15 Management of Associated Injuries (Clavicle and Scapula)

Peter A. Cole, Sara C. Graves, and Lisa K. Schroder

It is important to understand the suspensory complex which helps to link the axial and appendicular skeleton, defined by Goss as the *superior shoulder suspensory complex* (*SSSC*) [1]. This anatomical relationship consists of a bone and soft tissue "ring" at the end of a superior and inferior bony strut. The ring consists of the distal clavicle, acromioclavicular ligaments, acromial process, glenoid process, coracoid process, and coracoclavicular ligaments. The superior strut is the clavicle proximal to the coracoclavicular ligaments, while the inferior strut is the scapula. Combined, the scapula and the clavicle, their associated ligaments, together with the 18 muscles which act on or across the glenohumeral joint, provide a biomechanical platform for the function of the shoulder and upper extremity (Fig. 15.1).

Scapular and clavicle fractures are often associated with other injuries [2–5]. Commonly, they occur in conjunction with injuries to the chest wall, other portions of the SSSC, and ipsilateral fractures and dislocations. The increasing use of multidirectional CT in trauma patients has increased the detection and understanding of injuries to the shoulder girdle as well as other associated injuries. A recent review of the National Trauma Databank [6] compared patients with scapula fractures to a control group and found that the Injury Severity Score was nearly double in patients with scapula fractures (19.2 vs. 9.9). Interestingly, they found that the rate of associated rib fractures was 52.9 %, a similar rate to that found in a 1985 study [2] in which the proportion was 53.6 %.

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Clavicle Fractures

Background

History

Clavicle fractures have been diagnosed and treated since antiquity. In 400 BC Hippocrates recommended a period of recumbence for those who had sustained a fracture of the clavicle: "It is of great importance, however, that the patient should lie in a recumbent posture. Fourteen days will be sufficient if he keep quiet, and twenty at most." [7] However, modern treatment has advanced considerably since this recommendation.

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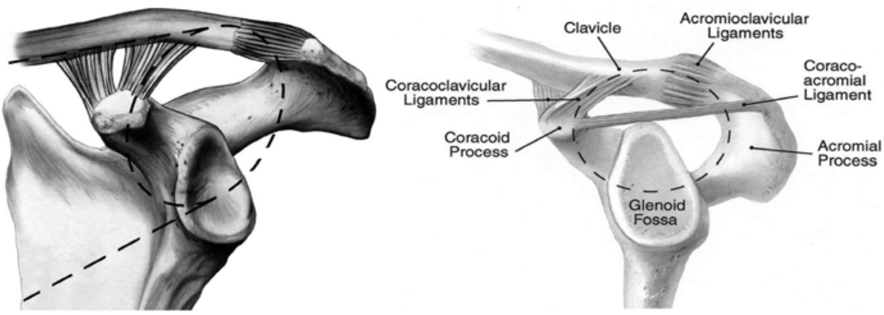

Fig. 15.1 The anatomical relationship defined by Goss [1] consisting of a bone and soft tissue "ring" at the end of a superior and inferior bony strut. The ring contains the distal clavicle, acromioclavicular ligaments, acromial process, glenoid process, coracoid process, and coracoclavicular ligaments. The superior strut is the clavicle proximal to the coracoclavicular ligaments, while the inferior strut is the scapula (Reproduced with permission. *Source*: Goss TP: Double disruptions of the superior shoulder suspensory complex. J Orthop Trauma. 1993;7(2):99–106)

Epidemiology

Clavicle fractures are the most common fracture in adults at 2–10 % [8–10]. In men, the incidence of clavicle fractures begins to decline after the age of 20; however, for women, the incidence is more constant with a tendency toward a bimodal distribution in adolescence and elderly age groups [8]. Mid-shaft fractures, representing over 75 % of the total, are most common and have a declining incidence with age [9].

Development

After birth, the clavicle continues to grow in length until the ossification centers fuse. The clavicle grows most rapidly in length prior to age 9 in girls and age 12 in boys [11, 12]. In the modern era, clavicles have been found to fuse at the age of 15 years on the average in women and 16 years of age in men.

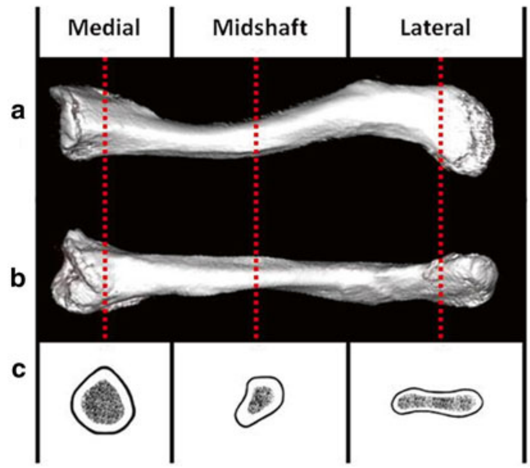

Fig. 15.2 Clavicle morphology viewed from superior to inferior (**a**) and anterior to posterior (**b**) with cross-sectional slices through medial, middle, and lateral segments (**c**). This morphology must be taken into account during implant placement and instrumentation

Anatomy

Osteology

The clavicle is an S-shaped bone with unique anatomical features. The name is derived from the Latin name for a similarly shaped musical instrument. The apices of the bone are anteromedial and posterolateral with a transition occurring approximately two thirds of the way from the sternal attachment. There is not a discrete medullary cavity associated with the bone as there is a capacious medial shape, tubular mid-portion, and flatter lateral portion (Fig. 15.2a–c). The two joints at either end are both diarthrodial joints, which have little inherent bony stability. They derive most of their stability from strong ligamentous and capsular attachments. The sternoclavicular joint is responsible for the majority of motion associated with the clavicle, with at least 35° of elevation-depression, 35° of protraction-retraction, and 50° of rotation. This contrasts with the acromioclavicular joint, which is responsible for much less motion [13, 14].

Attaching Muscle Groups/Deforming Forces

The carotid artery, vagus nerve, and jugular vein pass deep to the medial clavicle en route to the head and neck. The brachial plexus travels inferoposterior to the clavicle en route to the upper extremity. Deforming forces to the clavicle after injury include the sternocleidomastoid muscle which attaches to the superior border of the medial clavicle and the pectoralis major which attaches to the inferior border. The trapezius attaches to the superior border of the distal clavicle, while the deltoid originates from the distal/inferior clavicle. The conoid and trapezoid ligaments attach to the distal third of the clavicle and anchor it to the coracoid [15, 16]. The mid-portion is free of these muscular attachments and represents a weaker area of the bone. The different deforming forces lead to characteristic displacement patterns after fracture [17, 18].

Operative Dangers

With the anterior approach to the clavicle, the first structures encountered that should be identified are branches of the supraclavicular nerves (Fig. 15.3). These course from superior to inferior over the platysma musculature. The brachial plexus and subclavian artery and vein run inferior to the clavicle and are very closely approximated in the middle third of the bone (Fig. 15.4a, b). Inferior to the distal clavicle, the subacromial artery is encountered as well. This is relevant in the cases of inferior exposure of the bone in

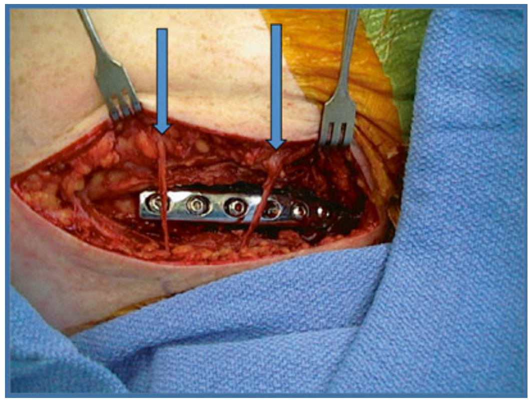

Fig. 15.3 An incision made for an open reduction and internal fixation of a clavicle fracture. The clavicle is post fixation, and crossing the wound, overlying the plate, are the two supraclavicular nerves (*arrows*), which have been protected. Sacrificing these nerves causes a patch of numbness inferior to the incision and is of little other consequence

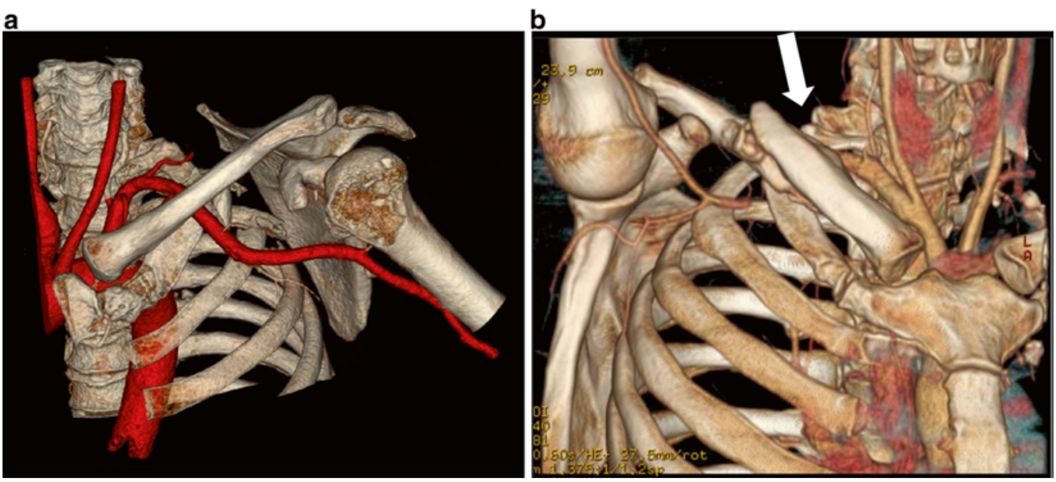

Fig. 15.4 Appreciate the intimate relationship of the subclavian artery in these arteriographic studies. (**a**) The artery is in *red* and the subclavian artery takeoff from the brachiocephalic trunk is easy to appreciate. (**b**) There is a middle one-third clavicle fracture, and the vulnerability during surgery to the subclavian vessels is easy to appreciate. The *white arrow* points to the crossover of the fractured clavicle and the subclavian artery

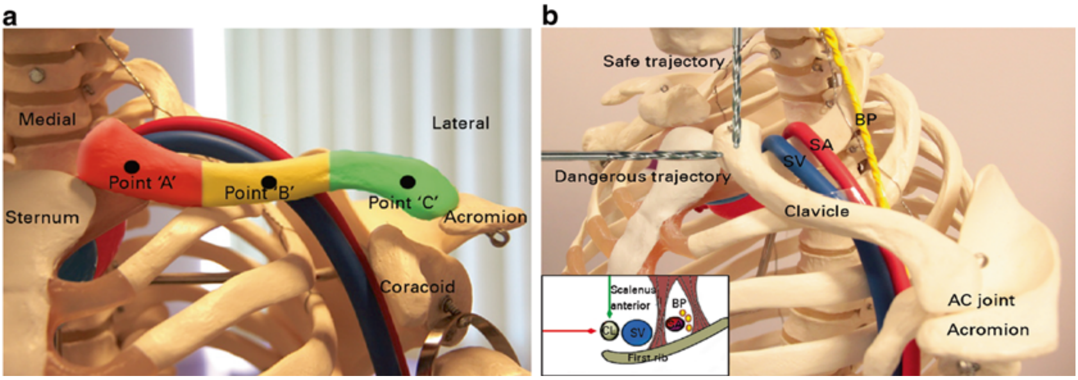

Fig. 15.5 This anatomical illustration details the relationship of the subclavian vessels to the clavicle. (**a**) An anterior to posterior orientation is shown in which a posteriorly directed drill puts the vessels at risk at the junction middle-distal 1/3rd and most medial 1/3rd of the clavicle. (**b**) A lateral to medial view illustrates both a safe and dangerous drill trajectory. Also shown with a *green arrow* (safe) and a *red arrow* (dangerous) in the inset illustration (Reproduced with permissions. *Source*: Sinha A, Edwin J, Sreeharsha B, Bhalaik V, Brownson P. A radiological study to define safe zones for drilling during plating of clavicle fractures. *J Bone Joint Surg Br*. 2011;93(9): 1247–1252. doi:10.1302/0301-620X.93B9.25739)

ensuring that inferiorly directed drills and screws are safely applied [19]. Knowledge of these anatomical relationships is critical during drill trajectory and orientation of instrumentation and implants (Fig. 15.5a, b) [20].

