### 6.1 Scapula and clavicle

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6.1 Scapula and clavicle

1 Scapular fractures

1.1 Epidemiology

The scapula is surrounded by muscles and it is further protected from injury by its vicinity to the thoracic wall. Thus, fractures of the scapula account for only 0.4–1% of all fractures in trauma patients [1]. In polytrauma patients, fractures of the scapula are always an indicator for severe thoracic trauma, sometimes including rupture of the thoracic aorta [2]. Isolated fractures are rare and are caused by a direct blow to the scapular region from behind. Associated ipsilateral fractures of the clavicle occur in about 25% of all cases and may lead to a floating shoulder. Fractures of the anteroinferior glenoid rim are a completely different case since they are the result of an anteroinferior dislocation of the glenohumeral joint.

1.2 Surgical anatomy

The entire upper extremity is connected to the torso via the scapula by several strong muscles and the acromioclavicular joint, which is the only bony connection. At first glance, the clavicle seems to act as an anterior strut to define the distance between the torso and the scapula. However, the true biomechanical function of the clavicle is still not fully understood. Goss introduced the concept of the superior shoulder suspension complex (SSSC) to explain the pathobiomechanics of some shoulder injuries [3].

The superior shoulder suspension complex consists of a bone and soft-tissue ring (the glenoid, coracoid process, coracoclavicular ligament, distal part of the clavicle, acromioclavicular joint, and acromion) at the end of a superior (clavicular shaft) and an inferior (lateral scapular body and spine) bony strut. Only a double disruption of the SSSC leads to instability with a floating shoulder.

1.3 Classification

The scapula is numbered bone 14 (Tab 1.5-1) [4]. A detailed classification has been proposed. However, a simplified and more practical version is demonstrated in Tab 6.1-1.

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<td>Scapular body</td>
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Tab 6.1-1 Simplified anatomical classification of scapular fractures.

1.4 Assessment and diagnosis

The clinical symptoms of a scapular fracture are quite nonspecific and frequently masked by the symptoms of concomitant injuries. With a fracture of the scapular neck, the suprascapular nerve is at risk of being injured as it runs through the scapular notch at the superior border. Suspected lesions of this nerve have to be ruled out by an electromyogram (EMG). The same holds true for suspected lesions of the axillary nerve.

The radiological examination consists of three trauma views of the shoulder (AP in scapular plane, lateral in scapular plane, and axillary projection). Involvement of the glenoid requires a CT scan to determine the number and size of the fragments as well as the extent of the articular displacement. The clavicle should always be assessed, as associated fractures are not uncommon.
Specific fractures

1.5   Treatment

1.5.1   Fractures of the scapular body (type A)
The vast majority of scapular body fractures can be treated nonoperatively. Immobilization of the shoulder is only required until pain subsides. Pendulum exercises are started as soon as possible, followed later by active range of motion exercises. Operative treatment is only indicated in the rare occasion of widely displaced fragments, which later would interfere with the movement of the scapula or the glenohumeral joint.

1.5.2   Fractures of the scapular processes (type B)
Nondisplaced fractures can be treated nonoperatively. Displaced fractures of the scapular spine are treated operatively because of their high percentage of nonunions and a possible risk of functional impairment after malunion. The spine is approached from posterior. Fixation is achieved with reconstruction plates 2.7, which are applied at the posterior aspect.

Isolated fractures of the coracoid can occur centrally or peripherally to the origin of the coracoclavicular ligament. In the more frequent central fractures, the ligament usually remains intact. Therefore, the fractured coracoid displaces with the lateral part of the clavicle if there is a concomitant dislocation of the acromioclavicular joint. In this unstable situation the coracoid process may be fixed with a 3.5 mm lag screw and the acromioclavicular joint is also stabilized. Peripheral fractures are treated nonoperatively, unless the fragments have completely lost all contact due to the caudally displacing force of the coracobrachialis muscle.

