative intervention for fractures of the clavicle. While the majority of clavicle fractures will heal with nonoperative care (a simple sling is probably best) and a prompt return of near normal shoulder function can be expected, there is a subset of fractures that benefit from operative intervention. Poor prognostic signs that have been defined include increasing fracture displacement (especially shortening), fracture comminution, and an increasing number of fracture fragments, especially in older patients. A meta-analysis of randomized clinical trials comparing operative versus nonoperative treatment for displaced midshaft fractures of the clavicle has revealed some consistent findings: Plate fixation is a reliable technique with a low nonunion rate, nonoperative treatment results in a nonunion rate of 20% to 25%, malunion remains a problem in nonoperatively treated patients, and primary fixation results in modest (10 points on a 100-point scale) improvement, in general, in the operative group. Anterior-inferior plate placement may have some advantages over superior plate positioning with respect to soft tissue irritation. IM fixation has many theoretical advantages and a high rate of success in skilled hands.
although results in the literature remain inconsistent. Although the difference is small, primary plate fixation provides significantly improved results in terms of strength and shoulder scores compared to delayed reconstruction. Malunion of the clavicle is a definite clinical entity that benefits from corrective osteotomy, which can usually be performed without a bone graft. Scapular winging from scapular malposition is a consistent, definable, and common finding following the failure of primary nonoperative care and the development of a nonunion or a symptomatic malunion, and it can lead to significant patient symptomatology. Future studies that are randomized, prospective, and comparative are needed to refine the indications for primary operative repair, investigate the role that scapular malposition plays, and determine the ideal method of fixation.

REFERENCES

SECTION TWO Upper Extremity


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