Classification

The Allman classification is most frequently used for clavicle shaft fractures. It divides the clavicle into anatomical thirds with the middle third being group I, the distal third group II, and the proximal third group III. These are in order of the frequency of appearance, with group I fractures representing 81 % of injuries, group II representing 17 % of injuries, and group III representing 2 % of clavicle fractures [9]. The Neer classification for distal third (Allman group II) fractures is based on whether or not the coracoclavicular ligaments are intact (Fig. 15.6) [21]. If they are intact, the fracture is at less risk for nonunion, but if torn, wider displacement is allowed and hence a higher risk of nonunion results.

Acromioclavicular Joint Dislocations

The acromioclavicular (AC) joint subluxates or dislocates when there is injury to one or more of the three important ligamentous structures which attach the lateral clavicle to the upper extremity. The coracoclavicular (CC) and coracoacromial ligaments as well as the AC joint capsule are responsible for the stability of the joint and when ruptured lead to characteristic injury patterns. Tossy and Allman developed classification schemes that describe the ligamentous injury and degree of displacement. Type I injuries represent partial tearing of the ligaments and are characterized by local AC joint tenderness: radiographs are normal. Type II injuries represent rupture of the capsule and AC ligament, but intact CC ligaments. There may be deformity and elevation of the clavicle, but this is limited to less than 1 cm. Type III injuries represent rupture of the AC capsule, and CC ligaments with pain, point tenderness, and plain films reveal complete dislocation. Rockwood later described three more severe injury patterns which are described according to the direction of displacement of the distal clavicle [22]. A type IV is complete disruption with the clavicle displaced posteriorly penetrating the trapezius. A type V is a more displaced version of a type III, where a type VI is when the clavicle is displaced and trapped caudal to the coracoid (Fig. 15.7) [22].

Clinical Evaluation

Clavicle fractures can occur with low- or high-energy trauma. Associated injuries (such as to the chest wall or scapula) should be ruled out.

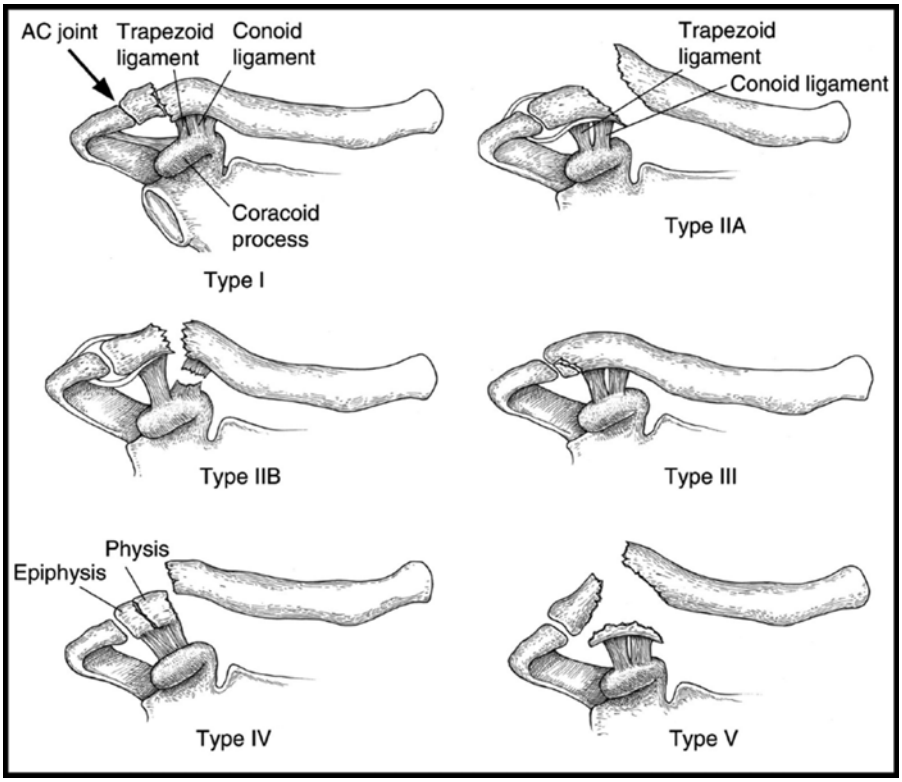

Fig. 15.6 Illustrated is Neer's lateral third clavicle fracture classification. Note the importance of the relationship to the coracoclavicular ligaments that distinguishes different patterns (Reproduced with permissions. *Source*: Banerjee R, Waterman B, Padalecki J, Robertson W. Management of distal clavicle fractures. *J Am Acad Orthop Surg*. 2011;19(7):392–401)

Given the relationship between the clavicle and the subclavian vessels and brachial plexus, close attention should be paid to a detailed distal neurovascular examination. The skin should be examined for the presence of an open fracture, severe tenting, or abrasions.

Initial radiographic imaging should consist of plain films, including a chest radiograph, which should be examined for associated thoracic injuries, including hemo- or pneumothorax and rib fractures. Clavicular films should be obtained. If patient comfort and absence of other injuries necessitating supine positioning allows, dedicated upright clavicle films should be obtained. Usually, advanced imaging modalities to assess the clavicle itself are not necessary. A CT scan can be useful to assess for other injuries in patients with a high-energy mechanism or in cases where a pathologic fracture is suspected. The protocol we use at our institution includes a supine and upright 15° caudal tilt view and a bilateral clavicle view to include both AC joints (Fig. 15.8a–c). Radiographic protocols for clavicle fractures continue to evolve.

Nonoperative Treatment

Nonoperative treatment has been the mainstay of treatment for the majority of clavicle fractures until recently. Improved clinical outcomes have not been demonstrated for any strategy over simple sling immobilization with early shoulder and elbow range of motion. Specifically, sling versus figure of eight brace immobilization have been proven to result in no difference in outcome [23].

There have been several recent randomized studies demonstrating lower symptomatic nonunion

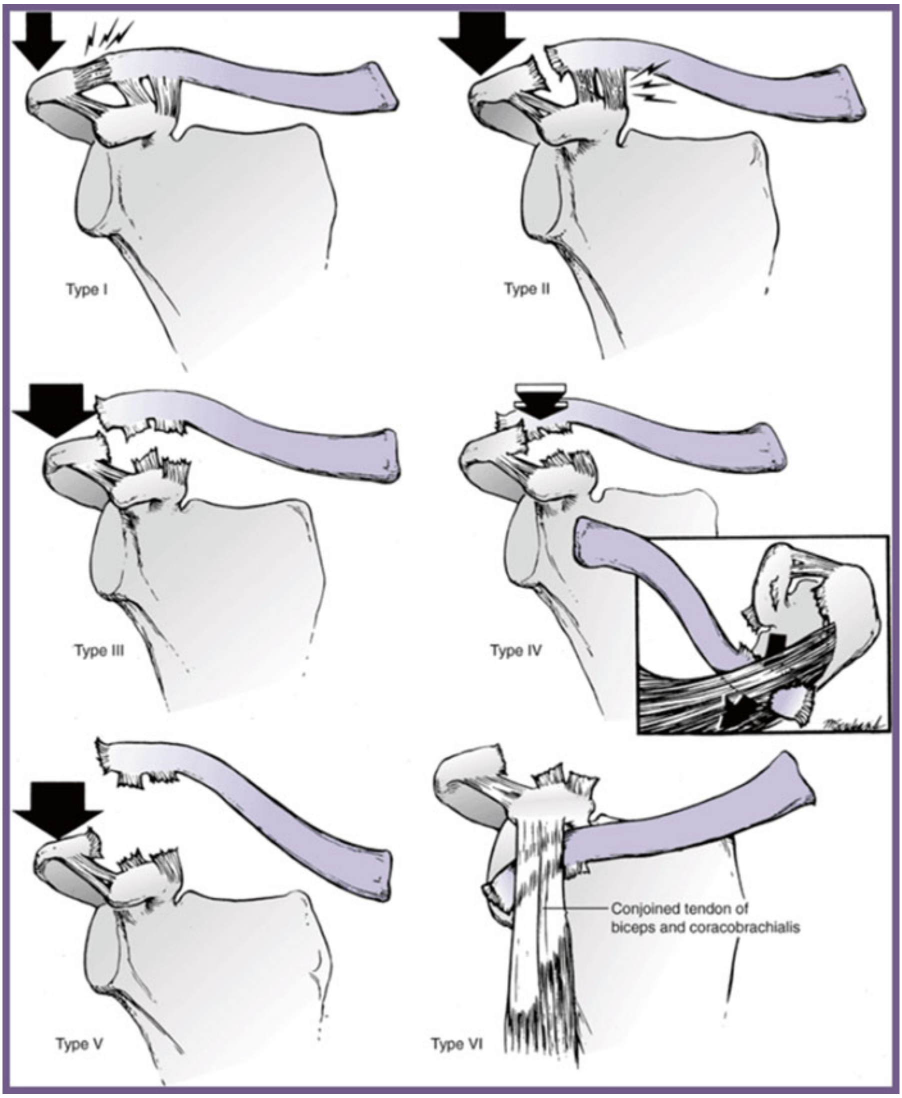

Fig. 15.7 Illustrated is the Allman acromioclavicular (AC Separation) classification which was expanded by Rockwood. Type IV and V separations are absolute indications for surgery, whereas type III surgery is controversial and probably suited only for young and active patients or to accomplish cosmetic goals (Reproduced with permissions. *Source*: Galatz LM, Williams Jr GR. Acromioclavicular Joint Injuries. In: Bucholz RW, Heckman JD, Court-Brown CM, eds. *Rockwood & Green's Fractures in Adults*. 6th ed. Lippincott Williams & Wilkins; 2006:1331–1364)

rates and better functional outcomes with reduction and operative fixation of displaced mid-shaft clavicle fractures in young (16–60 years of age), active patients, though this carries the risk of hardware irritation and the possibility of wound complications. Another relative indication for surgery is the displaced "floating shoulder" with dual injuries to the SSSC. It is important to be aware of the risk/benefit ratio for both operative and nonoperative treatment and discuss these issues with patients in a combined decision-making process.

Patients should be followed closely until the fracture consolidates with repeat upright clavicle films at weekly intervals for 3 weeks to ensure displacement remains within acceptable parameters because progressive displacement has been shown (Fig. 15.9a–c) [24]. During this period, elbow and shoulder range of motion should be encouraged.

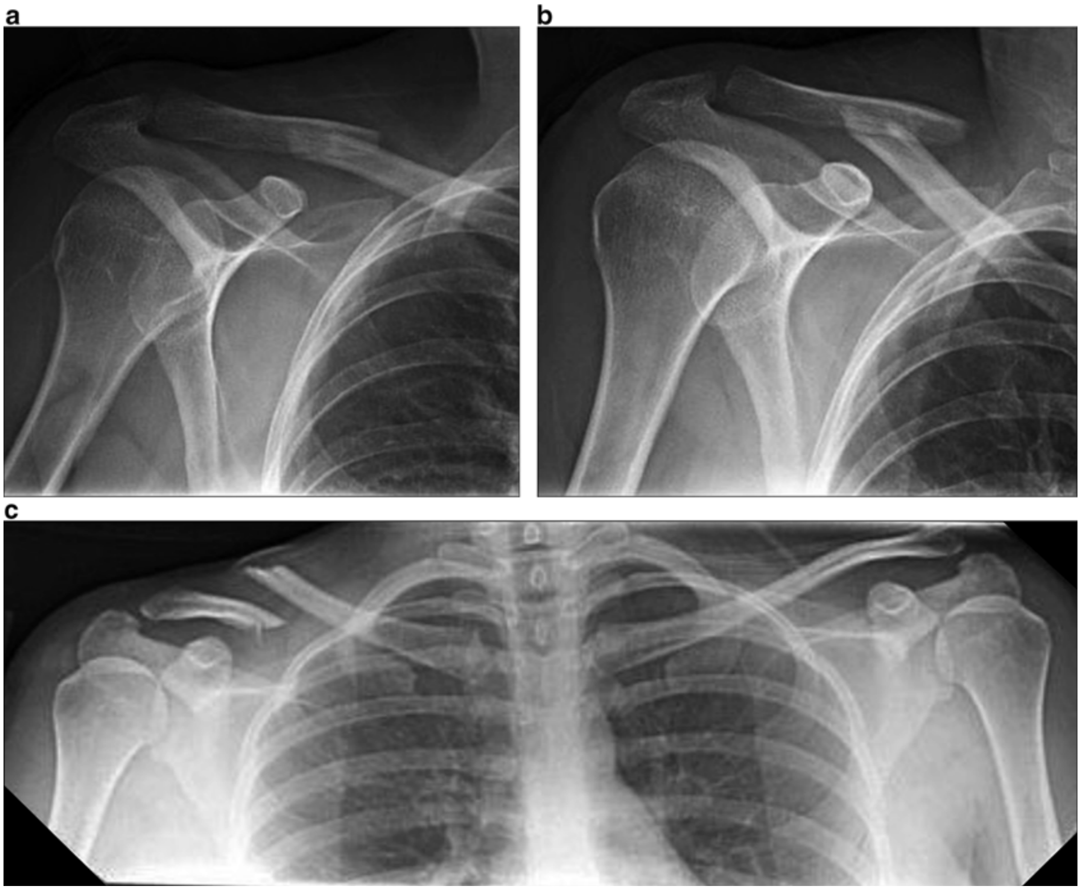

Fig. 15.8 Examples of plain radiographic imaging techniques with the patient in the supine position (**a**) and upright (**b**). (**b**) Shows increased displacement on upright films performed just after supine imaging (**a**). (**c**) Demonstrates medialization that is comparable and measurable on a bilateral upright clavicle film

Operative Treatment

Indications

For completely displaced mid-shaft clavicle fractures, several recent randomized studies have shown lower rates of nonunion, symptomatic nonunion, and higher functional outcome scores with open reduction and internal fixation [25, 26]. The rate of nonunion after the nonoperative treatment of mid-shaft clavicle fractures has been reported to range from 5 to 25 %. A 2013 retrospective review of 941 patients with nonoperatively treated displaced mid-shaft clavicle fractures by Murray and Robinson found a nonunion rate of 13.3 %. In multivariate analysis, smoking, comminution, and fracture displacement were most predictive of nonunion [27].