Displaced fractures of the acromion need to be reduced and fixed since malunions may lead to impingement upon the rotator cuff. Stable fixation is achieved with 2.7 mm lag screws or tension band wires.

1.5.3   Fractures of the scapular neck (type C)
If the scapular neck is fractured, the glenoid fragment is usually displaced medially. This shortening leads to decreased tension and working length of the rotator cuff muscles, which may result in a functional impairment. Additionally, the glenoid fragment may also be rotated. Due to the pull of the long head of the triceps brachii muscle, the articular surface most frequently faces caudal. According to some authors, this may lead to instability of the glenohumeral joint. Shortening of more than 1 cm and rotation of more than 40° was considered an indication for ORIF by another author [5]. Usually, a reconstruction plate 3.5 is applied on the lateral margin through a posterior approach.

1.5.4   Articular fractures (type D)
Displaced fractures of the anteroinferior glenoid rim (Bankart fractures) may be treated operatively to restore the joint surface and—even in small fragments—to avoid chronic instability of the glenohumeral joint. Through a deltopectoral approach the fragments are reduced under direct vision and fixed with 2.7 mm lag screws inserted from the outside of the joint capsule. Because of the rather soft quality of the bone the screws should be long enough to get purchase in the posterior cortex of the scapular neck.

Most authors recommend ORIF for displaced fractures of the glenoid fossa (more than 2 mm) to restore joint congruity and to avoid development of posttraumatic arthrosis. Ideberg, however, recommends nonoperative treatment for displaced articular fractures as long as the humeral head remains centered in the glenoid fossa [6].

■ Acromion fractures have to be differentiated from an os acromiale, which is a bilateral anatomical variation in over 60% of cases.
Depending upon the fracture morphology (CT scan) a superior or posterior approach is chosen. The articular fragments are fixed with 2.7 or 3.5 mm lag screws (Fig 6.1-1). In comminuted fractures involving the scapular body and the glenoid it is quite often sufficient just to anatomically restore the articular surface and to realign the reconstructed glenoid to the lateral margin, while the fragments of the comminuted body are not touched at all.

1.5.5 Scapula and ipsilateral clavicle (type E)
Fractures of the scapular neck and the ipsilateral clavicle represent a double disruption of the superior shoulder suspension complex (SSSC). This injury—if displaced—may lead to an unstable floating shoulder where the glenoid faces caudal [3]. In order to avoid massive shortening of the shoulder girdle and poor functional results due to abduction weakness and decreased range of motion, ORIF can be recommended.

Fig 6.1-1a–b
a Transglenoid fracture with marked dislocation of the fragment.
b Reduction through partially open joint capsule, temporary fixation with a K-wire followed by fixation with two lag screws.
Specific fractures

regardless of the initial displacement [7, 8]. Newer publications, however, report equally good results with nonoperative treatment. Edwards et al concluded that nonoperative treatment of floating shoulder injuries is appropriate, especially with those that are minimally (less than 5 mm) displaced [9]. Egol et al summarized that operative treatment cannot be recommended and that each patient must be treated individually [10]. Van Noort et al stated that this injury is not inherently unstable and, in the absence of caudal dislocation of the glenoid, conservative treatment achieves a good functional outcome [11].

If surgery is indicated, ORIF of the clavicular fracture is usually sufficient because reduction of the scapular neck fracture is achieved by ligamentotaxis through the intact coracoclavicular and coracoacromial ligaments (Fig 6.1-2).

Fig 6.1-2a–b

a The combination of fractures of the clavicle and the scapular neck renders the entire shoulder girdle unstable. The lateral fragment of the scapula rotates due to the weight of the arm.

b To restore stability it is usually sufficient to fix the clavicle with a reconstruction plate 3.5 or LC-DCP 3.5 or LCP 3.5.
1.6 Approaches

There are three different standard surgical approaches, which are chosen according to the morphology of the fracture.