Functional outcomes have been shown to be better at most time points overall for patients treated with primary operative fixation [25]; however, these differences diminish when symptomatic nonunions are excluded [26]. Symptomatic malunion rates are also higher in nonoperatively treated patients [28]. An example of clavicular malunion with clinical deformity following nonoperative treatment is shown in Fig. 15.10. However, some have argued that good outcomes can be achieved in this setting by late reconstructive surgery and that the higher attendant costs and risks of primary operative fixation are not justified [29]. An understanding of the indications for operative treatment will continue to improve as further randomized studies delineate prognostic factors for poor outcome following closed treatment [30].

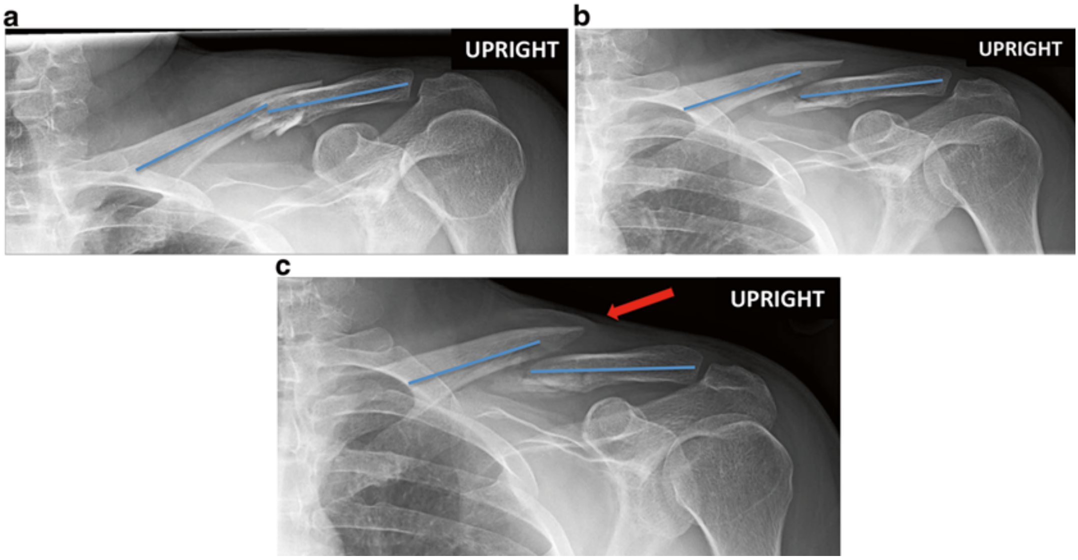

Fig. 15.9 (**a**) is an X-ray of an injury showing a middle 1/3rd clavicle fracture with minimal angular deformity or medialization. (**b**) and (**c**) demonstrate incremental displacement at 7 and 14 days after injury, respectively. This sequence shows the importance of serial radiographs at weekly intervals to assess displacement and determine surgical indications

Fig. 15.10 Cosmetic deformity associated with clavicle malunion. One can appreciate a common complaint, in which straps slip down the shoulder

Medial third clavicle fractures are relatively rare accounting for <5 % of injuries to the clavicle; however, the degree of displacement is also linked to the risk for nonunion. Lateral third clavicle fractures with ruptured coracoclavicular ligaments are also associated with higher nonunion rates [28]. The precise degree of displacement associated with an unacceptably high risk of symptomatic nonunion and diminished function remains to be determined: patient selection is highly relevant in the proper decision for surgery.

Surgical Technique

The surgeon should preoperatively analyze the fracture pattern and displacement with the plan to restore length, alignment, and rotation. The patient is positioned in the beach chair position with all bony prominences well padded. The ipsilateral limb should be prepped to aid in fracture reduction and allow for easier restoration of length, alignment, and rotation. The patient's anatomy is marked for a proper incision which should be just caudal to the bony prominence so hardware is not directly beneath the incision.

Plate Fixation

The length of plate fixation depends on the quality of the bone, the degree of comminution, the type of plate, the age of the patient, and their anticipated compliance. Plate placement can be in the superior or anterior position. Anterior plate

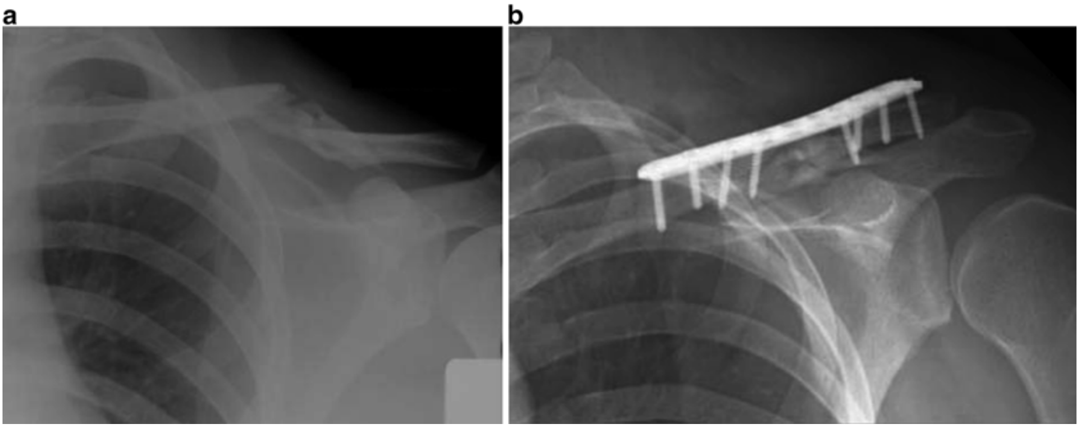

Fig. 15.11 (**a**–**b**) Bridge plating technique for a shortened comminuted clavicle fracture. Using this technique, the surgeon must preserve blood supply and employ a low strain zone over a longer working length of the plate; otherwise, the plates will be too stiff for the anatomy prescribed for this technique

placement was shown in one biomechanical cadaveric study to provide greater stiffness [31], and it has been associated with less prominence of the plate and diminished risk of injury to nerve or vessels and failure of fixation [32, 33]. However, superior plating remains more common in clinical practice [33], is familiar for most surgeons, and may yield a biomechanical advantage in middle third clavicle fractures over anterior plating.

The incision is taken down through subcutaneous tissue to expose the fascia surrounding the platysma musculature. The platysma is then cut directly to the periosteum, and cautery is useful for this vascular plane. A thick cuff is preserved to facilitate later repair. Any identified cutaneous branches of the supraclavicular nerve, usually present more medially within the platysma muscle, are preserved to prevent peri-incisional numbness. The patient should be warned of this potential for numbness preoperatively so expectations are managed. Minimal, but sufficient, periosteal dissection to allow for fracture exposure, reduction, and plate placement is performed. Careful retraction should respect posterior and inferior vital structures. Bone reduction forceps can be placed on either end of the fracture and used to manipulate the bone fragments back into position. Free draping of the arm allows elevation and rotation to achieve the appropriate alignment is useful and minimizes soft tissue trauma in obtaining reduction. Once aligned, bone reduction forceps placed in pilot holes on each side of the fracture can be used when stable bone ends allow for compression. K-wires can be used to provisionally hold large butterfly fragments. Greater comminution should be bridged, and devascularization and exposure of the comminution zone should be avoided. In such cases, the fracture is fixed distally first, and the plate used as a reduction aid to restore length and rotation. With the fracture reduced, lag screw fixation is employed when possible. Small, comminuted fragments that cannot be captured with lag screw fixation can be fixed in location with suture, and such fractures should be spanned with a plate in the bridging mode (Fig. 15.11a, b). A plate of the appropriate size is selected and contoured to the patient's anatomy. The goal should be a minimum of three bicortical screws on each side of the fracture. Straight dynamic compression plates are often prominent, while pelvic recon plates may not be strong enough for the forces acting on the fracture: for these reasons, the implant of choice is a pre-contoured compression plate designed specifically for clavicular fixation.

A single flat-plate radiograph or C-arm image should be obtained prior to closure to ensure that no screw tips are prominent as brachial plexus irritation or trauma to the subclavian artery or vein has been reported. It can be helpful to place a flat plate behind the patient's shoulder prior to prepping and draping, so that the cassette is in position for good imaging without disruption of the sterile field after fixation. Closure of the platysma and fascia as one layer is performed using 2-0 braided sutures. The subcutaneous tissues are re-approximated with inverted sutures, and the skin is best approximated with subcuticular absorbable monofilament suture that provides a cosmetic closure.

Intramedullary Nail Fixation

For simple, non-comminuted fracture patterns, intramedullary fixation is an attractive option as it requires less operative dissection [34]. Historically, Rockwood [35, 36], Hagie [37–40], and Knowles [41] pins were used for intramedullary fixation of clavicle fractures, but particularly in comminuted or rotationally unstable fracture patterns, they have been associated with high rates of implant failure and infection due to hardware prominence at the insertion site [36, 37]. Intramedullary nailing is demonstrated in Fig. 15.12a, b. Another technique is the use of titanium elastic nails [41]. The technique described for this includes the use of a medial opening point on the clavicle using an awl or a drill, followed by closed or mini-open reduction of the fracture and advancement of the nail past the fracture site. Nails are removed after fracture union. These have good results in several small case series and retrospective studies [41–43]. Other nailing systems have recently been developed and allow for locking and length-stable fixation which is an attractive option: it remains to be seen what their exact role will be in this area.

Distal Third Clavicle Fractures

Distal clavicle fractures and acromioclavicular separations represent a surgical challenge to treat due to the frequent lack of bone to support fixation at the end of the clavicle. Furthermore, the deforming forces are strong and differ depending on whether the injury is a pure dislocation of the AC joint or a distal clavicle fracture with disrupted CC ligaments. The deforming forces cause superior migration of the proximal segment, while the distal segment often caudally displaces because of the force of gravity and muscular contractions across the shoulder. Pre-contoured locking plates which allow for fixation in osteoporotic bone can be useful as well [41]. These implants take advantage of multiple distal clavicular screws at different vectors to maximize purchase in the short distal segment. These plates can also be augmented with a repair of the coracoclavicular ligaments, a treatment combination which may enhance stability [44]. Alternatively, simple reconstruction of the coracoclavicular ligaments in isolation with tape or an endobutton technique has also been used successfully in isolation [45, 46] but may be more vulnerable to failure (Fig. 15.13a, b).