**Deltopectoral approach**
This approach is used for fractures of the anteroinferior glenoid rim as the humeral head can be partially dislocated posteriorly to visualize the glenoid rim. Since the stability of the joint is restored after fixation of the fragment, the capsule is closed at the end without any shifting procedure and the transected or split subscapularis tendon is meticulously sutured in order to avoid any limitation of the shoulder range of motion.

**Superior approach**
This approach is used for superior glenoid fragments. The skin incision runs in the middle between the clavicular and scapular spine, as far laterally as possible. The fibers of the trapezius muscle are split. Depending upon the localization of the fragment, the supraspinatus muscle is carefully retracted posteriorly or anteriorly. The scapular notch is always identified to avoid damaging the suprascapular nerve. To facilitate proper placement of screws parallel to the articular surface, the posterior part of the lateral clavicle can be partially resected.

**Posterior approaches**
The classical approach, as described by Judet (Fig 6.1-3), gives access to the posterior aspect of the scapular body, the scapular neck, and the glenoid. The patient is placed in a lateral decubitus or a prone position with the arm freely draped. The skin incision starts at the posterior corner of the acromion, follows the inferior margin of the scapular spine to the medial scapular border, and curves inferiorly along the medial border to the inferior angle. The deltid muscle is detached from the scapular spine and the infraspinatus muscle can be completely detached from its lateral origin and elevated from the posterior aspect of the scapula. This extended dissection, however, is only necessary for complex scapular fracture treatment.

In the majority of cases only the posterior rim of the glenoid, the scapular neck, and the lateral border of the scapula need to be visualized. The skin incision for the simplified posterior approach starts 2 cm medial to the posterior corner of the acromion and runs parallel to the lateral border of the scapula. The inferior border of the deltid muscle is identified and elevated. The scapular bone and the posterior joint capsule are reached through the interval between the infraspinatus and teres minor muscles. Abduction of the arm raises the inferior border of the deltid muscle, allowing access to the cranial part of the joint capsule. Care must be taken not to injure the suprascapular nerve as it exits the scapular notch as well as the axillary nerve as it exits the quadrangular space just below the teres minor muscle.

1.7 Postoperative treatment

Active range of motion exercises are commenced on the first postoperative day. With fractures of the anterior glenoid rim that have been operated through a deltopectoral approach, external rotation is limited to the neutral position and abduction in the scapular plane is limited to 90° for the first 6 weeks.
**Specific fractures**

Fig 6.1-3a–b  Posterior approach to the scapula.

- **a**  Lateral decubitus; incision from the tip of the acromion along the inferior margin of the scapular spine to the medial scapular border and curved inferiorly along the medial border to the interior angle of the scapula.

- **1**  Suprascapular nerve and artery.
- **2**  Posterior circumflex humeral artery/axillary nerve.

- **b**  The deltoid muscle (3) is sharply dissected from the scapular spine and the base of the acromion with a small tissue border left on the spine to facilitate reattachment. The deltoid muscle is then carefully moved laterally, avoiding damage to the axillary nerve and circumflex humeral artery (2). Approach the lateral margin of the scapula and the glenoid (4) by separating the infraspinatus (5) and the teres minor (6) muscle. A small arthrotomy is now possible. Be careful not to damage the circumflex scapular vessels (7).
2 Clavicular fractures and dislocations of adjacent joints

2.1 Epidemiology

Injury to the clavicle is estimated to constitute about 4–10% of skeletal trauma presenting at an emergency department. The vast majority of patients report a direct fall onto the shoulder or a direct blow, most often sustained during an outdoor leisure activity. Men outnumber women by 2 to 1 and present at a younger age (30-year-old versus 39-year-old). More than 2/3 of the fractures are located in the middle section of the clavicle. Fractures of the sternal part account for 2%, the rest involve the acromial part [8]. Clavicular injuries are generally treated nonoperatively with more than 100 possible options [12], most of which include immobilization in a sling until pain ceases. However, complications of nonoperative treatment (eg, shortening, deformity and malunion with pain and physical impairment) and new fixation techniques and implants have generated renewed interest in operative fixation of clavicular fractures.

2.2 Surgical anatomy

The clavicle is S-shaped and forms the only bony connection between the upper limb and the torso. The close proximity of the brachial plexus and the subclavian vessels should be recognized. During movement of the arm and shoulder the clavicle also rotates around a virtual axis between the sternum and the acromion. As a consequence the tension and compression sides change. This may suggest that an intramedullary implant would be the best biomechanical choice for fracture fixation in this short tubular bone.

2.3 Classification

Allman divides the clavicle into three parts, group I representing the middle third, group II and III the lateral and medial third [13]. Three subgroups exist for every group, “a” being the nondisplaced, “b” the displaced, and “c” the multifragmentary fracture type. The OTA classification recognizes the medial end, the diaphysis and the lateral end [4]. The diaphysis counts nine subgroups similar to the subgroups known from the Müller AO Classification of fractures—long bones, where the clavicle is coded bone 15 (Tab 1.5-1).

2.4 Assessment and diagnosis

The clavicle is one of the few bones which can be examined by palpating its whole length. Hematoma, deformation, imminent skin perforation, or unusual mobility are easily detectable. Radiological investigations commonly include an AP and a 30º cranial tilt view. However, if shortening of the clavicle influences the decision on operative treatment, a PA 15º caudal x-ray more reliably assesses differences compared to the noninjured side [14]. Irrespective of the cause of trauma, assessment of a clavicular injury also includes a neurological and vascular examination of both arms.

2.5 Treatment

2.5.1 Treatment of clavicular shaft fractures

Ever since Hippocrates described the nonoperative management of closed clavicular fractures, immobilization until pain ceases has been standard treatment.
Specific fractures

There is sufficient evidence showing that immobilization with a simple sling produces the same results as a figure-of-eight bandage, but less pain. In addition, the latter requires regular adjustment and causes a lot of inconvenience. Even without physiotherapy, full recovery of shoulder mobility may be expected after 6–8 weeks. In most cases, nonoperative treatment of closed clavicle fractures is highly successful and uneventful.

Primary operative treatment is indicated for open fractures, imminent skin or pleura perforation by one of the fragments, and associated or progressive injuries of the neurovascular bundle. Relative indications for surgery include concomitant injuries of the ipsilateral upper extremity, spinal cord injuries, or polytraumatized patients. Floating shoulder injuries with severely displaced or unstable ipsilateral scapular neck and clavicular fractures may require operative treatment. In these cases it is usually sufficient to fix the clavicular fracture. Depending upon the specific requirements of certain patient populations, operative treatment may be considered (e.g., professional athletes). Furthermore, there is a growing number of reports suggesting that the results of nonoperative treatment are less satisfactory than assumed [15, 16].

- **Residual pain and functional outcome seem to correlate with the amount of shortening of the clavicle. Therefore, operative treatment should at least be discussed with patients who sustained grossly displaced or multifragmentary fractures.**

Exact indications for surgery however, are lacking.

**Plating**

The patient is placed in a beach chair position. Either an infrACLavicular incision parallel to the long axis of the bone or a saber-cut incision perpendicular to the long axis is used. The former provides a more convenient, unlimited access to the entire length of the bone, whereas advocates of the latter claim better cosmetic results and less damage to the suprACLavicular cutaneous nerves. In our experience reducing the tension on the skin suture through a meticulous adaptation of the platysma muscle at the end of the operation is much more important for a good cosmetic result than the type of skin incision.