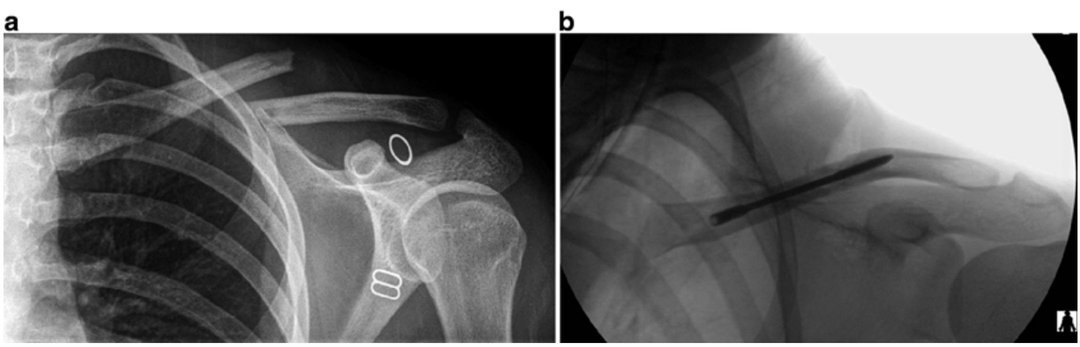

Fig. 15.12 Pre- (**a**) and postoperative (**b**) images of a clavicle fracture fixed with a nail. This transverse midshaft clavicle fracture is perfectly suited, because it can be reduced closed or with a mini-open technique minimizing the scar. Comminuted clavicle fractures may be rotationally and axially unstable after nailing and lead to malunion

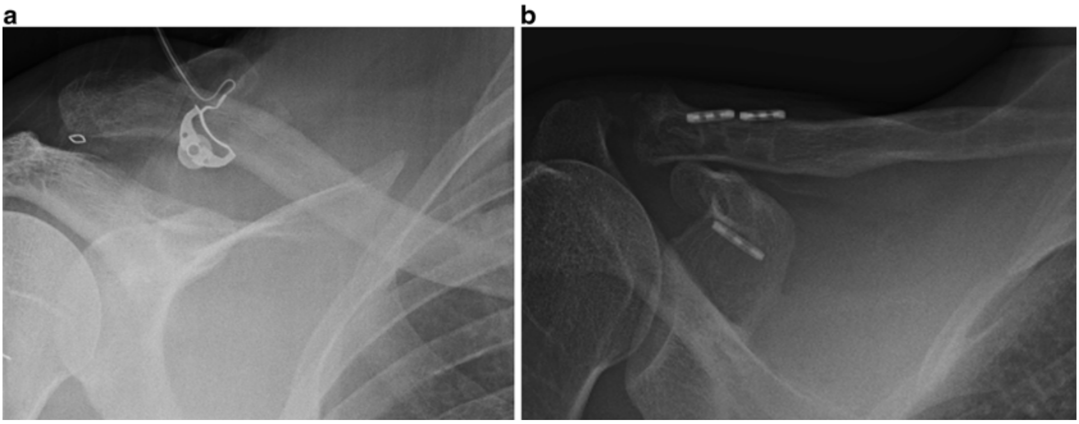

Fig. 15.13 A pre- (**a**) and postoperative (**b**) image of an acromioclavicular dislocation which was fixed with a tightrope technique in which two heavy fiber wire suture are passed through the clavicle and coracoid, both tethered to their respective bones and tied over small metal stays to help prevent cutout

For far lateral clavicle fractures, it is often difficult to obtain sufficient purchase in the distal fragment with plate fixation: in such cases, a specially contoured hook plate (Synthes Depuy, USA, Paoli, PA) has been used [47] which is slid beneath the acromion posterior to the AC joint. This implant allows for screw fixation into the clavicle, while the distal hook levers under the neck of the acromion (Fig. 15.14a–c). These typically need to be removed after fracture union because the implant does cross a mobile joint, and osteolysis and fracture of the acromion has been reported [48]. The hook plate is also a viable treatment option for isolated AC joint dislocations.

Sternoclavicular Dislocations [49–53]

Sternoclavicular dislocations occur as a result of direct trauma or indirect forces through the shoulder. In skeletally immature patients up to approximately 20 years, medial physeal fractures can be mistaken for dislocations. Dislocations are either anterior or posterior. Concomitant injury to mediastinal structures in posterior dislocations must be ruled out. These may include injuries to the trachea or larynx, and esophagus. The brachiocephalic trunk and neurologic injury to the phrenic nerve should be ruled out with a thorough history and physical examination. A CT angiogram or arteriography is indicated in posterior dislocations to assess the great vessels for injury that may include intimal damage, pseudo-aneurysm, or simple compression. These findings will help guide treatment.

When attempting manipulation of the posterior dislocation, it is important to have communicated directly with a cardiac surgeon so that they can be on standby in the event of a major arterial hemorrhage. This is imperative if a preoperative arteriographic radiography has not been done or has shown any abnormality. Postreduction clinical examination and observation are mandatory. In the acute setting, closed reduction and stabilization is recommended for both anterior and posterior dislocations to restore anatomy, reduce deformity, and improve long-term function. The decision to proceed with open reduction if closed reduction is unsuccessful depends on the health and activity level of the patient. Physeal disruptions are also amenable to operative fixation. In such cases, a plate is used to capture the medial fragment, ideally with locked fixation to avoid loosening and pullout (Fig. 15.15a–e). Suture fixation alone with heavy-braided suture is possible. These patients must be immobilized for approximately 2 weeks because they can experience cutout due to deforming forces.

For closed reduction of anterior dislocations, the patient is placed supine with a pad between the shoulders, and direct pressure is applied on the

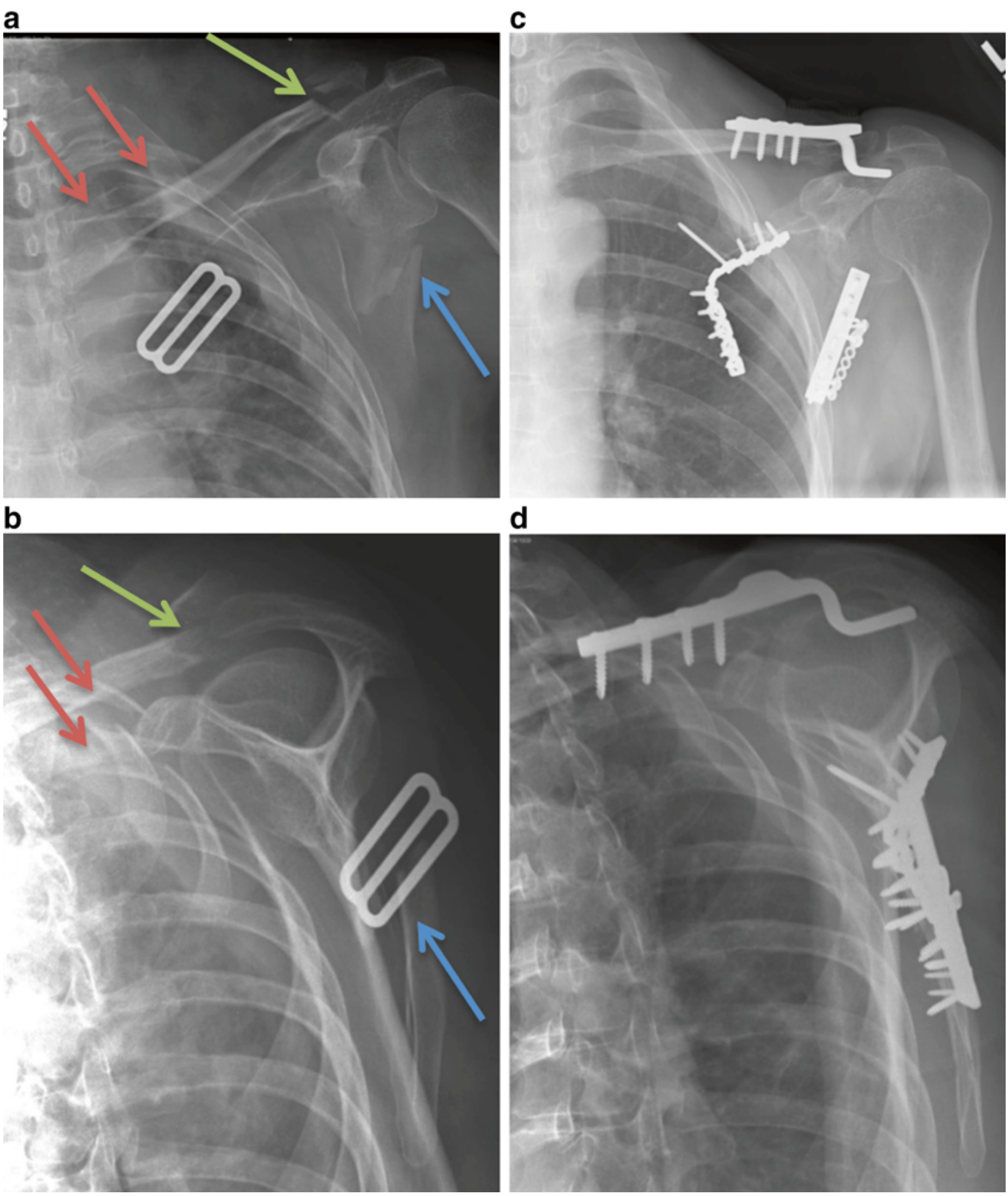

Fig. 15.14 Illustrative example of a hook plate (Synthes USA, Paoli, PA) fixation of a lateral third clavicle fracture (*green arrow*) with ipsilateral scapula (*blue arrow*) and no. 2 and no. 3 rib fractures (*red arrows*) as seen preoperative anterioposterior (**a**) and scapula Y (**b**) radiographs. Following consolidation of all fractures as seen on the anterioposterior (**c**) and scapula Y (**d**) follow-up radiographs, the patient underwent hook plate removal

medial clavicle in a posterior direction. These can be quite stable after reduction: if not, an open reduction may be indicated in a high-demand patient. The technique for posterior dislocation involves the placement of a pad between the scapulae; traction is applied to an extended/abducted arm with counter traction or posterior pressure applied to the shoulder. A sterile towel clip can also be used percutaneously to grasp the medial clavicle and reduce it (Fig. 15.16a).

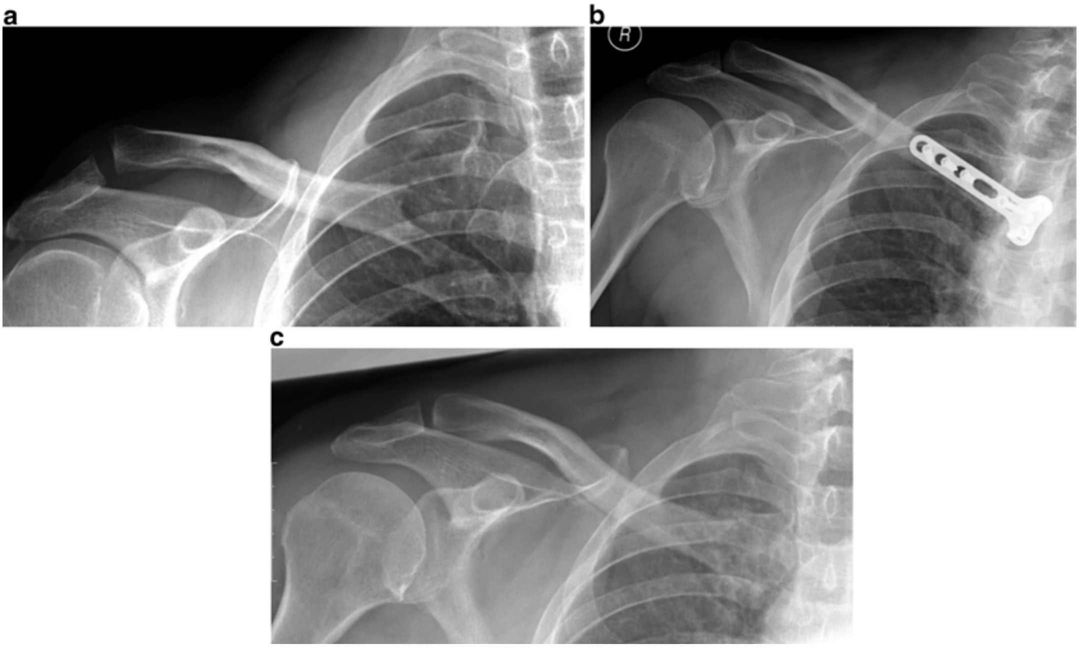

Fig. 15.15 Example of locking plate fixation of a medial third clavicle fracture dislocation injury (**a**), postfixation (**b**), and healed following hardware removal (**c**) anterioposterior X-rays

Posterior dislocations are frequently stable once reduced, but if closed reduction fails, open reduction and stabilization is performed with heavy-braided suture repair of the capsule and periosteum (Fig. 15.16b, c). Ligamentous reconstruction has been described, but typically for chronic dislocation variants and they are fraught with high failure rates. The authors' preferred management strategy for painful chronic dislocations is medial clavicle resection with imbrication of the scar tissue and capsule. Generally patients are very satisfied with resolution of both deformity and pain. The use of smooth pins for stabilization of dislocations is to be avoided due to the potentially catastrophic complication of pin loosening and migration.

Scapula Fractures

Background

History

In the first description of a scapula fracture in 1579, Dr. Ambroise Pare wrote, "When the fracture involves the neck of the scapula the prognosis is almost always fatal, as was also the case of some famous people, for instance the King of Navarre." It is unclear whether it was the fracture itself that he thought the mortality was attributable to or to the likely associated injuries. Other French surgeons such as Jean-Louis Petit, Joseph Guichard Duverney, and Pierre-Joseph Desault furthered the classification and treatment considerations of scapula fractures. Albin Lambotte is credited with the first internal fixation of a scapula fracture in 1911 [54].

Epidemiology

In a Massachusetts General Hospital study from 1938, the incidence of scapula fractures was found to be 1 % of all fractures. A study in the Swedish population from 1995 found an incidence in the population of 0.01 % [55]. Scapular fractures are associated with large amounts of force imparted: concurrent injuries are present in up to 85–95 % of cases [2, 3, 6, 56]. The most frequently associated injuries were rib fractures (52.9 %), lung injury (47.1 %), and head injury (39.1 %) in a 2008 National Trauma Data Bank retrospective review by Baldwin et al. [6].

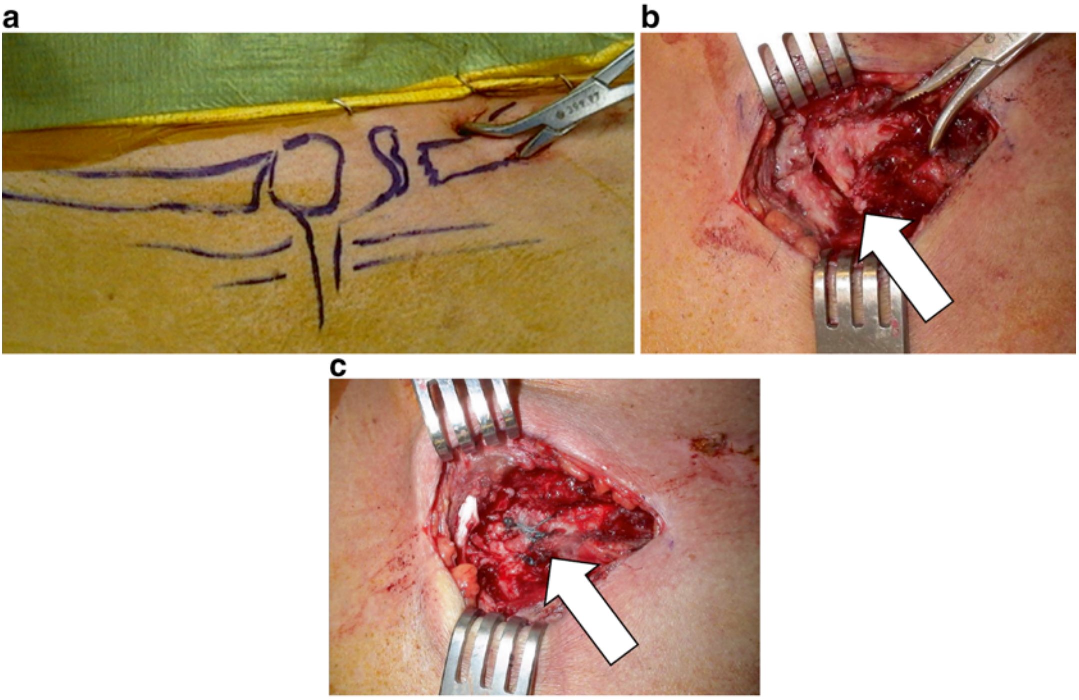

Fig. 15.16 An 18-year-old patient with proximal clavicle physeal dislocation. Closed reduction was possible with percutaneous application of a towel clip, as shown (**a**). Due to instability, the dislocation was exposed (**b**) and heavy-braided suture used in repair (**c**). The dislocation (**b**) and suture repair (**c**) are indicated by the *white arrows*

The results reported in their paper are shown in Table 15.1. Approximately 13 % of scapula fractures have associated neurovascular injuries that are important to identify prior to the initiation of treatment. The axillary and suprascapular nerves are most commonly injured, although other brachial plexus injuries can occur. The brachial, subclavian, or axillary arteries are injured in just over 10 % of fractures [2].

Table 15.1 Frequency of associated injuries with scapula fractures in Baldwin's review of the National Trauma Database from 1994 to 2002 with 9,453 scapula fractures included in the study [6]

	Percentage sustaining (Baldwin National Trauma Database Study) (%)	Historical reports (%)
Rib fracture	53	44–53
Any lung injury	47	20–66
Head injury	39	20–45
Spinal fracture	29	10
Clavicle fracture	25	16–39
Upper extremity fracture	23	44–50
Lower extremity fracture	22	
Abdominal injury	17	3
Pelvic fracture	15	5–18
Facial fracture	12	9–20
Death before hospital discharge	6	0–14

Development

Embryology

The scapula begins to form during 6–8 weeks of gestation at the level of the 4th–5th ribs. During further development, it descends under the direction of the apical ectodermal ridge. It undergoes intramembranous ossification. There are several well-described conditions associated with the normal development of the scapula. For example, in os acromiale, an (occasionally symptomatic) segment of the acromion process is present in ~8 % of the population. This is a bilateral condition in 33.3 % of those who have it [57].

Anatomy

Osteology

The scapula is broad and curves with the posterior aspect of the thorax between the second to seventh ribs, and it serves as the insertion or origin for 18 muscles. Triangular in shape, it tapers from greater width along the lateral border, is thin in the middle, and medially there is a slightly developed vertebral border. It has three distinct processes and two articular surfaces as well as the scapulothoracic joint all with important roles. The scapular spine in the middle separates the infra- and supraspinatus muscle groups and is an attachment for the posterior deltoid and trapezius muscles. The scapular notch is near the base just medial to the coracoid, and in this notch, the overlying suprascapular artery is separated from the underlying nerve by the transverse scapular ligament. Compression of the nerve here at the notch leads to weakness of both the infra- and supraspinatus.

The coracoid process originates from the upper portion of the scapula and is oriented anterolaterally at 120–160°. It forms the attachment site for the coracoclavicular ligaments at its base, as well as the coracohumeral and coracoacromial ligaments. It is the origination site of the coracobrachialis, short head of the biceps, and pectoralis minor. The acromial process articulates with the clavicle at the acromioclavicular (AC) joint and is the insertion site for the deltoid laterally. The rotator cuff tendons pass below it. The geometry of the acromion varies among individuals from a flat surface, to a gentle curve, to a hooked shape.

The glenoid is retroverted approximately 5°, with 10–15° of upward inclination, although the degrees of inclination vary between individuals. The glenohumeral joint has the least bony constraint of any joint in the body. The glenohumeral ligaments attach here and increase the stability of the shoulder joint. The broad, flat portion of the scapula on its anterior surface serves as the origin of the subscapularis. The scapula is balanced and moves through concerted motion of the muscles that attach on its surface. Injury to the long thoracic nerve or serratus anterior dysfunction causes medial winging of the scapula (Fig. 15.17). Injury to the spinal accessory nerve or trapezius causes lateral winging with shoulder depression and inferior angle lateral rotation.

Fig. 15.17 A clinical photograph of an 18 year-old male with an injury to the long thoracic nerve or serratus anterior dysfunction causing medial winging of the right scapula

Classification

There are a number of different classification schemes depending on which part of the scapula is injured. Fractures of the coracoid can be classified by the Ogawa classification, in which a type I fracture is posterior to the coracoclavicular ligament and is associated with other shoulder injuries. A type II fracture is anterior to the coracoclavicular ligament and can usually be treated nonoperatively [58]. The Eyres classification [59] divides coracoid fractures into the tip (I), midbody (II), base (III), with scapular body involvement (IV), and with glenoid involvement (V) with A and B suffixes denoting additional injury to the SSSC.

The Ogawa classification for acromion fractures divides them into lateral and medial, based on their extension to the spinoglenoid notch [60].

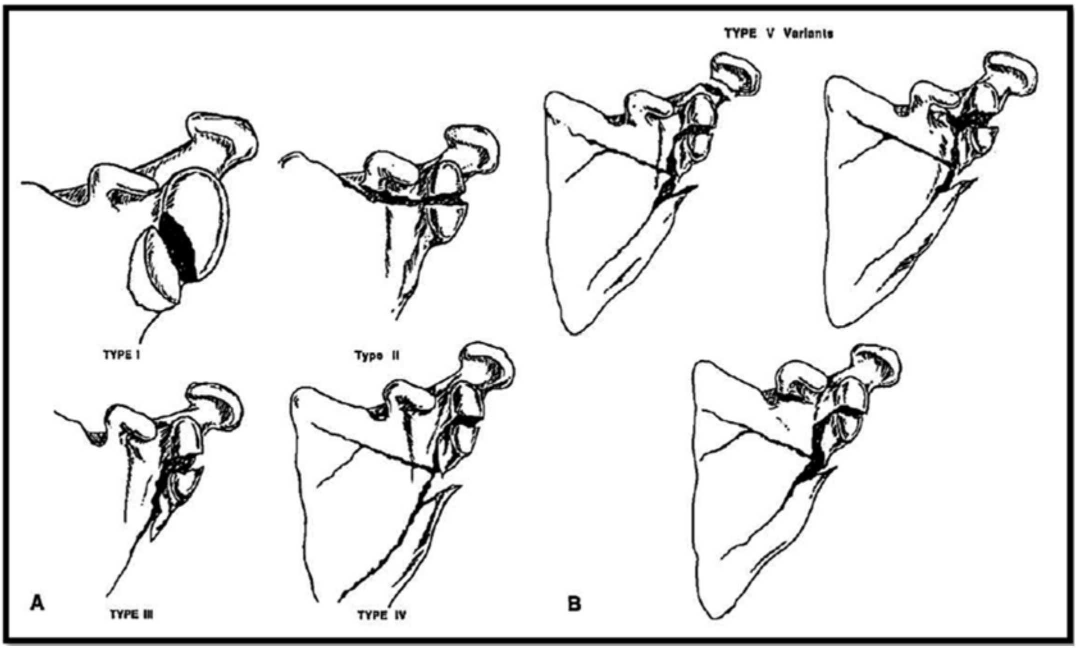

Fig. 15.18 Modified Ideberg classification of scapular glenoid fractures (Reproduced with permissions. *Source*: Mayo KA, Benirschke SK, Mast JW: Displaced fractures of the glenoid fossa. Results of open reduction and internal fixation, Clin Orthop Relat Res 347:122–130, Febr 1998)

Kuhn also proposed a classification system that classifies acromial fractures by the location, direction, and degree of displacement. A type III reduces the subacromial space and therefore requires treatment [61].

Glenoid fractures and scapular body fractures can be classified by the modified Ideberg classification (Fig. 15.18) [62]. The AO foundation also proposed a classification system, based on fracture pattern and location [63].

Clinical Evaluation

History and Physical Examination

Given the extremely high rate of associated injuries with scapula fractures, it is critical to perform a thorough evaluation for other areas of pain or discomfort. Any other potential area of injury should be appropriately followed up with imaging and necessary surveillance. A thorough history and complete physical examination should be performed. Pre-injury activity level, functional status, and surgical risk factors should be obtained. A detailed physical examination to rule out other injuries and assess neurovascular status including the suprascapular and axillary nerves should be performed. Abrasions or degloving injuries over the scapula should be accounted for in planning treatment and potential incisions (Fig. 15.19).

Radiographic Evaluation

The initial radiographic imaging for scapula fractures should include a chest radiograph, AP (Grashey), scapula Y, and axillary views of the shoulder joint. The clavicle should also be assessed as a part of the initial work-up.

Intra-articular involvement and degree of displacement should be determined. Intra-articular involvement should be assessed by CT scan. Criteria assessed on the initial radiographs include the glenopolar angle, angular deformity, and medialization or lateral border offset [64]. Definitions for these are as follows:

Glenopolar angle—On the AP view of the scapula, the glenopolar angle is the angle between a line drawn from the inferior glenoid to superior glenoid and a line from the superior glenoid to the inferior angle of the scapula (Fig. 15.20a).