Plates may be applied to the anterior or superior aspect of the clavicle. Superior placement best avoids detachment of the muscles, since the bone is exposed between the insertion of the trapezius and the pectoralis major and deltoid muscles. Biomechanically there is no significant advantage for either plate position. Anterior placement should provide better screw purchase, because of the larger diameter of bone in the transverse plane. With superior placement of the plate, the subclavian vessels are at risk of injury during drilling and screw insertion, whereas with anterior placement the structures of the brachial plexus may be damaged. Depending upon their biomechanical function either straight 3.5 mm plates (LC-DCP or LCP) or reconstruction plates 3.5 may be used (Fig 6.1-4). Reconstruction plates are easier to apply to the S-shaped bone, but are mechanically weaker than straight plates and should be used with caution to bridge a comminuted fracture. They may safely be used with lag screws for neutralization or for axial compression. The plates should be sufficiently long to allow three screws to be inserted in each main fragment. Anatomical reduction and correct rotational alignment may be difficult to achieve. Sometimes it is helpful to reduce and fix the bigger intermediate fragments first with 2.0 or 2.4 mm lag screws to one or both main fragments before applying the plate. It is important to preserve the soft-tissue attachments. Bone grafting in primary surgery is not necessary. Due to the risk of refracture, implant removal generally is not recommended before 2 years after ORIF. There are only a few reports in the literature on the results of ORIF with plates. Nonunion rates of 3–8.3% were noted [17–19].
Fig 6.1-4a–e  Midshaft fractures of the clavicle.

a–c  Wedge fracture fixed with a 7-hole reconstruction plate 3.5 on top. One independent 2.4 mm lag screw.

d–e  Bridging plate for multifragmentary fractures. Anterior placement of a LC-DCP 3.5 for better purchase of the screws.
**Intramedullary nailing**

Stiff pins or thick K-wires are not satisfactory because of the risk of implant migration and damage to nearby neurovascular structures. However, the titanium elastic nails (TEN) have opened new perspectives for percutaneous intramedullary fixation (elastic stable intramedullary nailing, ESIN) of the clavicle (Fig 6.1-5). The patient is placed in a supine position on a radiolucent table. A 2 cm skin incision is made over the sternal end of the clavicle. A 2.5 mm drill hole is made in the anterior cortex. The entry point is then enlarged with an awl in a slightly lateral direction. A 2.0–3.5 mm titanium elastic nail (TEN) is inserted with oscillating movements and—under image intensification—advanced across the fracture site. In about 50% of the cases closed reduction cannot be achieved. In these cases the fragments are exposed through a 2 cm incision over the fracture site enabling direct manipulation and reduction. The tip of the TEN is advanced as far laterally as possible without perforating the cortex. The medial end of the intramedullary nail is then cut off and should be buried subcutaneously [20]. The new, blunt endcaps (Fig 6.1-5d) prevent backing out of the TEN. Postoperative immobilization is not necessary. If this technique is used in multifragmentary fractures, abduction of the shoulder is limited to 90° for the first 3 weeks. Hardware removal is not mandatory but can be done after 8 months (at the earliest) through the initial sternal incision. First results of this technique are promising, with good pain relief and significant improvement of shoulder function. Patients with an additional injury of the lower limb are able to

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**Fig 6.1-5a–d**

*a–c*  Titanium elastic nail (TEN) for displaced clavicular fracture. Medial entry point. Closed reduction is possible in about 50% of cases.

*d*  Endcap to be slipped over the cut end of the nail and anchored in the bone by the thread.
walk with crutches within the first week. Possible complications include painful skin irritation from the protruding end of the TEN (6%). In a comparative study, the nonunion rate was lower and the cosmetic and functional result better than with nonoperative treatment. Secondary shortening of the fracture may occur and in comminuted fractures plate osteosynthesis is still preferred.

### 2.5.2 Treatment of fractures of the lateral end of the clavicle

Treatment of fractures of the lateral end of the clavicle has been a matter of debate for a long time. There is recent evidence that nonoperative treatment is a safe and effective policy [21]. This applies to displaced fractures of the lateral end of the clavicle if there are neither compromised soft tissues nor an ipsilateral disruption of the superior shoulder suspension complex [22].

Primary operative stabilization is mandatory in open fractures, in a double disruption of the SSSC, or with severe skin involvement. Nonunion of displaced fractures at this site is fairly common and may be an indication for surgery. Treatment options include banding of the clavicle to the coracoid process with stitches made of strong resorbable or nonresorbable materials, Bosworth screw technique [23], plate fixation using LCP T-plates 3.5 (Fig 6.1-6) or a hook plate (modified Balser plate), which hooks under the acromion (Fig 6.1-7). There is no evidence to support the superiority of any of these.