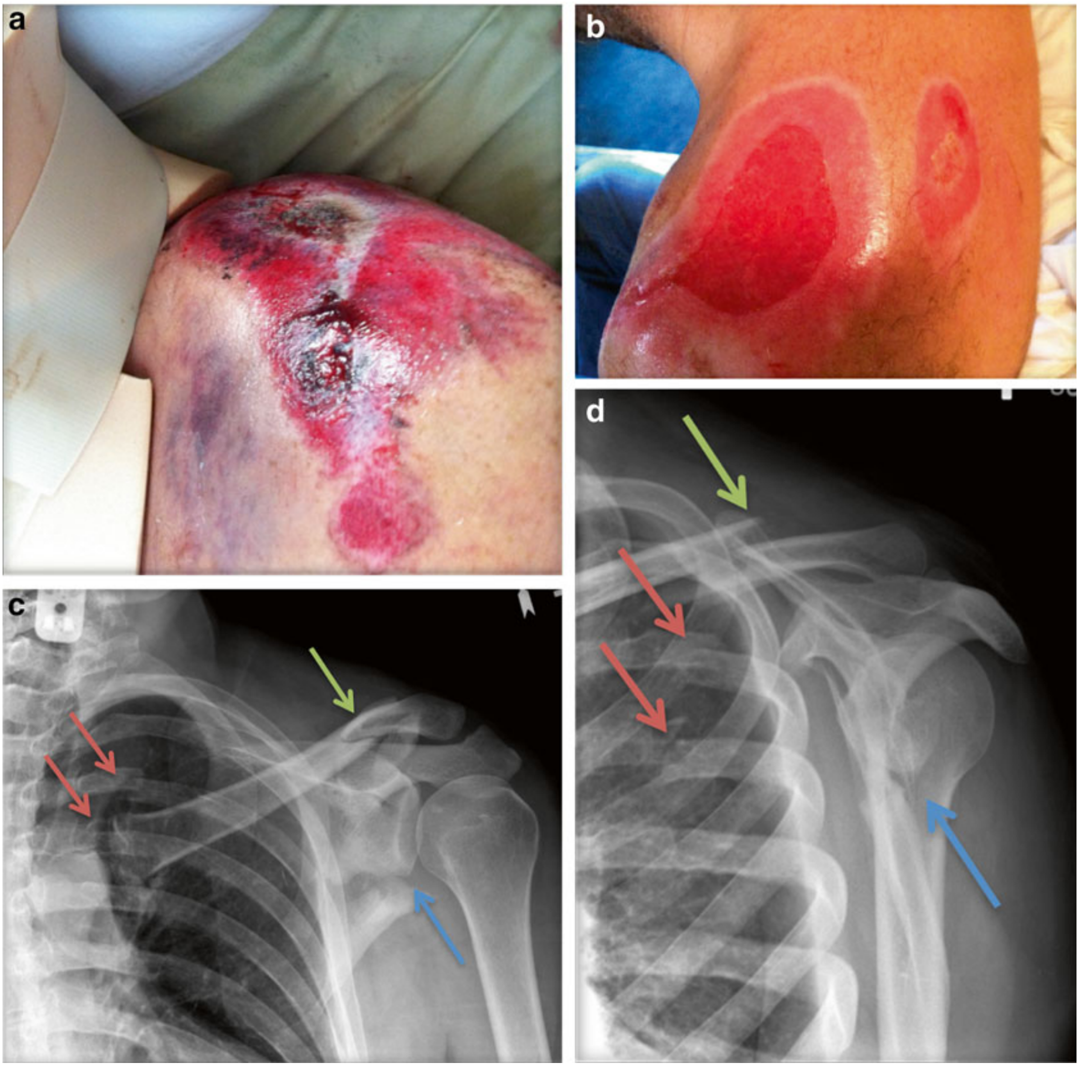

Fig. 15.19 (**a**) A clinical image of the skin abrasion in a patient having a severe high-energy shoulder girdle injury involving the clavicle (*green arrows*), scapula (*blue arrows*), and ribs no. 3 and no. 4 (*red arrows*) as seen in the anterioposterior (**b**) and scapula Y (**c**) injury radiographs. Operative repair is delayed until skin re-epithelialization occurs to reduce the risk of postoperative complication (**d**)

Angular deformity—is measured on the scapular Y view and is measured from lines parallel to the proximal fragment and distal fragments (Fig. 15.20b).

Lateral border offset—represents the width of displacement of the lateral border proximal fracture apex to its originating location inferior to the glenoid. This is also referred to as "medialization of the glenoid," but as there are degrees of glenoid medialization and scapula body lateralization, lateral border offset is a more accurate term (Fig. 15.20c) [64].

Advanced Imaging Indications

If the initial imaging reveals significant displacement, then a CT scan is the advanced imaging of choice for precise determination of preoperative displacement and for operative planning purposes [65]. If the patient has already received a CT scan as a part of their initial trauma evaluation, 3D

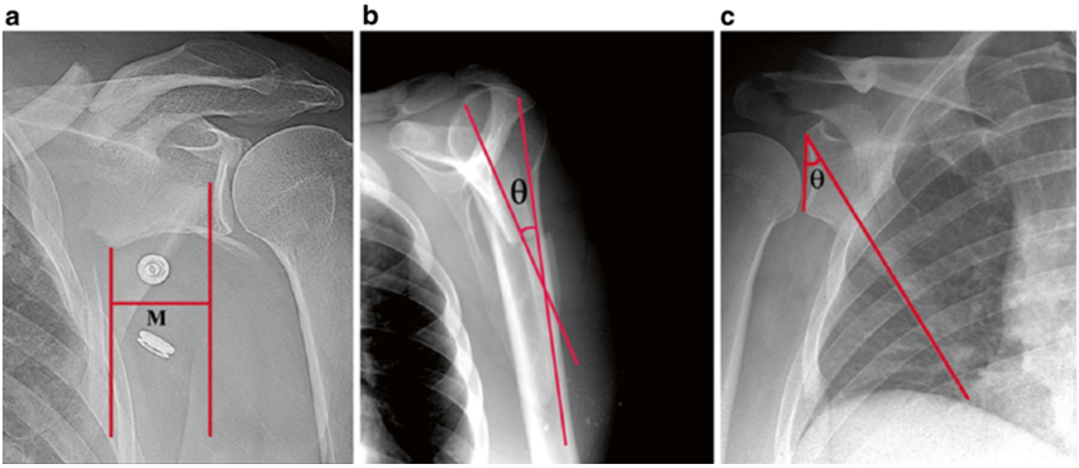

Fig. 15.20 (**a**–**c**) Initial measurement of displacement for scapular body fractures occurs, utilizing 2D radiographs. Medialization or lateral offset (**a**), angulation (**b**), and glenopolar angle (**c**) measurements are shown here

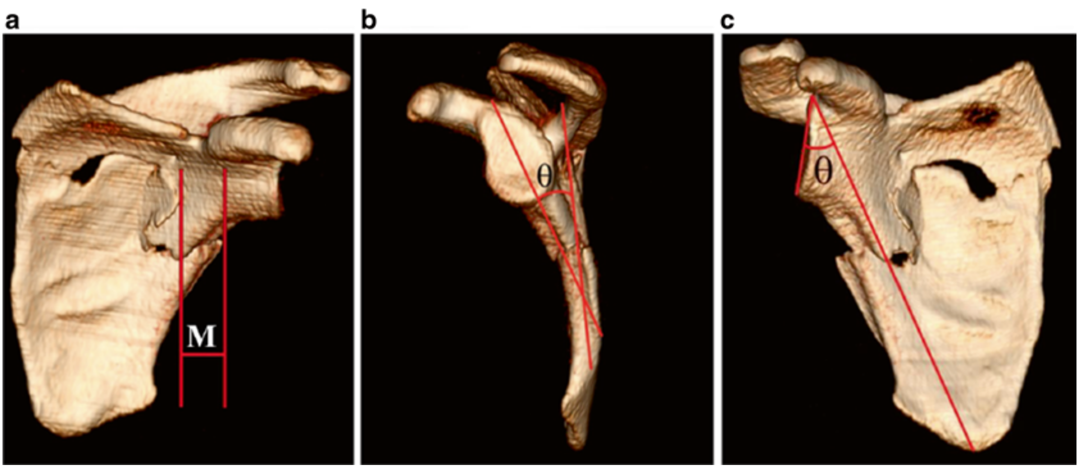

Fig. 15.21 (**a**–**c**) 3D reconstructions of the scapula are utilized to measure with a greater accuracy. Medialization or lateral offset (**a**), angulation (**b**), and glenopolar angle (**c**) measurements

reconstructions can be obtained and utilized to repeat radiographic measures of the scapula fracture with a greater accuracy (Fig. 15.21a–c).

Nonoperative Treatment

Nonoperative treatment has historically been the mainstay for most fractures of the scapula with the exception of displaced intra-articular fractures involving the glenoid and highly displaced body and neck fractures. Emerging evidence suggests that other fracture patterns which traditionally had been treated nonoperatively may have superior functional outcomes following operative fixation [66–71].

Indications for nonoperative treatment include non-displaced or minimally displaced fractures throughout the scapula. Nonoperative treatment for most scapula fractures entails sling immobilization with elbow and pendulum range of motion for 2–3 weeks with progressive gentle range of motion as tolerated. It is important to see the patient and obtain repeat radiographs at 1 week intervals after the injury to ensure further displacement has not occurred, until there is fracture

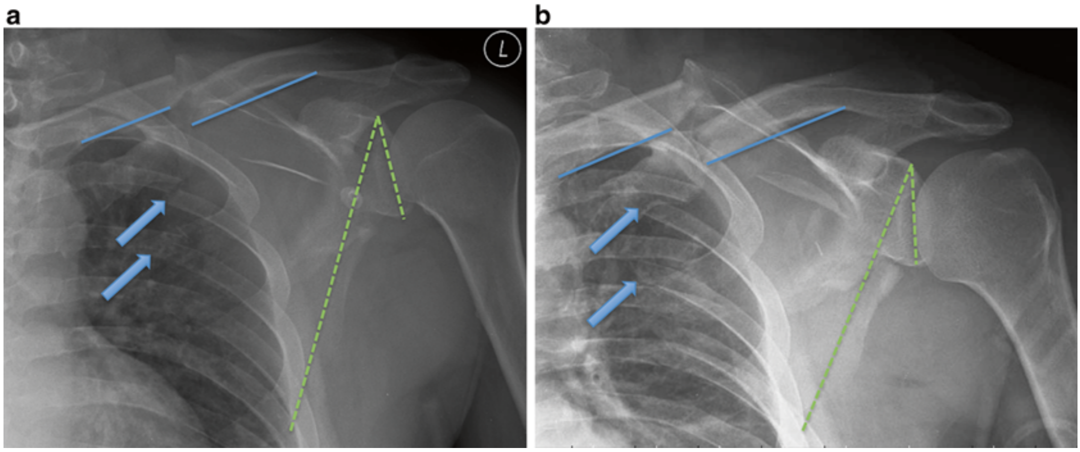

Fig. 15.22 This patient presented with a double disruption of the SSSC having both clavicle and ipsilateral scapula neck fractures with concomitant rib fractures. Though initially treated nonoperatively, this case illustrates a substantially unstable injury pattern which was initially a non-displaced fracture pattern (**a**). Serial radiographs taken at day 7 post-injury reveal a significant worsening of alignment despite immobilization (**b**)

consolidation [72]. This careful follow-up becomes particularly critical in the presence of associated rib fracture as the underlying support structure of the thoracic cavity is also compromised (Fig. 15.22a, b). Given the rich muscular and vascular envelope of the scapula, scapular fractures heal very quickly in most individuals. By 3 months, most patients can return to full activity.

Operative Treatment

Acromion

Fractures of the acromion can be managed nonoperatively if they are minimally displaced. The author's criteria for fixation include: (1) symptomatic nonunion (these are defined by an obvious fracture line on radiographs 6 months after injury with CT documentation or no progressive healing for 3 months with localized pain), (2) subacromial impingement (if the acromion tips into a caudad position due to the deforming forces of extremity weight and gravity, impingement can result), (3) displacement greater than or equal to 5 mm on radiographic examination, (4) open fractures, and (5) multiple disruptions of the SSSC [73, 74]. The surgical approach is dependent on the location of the fracture. Transverse fractures across the base or neck can be addressed with the patient in a lateral position and approached along the posterior border of the acromion just off the prominence. The deltoid is elevated from the posterior aspect of the spine and reflected with the infraspinatus to expose the fracture. Small fragment lag screws and 2.7 mm reconstruction plates can be applied to fix the fracture after it has been reduced. A thin superior plate can be used to augment fixation in comminuted variants and provides a tension band effect. More distal fracture patterns can be managed with tension band fixation along the posterior surface with mini-fragment plates or even a tension band figure of eight wire. In these specific fracture patterns, good or excellent results can be obtained in with regard to clinical outcomes [73].

Coracoid

Unstable, displaced fractures or fractures with other SSSC injuries can lead to discomfort and altered function due to the number of structures inserting or attaching to the coracoid process. The authors' indications for surgical intervention include (1) symptomatic nonunion with focal pain, (2) greater than 1 cm of displacement on radiographs, and (3) multiple disruptions of the SSSC [74, 75]. Most coracoid fractures involving the tip, midbody, and base can be addressed through an anterior deltopectoral approach using beach chair positioning. The clavipectoral fascia over the coracoid is incised. The superior slope of the coracoid is dissected until the fracture can be identified, freed of intervening soft tissues, and reduced. In coracoid fractures through the base, the coracoclavicular ligaments must be dissected off the posterior surface of the coracoid to appreciate the fracture. A 4 mm Shantz pin in the coracoid can be used to manipulate it and compress it for reduction. Small fragment lag screws or 1/3 tubular plates can be used to secure the fixation. For fractures involving the glenoid, in which the superior glenoid fracture exits below and involves the coracoid, an anterior approach can be extended to a formal deltopectoral approach to the shoulder in order to evaluate the articular reduction and obtain fixation at the level of the glenoid first. If fractures are associated with the scapular body, the coracoid can be indirectly reduced by an anatomic scapular body reconstruction if it is attached to the cephalad neck segment [75].

Glenoid

Displaced fractures of the glenoid articular surface should be operatively addressed to maintain the stability of the glenohumeral joint and prevent joint incongruity, which can lead to arthrosis. The precise level of displacement or fracture size that corresponds to fragments requiring fixation remains controversial: generally accepted indications for operative fixation include 2–4 mm of articular step-off, fragments >25 % of the articular surface, or displacement associated with joint subluxation. A deltopectoral approach to the shoulder and restoration of the articular surface with lag screws and plate fixation is utilized for the most common anterior fracture patterns. Mini fragment fixation is useful in such cases, applying a buttress plate to the anterior glenoid (Fig. 15.23) [76]. Arthroscopic visualization of the joint surface can be used to assess the reduction in the case of percutaneous fixation of small glenoid fragments. Glenoid rim fractures are frequently associated with shoulder dislocations (bony Bankart lesions) and are less commonly associated with chest wall injuries, but rather the result of sporting and lower energy activities.

Fractures involving the posterior glenoid can be isolated or combined with scapula neck fractures. In such cases, a posterior approach, while the patient is in the lateral decubitus position leaning slightly forward, is most useful (Fig. 15.24). A straight incision is used over the glenohumeral joint, elevating the deltoid and working anterior to it between the infraspinatus and teres minor along the posterior glenoid rim. Alternatively, a Judet incision is more useful for glenoid fractures associated with scapula body fractures.

Extra-articular Fracture Patterns

The indications for surgical intervention remain somewhat controversial and lacking in high level evidence to support operative versus nonoperative treatment for scapular neck and body fractures. One should pursue the basic principles of operative decision making for fractures in general, seeking to restore stability, length, alignment, and rotation of displaced patterns. Using this principle, indications for operative fixation include (1) angular deformity greater than or equal to 45° on a scapular Y radiograph or 3D CT scan, (2) lateral border offset (formerly viewed as medialization of the glenoid) greater than 2 cm, (3) glenopolar angle less than 22° on a Grashey AP view, or (4) displaced double disruptions of the SSSC greater than or equal to 1 cm [77]. With these operative criteria, the senior author has been able to demonstrate low complication rates and good functional outcome scores [71]. These criteria should be used in concert with assessment of the fracture characteristics, risk factors and functional expectations of the individual patient, as well as the skill and experience of the surgeon.

The preferred technique for the operative treatment of most scapular body fractures is a Judet incision with either an extensile approach or intermuscular windows between teres minor and infraspinatus. This decision depends on characteristics and age of the fracture as well as the experience of the surgeon. These patients often present late to the operating surgeon because of management of more critical injuries. In this delayed context, abundant callus is often present

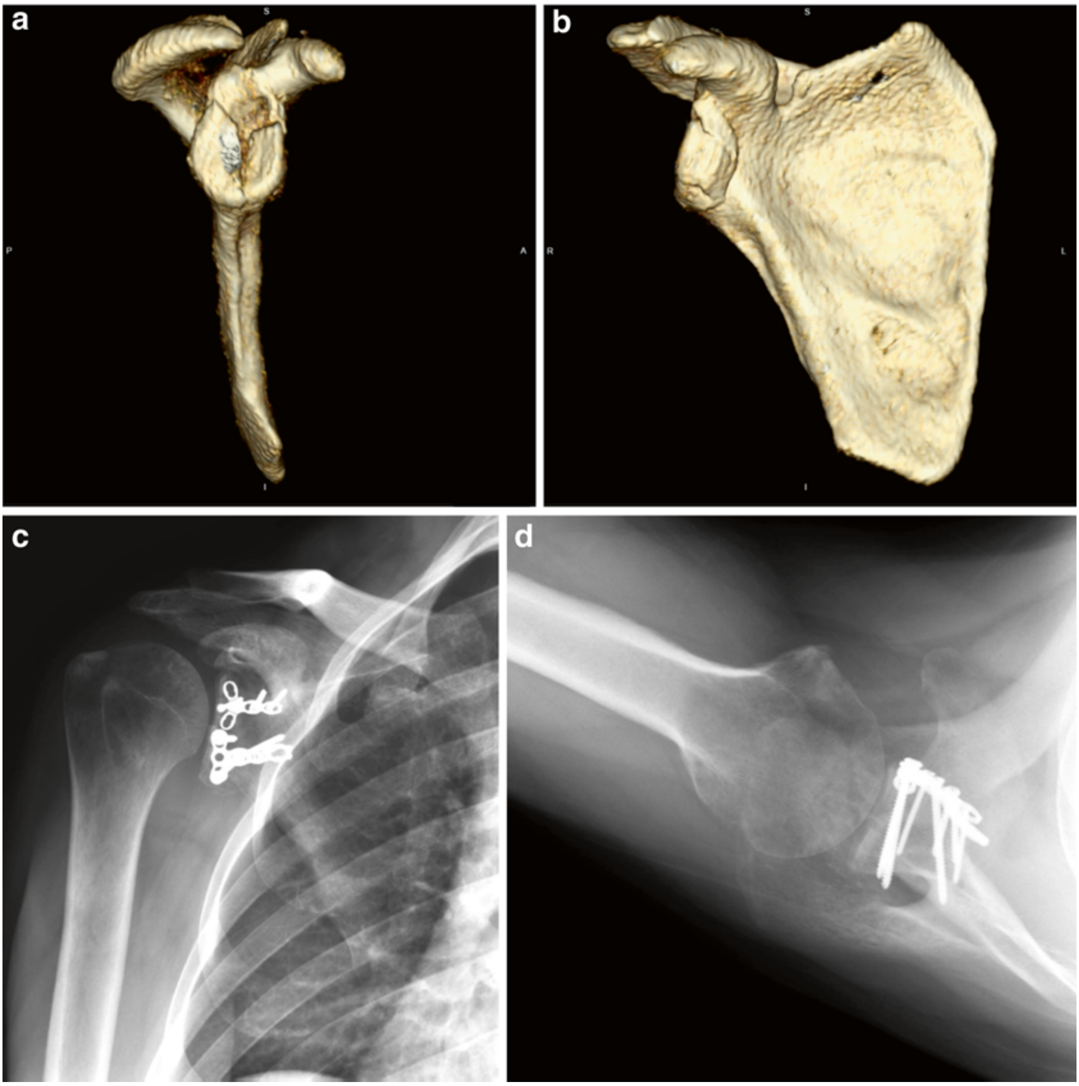

Fig. 15.23 The 3D reconstructed CT image oriented in the anterioposterior (**a**) and the scapula Y (**b**) views for a patient presenting with a displaced anterior scapular glenoid fracture requiring operative fixation. Mini fragment fixation was placed anteriorly, and postoperative anterioposterior (**c**) and axillary (**d**) radiographs show fracture consolidation and healing at final follow-up

and makes the reduction more challenging even as early as 2 weeks. If this is the case, the full extensile Judet approach is utilized, in which the entire muscular envelope of the rotator cuff and deltoid is elevated on its pedicle. The setup for the approach to the scapula includes the lateral position, allowing the patient to fall forward slightly. This involves the use of an arm-board attachment for the standard operating room table. The nonoperative arm is well-padded and in a relaxed, non-tensioned position on the arm-board. Specialized Bone Foam (Bone Foam Inc., USA, Plymouth, MN) positioners with room for the well-arm are optimal. With the patient forward approximately 30° in a "floppy lateral" position, full access to the hemithorax to the vertebral line is obtained. The involved arm, back, and neck are sterilely prepped and draped.

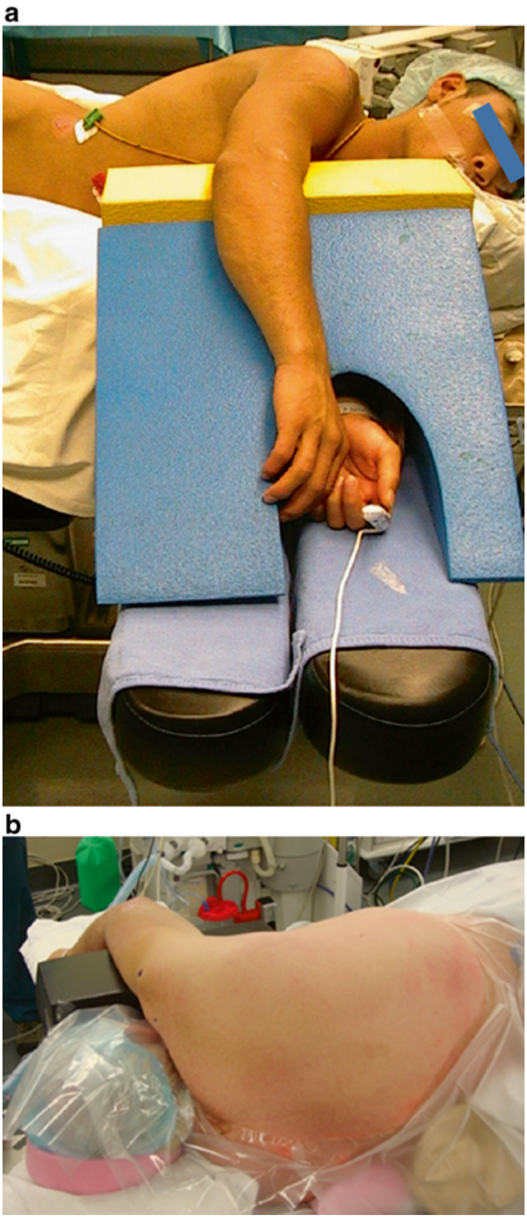

Fig. 15.24 (**a**–**b**) These patients are positioned for a posterior surgical approach to the scapula. In the lateral decubitus (floppy forward) position, the entire injured arm is sterilely prepped and remains free for manipulation to assist in reduction maneuvers during the procedure

The axilla is sequestered with a strip of adherent plastic sheeting.

The bony anatomy of the shoulder and scapula is marked on the skin. Even in larger patients, a sulcus which marks the scapular spine and interval between supra- and infraspinatus is often palpable. The skin incision should be a centimeter caudal and 1 cm medial to the vertebral border of the scapula and slopes from the spine around the superior angle roughly in the shape of a boomerang. Sharp dissection is carried down through the skin and subcutaneous tissues to the fascia overlying the muscle. Depending on whether the full Judet extensile dissection is desired (as is the case for more complex patterns or delay in presentation) or whether an intermuscular approach is desired (for simple fracture patterns), the surgeon should be prepared to elevate the muscles off the glenoid fossa or elevate the subcutaneous tissue off the posterior muscular fascia.

For the Judet approach, the infraspinatus, teres minor, and deltoid are elevated off their origins as one musculocutaneous flap. These muscles are elevated en bloc off the scapular spine and the infraspinatus fossa subperiosteally and then rotated on the lateral suprascapular neurovascular pedicle to reveal the body and neck of the scapula. The subscapularis muscle anterior to the scapula is undisturbed and provides great vascularity for high healing potential (Fig. 15.25a–c). Alternatively, as stated above, intermuscular windows can be used to access different portions of the scapula when less complete visualization or mobilization is necessary. Windows can be created along the spine of the scapula (between deltoid and trapezius), the vertebral border (between rhomboids and infraspinatus), or more laterally between infraspinatus and teres minor to access the lateral border and posterior glenoid.