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**Fig 6.1-6a–d**

a Displaced fracture of the distal clavicle with rupture of the coracoclavicular ligament.

b–c Fixation with a lag screw (through the plate) and a 45° oblique LCP T-plate 3.5 using locking head screws.

d The plate should be carefully contoured so that the locked screws are not parallel but converge.

If a fragment is not large enough to use a lag screw, it is probably not appropriate to use this plate.
Specific fractures. In missed or “delayed” cases an alternative may be excision of the lateral end of the clavicle with stabilization of the coracoclavicular ligaments (Weaver-Dunn procedure).

2.5.3 Treatment of acromioclavicular joint dislocation

The Tossy and Allmann classification modified by Rockwood seems to be the most appropriate [22]. He identifies six subgroups, of which type I (sprain of the acromioclavicular ligament) and II (acromioclavicular joint disruption with sprain of the coracoclavicular ligaments) are treated nonoperatively. Type III (dislocation of the joint with rupture of the acromioclavicular and coracoclavicular ligaments) may initially be treated nonoperatively. Persisting complaints might later be an indication for a lateral clavicle resection or fixation with a hook plate. In type IV injuries the lateral end of the clavicle protrudes posteriorly through the trapezius muscle, which will permanently hamper realignment of the joint and therefore should be operated. Dislocations of type V variety (acromioclavicular and coracoclavicular ligaments disrupted, deltoid and trapezius muscles detached from the lateral end of the clavicle, gross disparity between clavicle and scapula) should be operated upon primarily. Finally, type VI dislocation is a very rare case in which there is an anteroinferior dislocation of the lateral end of the clavicle underneath the coracoid process, which requires an open reduction.

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Fig 6.1-7a–b The clavicular hook plate. Superior approach to the distal clavicle.

a Fracture reduction and identification of the acromioclavicular joint allows introduction of the hook plate into the subacromial space.

b Proximal fixation provides stability and allows early postoperative mobilization. Some degree of shoulder impingement is inevitable and these plates always need to be removed.
Many different techniques have been proposed for operative treatment. The lateral end of the clavicle can either be fixed to the acromion or the coracoid process or to both, using modified tension band techniques with wires or resorbable bands, a single screw (Bosworth technique, Fig 6.1-8) or a hook plate (modified Balser plate) [23–25].

2.5.4 Treatment of sternoclavicular joint dislocation
The sternal end of the clavicle is the last growth plate in the clavicle to completely ossify so that a sternoclavicular dislocation may still be a physeal injury, either Salter–Harris type I or II. Diagnosis on plain x-rays can be very difficult and careful physical examination for tenderness and asymmetry is...
Specific fractures

Only a CT scan will provide sufficient information on the extent of the dislocation and possible associated bone injury. Dislocations are either anterior or posterior, the latter of which might lead to respiratory problems. Posterior dislocations are corrected by closed reduction or with a percutaneously applied pointed bone-holding forceps. Normally they are stable after reduction and will not require additional fixation. In contrast, anterior dislocations may be reduced easily but are unstable. Primary operative treatment, however, is only indicated for cosmetic reasons, since persistent dislocation does not lead to any functional impairment. If indicated, the sternal end of the clavicle is fixed to the sternum in a modified tension band technique using resorbable cords, bands, or a free tendon graft (e.g., palmaris longus muscle) in addition to the suturing of the torn capsular ligamentous structures. Fixation with K-wires is dangerous because there is a high risk of implant migration even if the ends of the wires are bent after insertion. Most publications report a high incidence of cosmetic impairment due to the postoperative scar and up to 50% of patients suffer from recurrent dislocations [26].

3 Bibliography

6.1 Scapula and clavicle


4 Acknowledgment

We wish to thank Christoph W Geel for his contribution to this chapter in the first edition of the AO Principles of Fracture Management.