Callus and interposed tissue are removed to expose fracture fragments both along the medial and lateral border, and the fracture fragments mobilized. A lamina spreader inside of fracture lines around the periphery, or Schanz pins in either the glenoid neck or lateral border can be utilized to mobilize fracture fragments. Provisional reduction is then effected using small pointed reduction clamps. It is most often useful to obtain the reduction of the lateral border first. Once the adequate medial and lateral border reductions have been affected, fixation of these may commence: a 2.7 mm reconstruction plate which lies along the inferior border of the

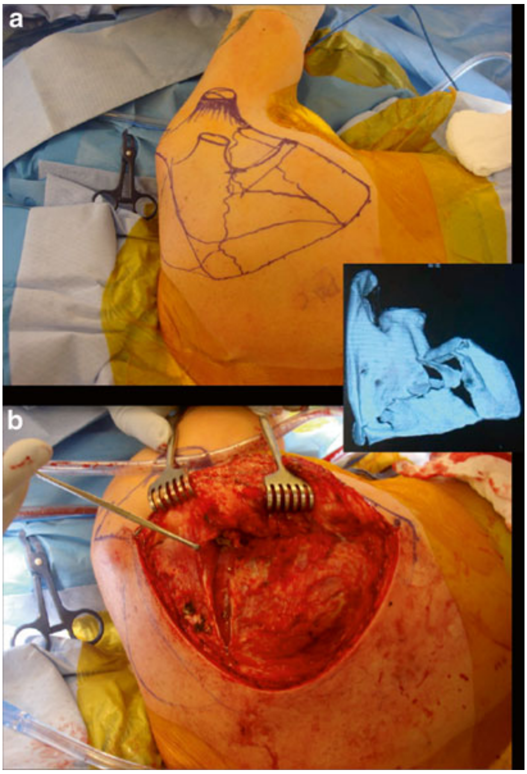

Fig. 15.25 (**a**) A modified posterior Judet approach is carefully planned, utilizing strategically placed intermuscular windows to address the patients common fracture pattern (*blue lines*). (**b**) Intraoperative photographs of the superficial anatomy illustrate a full-thickness fasciocutaneous flap, which is developed utilizing these landmarks: 1 cm caudal to the acromion spine and 1 cm lateral to the vertebral border and retracted laterally (*top* of image). Also shown is an intermuscular window between the trapezius and the deltoid (*arrow*) to access the inferior and medial margins of the scapular spine for plate fixation (**b**)

scapular spine, curving along the vertebral border is contoured around the angle for the most common fracture pattern (Figs. 15.26, 15.27, and 15.28). The surgeon may want to reinforce this fixation with a second adjacent 2.7 mm reconstruction plate for strength. The thickest bone and best fixation is found laterally. In the case of large comminuted midbody fracture fragments, spring plates with very short screw fixation can be utilized if the displacement is severe, but displacement can be tolerated in general in this very thin bone segment.

Once fixation has been performed, any devitalized muscle is debrided, the wound is irrigated, and closure commences. Drains are typically employed both deep below the fascia as well as under the subcutaneous flap when appropriate. The author's preferred technique for repair of the flap to the scapular spine is to use heavy-braided no. 2 sutures through drill holes along the scapular spine, supplemented with strong no. 1 vicryl closure for the rest of the fascial closure. The fascia is also re-approximated using these sutures. The subcutaneous layers and skin are closed with any preferred technique.

Rehabilitation begins with full shoulder passive and active range of motion for the first month and a light 3–5 pound weight restriction in the second month. Strength is then advanced according to symptoms until all restrictions are removed at 3 months post-op. Hand and wrist and elbow range of motion are encouraged from day one. Drains are discontinued when drainage is less than 15 mL per 8-h shift [78]. Generally good to excellent outcomes are to be anticipated with operative treatment of scapular body fractures that meet certain criteria. Patients usually return to close to their preoperative level of function with scapular body fractures with prudent and judicious application of operative fixation.

Summary

Scapula and clavicle fractures occur commonly in association with chest wall injuries. Typically, these injury associations occur after high-energy traumatic mechanisms, and all four combinations are common, namely, scapula-clavicle, ribs-clavicle, scapula-ribs, and ribs-scapula-clavicle combination. Most commonly in this scenario, the rib fractures are multiple and frequently constitute a typical "flail chest" in which there are more than four consecutive ribs fractured in two locations. Therefore, it is very important in patients who have multiple rib fractures, with or without pneumothorax or hemothorax, to carefully inspect the periphery of the chest radiograph for scapula or clavicle fractures.

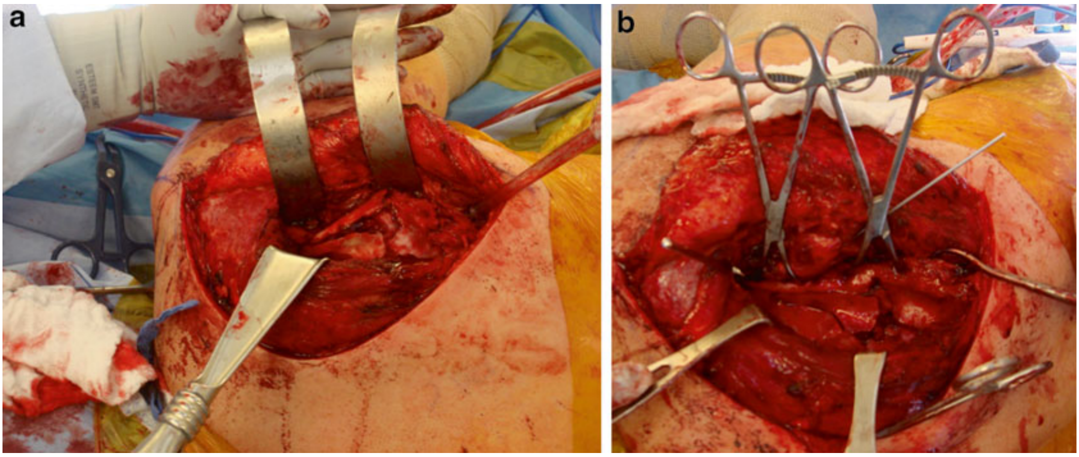

Fig. 15.26 (**a**) Intraoperative photographs indicating the intermuscular interval between teres minor and infraspinatus to access the bony anatomy of the displaced lateral border (**a**). Temporary reduction techniques utilizing small drill holes with towel clamps or k-wires are utilized prior to internal fixation with plates and screws (**b**)

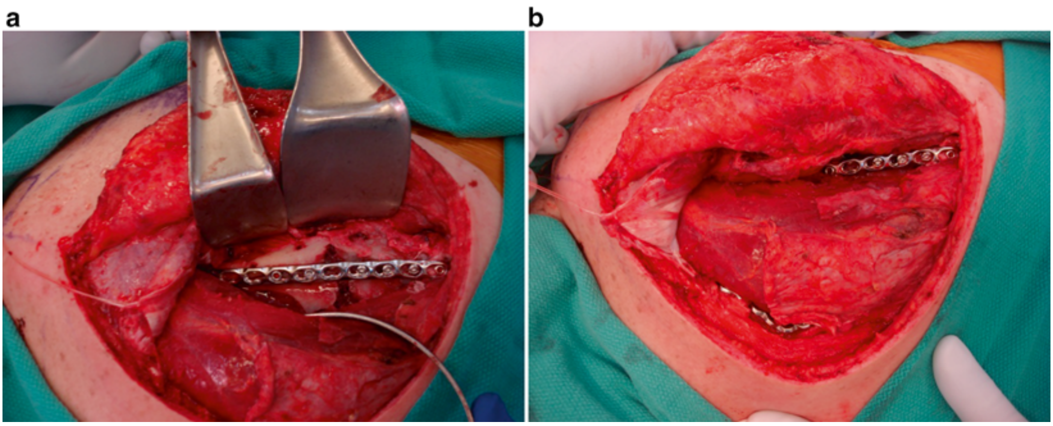

Fig. 15.27 Plate placement occurs in the internervous plane between the infraspinatus and teres minor, allowing good visualization of the lateral border and glenoid neck (**a**). Open reduction and internal fixation of the displaced scapula fracture completed both medially and laterally via superomedial and lateral intermuscular windows (**b**)

If there is any suspicion, formal shoulder films should be obtained. Similarly, in a patient with a high-energy scapula and/or clavicle fracture detected on shoulder films, formal inspection of the ribs on radiographs and physical exam of the chest should follow. Lastly, a full-body secondary survey must be done, and repeated, because the associated injury rate to other bodily areas and systems is very high.

From a treatment standpoint, it is useful to understand that multiple fractures occurring in the ipsilateral forequarter respond best to stabilization throughout the peri-injury period and rehabilitation phase of recovery. Lack of osseous stability promotes shoulder stiffness, and ultimately deformity is associated with dysfunction. Restoring stability to the displaced scapula and clavicle in this setting is beneficial, and it is often synergistic with operative fixation of multiple rib fractures.

Acknowledgment The authors acknowledge Amir Rizkala, M.D., for the assistance in selecting and preparing the images for this chapter.

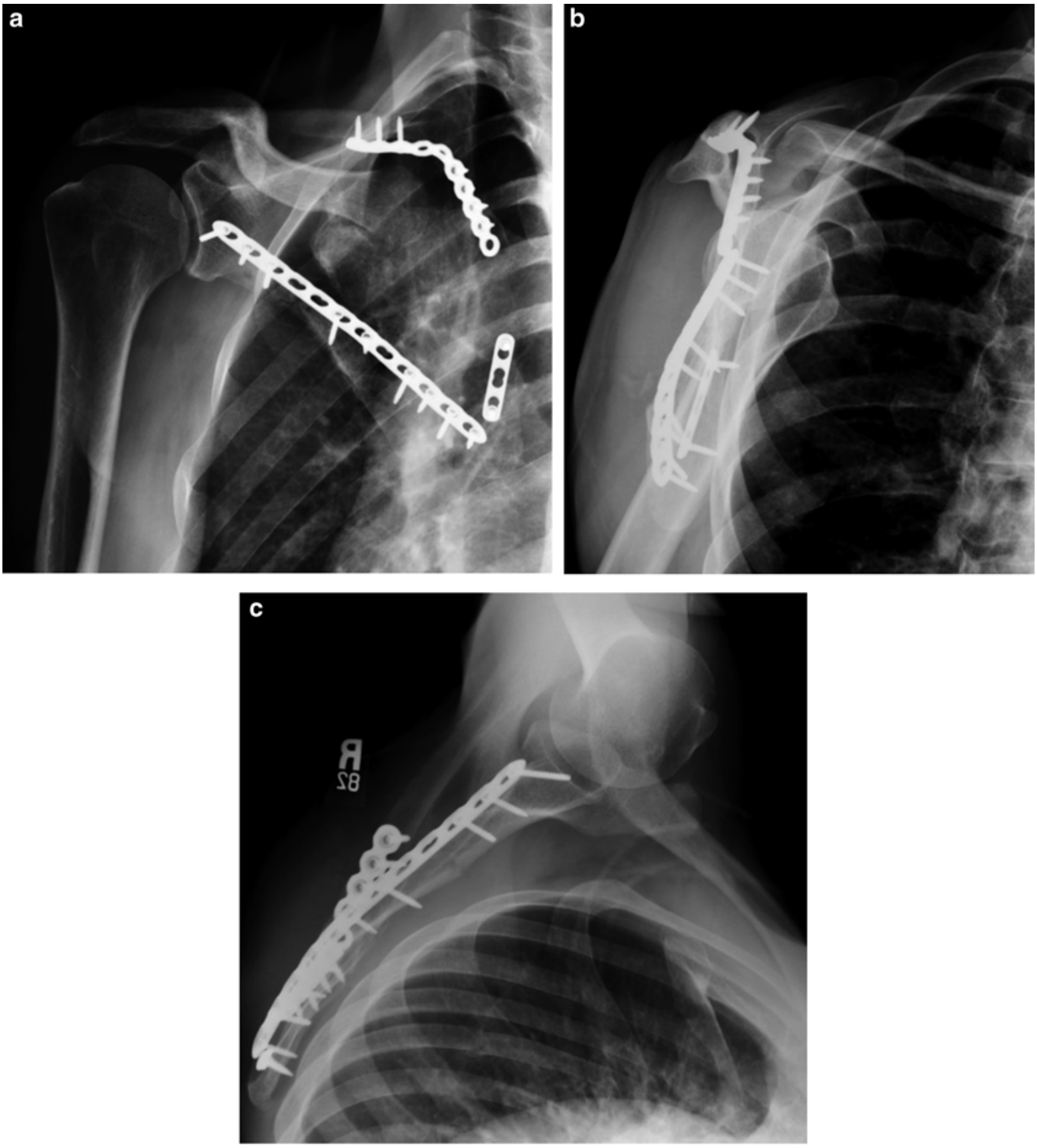

Fig. 15.28 Postoperative anterioposterior (**a**), scapula Y (**b**), and axillary (**c**) radiographs of the patient from the operative case illustrated in Figs. 15.25, 15.26, and 15.27

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