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Clavicula fractures: considerations when plating

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KEYWORDS

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Internal fixation
Plate fixation
Complications
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ABSTRACT

The preferred treatment of clavicula midshaft fractures in adults has gone from being very conservative into surgery being frequently recommended. However, based on recent meta-analysis favorable outcome with internal fixation is not as consistent as previously reported. Probably due to a combination of indications for surgery becoming too wide and surgery being performed by a wider group of surgeons. When using plating for clavicula fractures there are several considerations to consider to improve outcome while reducing the risk for complications. Traditionally a horizontal approach along the clavicula is used as it provides good exposure. However, this incision is associated with a high risk for permanent anterior chest wall numbness that might be very disturbing for patients. A vertical incision can instead be used. Plates are traditionally placed in a superior position. An alternative can be an anterior-inferior position that allows better soft tissue coverage, less risk for hardware protrusion, longer screws can be used and the risk for damaging the underlying neurovascular bundle is reduced. Angle-stable screw-plate systems has not in a convincing way shown any benefit in clavicula fractures. In part because most patients have good bone quality where conventional screws will be sufficient.

Introduction

Clavicular fractures are frequent injuries with an incidence of about 60 per 100,000 person-years [1,2]. They constitute approximately 4% of all fractures in adults and about 35% of all fractures that occur in the shoulder region [3,4]. Of fractures in the shoulder region, only fractures through the proximal humerus are more common in adults.

For a long time, clavicular midshaft fractures were considered as injuries where the natural course following non-operative treatment resulted in uneventful healing and complete restoration of function in almost all cases [5,6]. Based on such an assumption it is of course no surprise that non-operative treatment was the preferred treatment option for almost all midshaft fractures. In contrast, for lateral fractures if displaced, surgery has for a long time been an option with the aim to reduce and fix the fracture in order to restore the integrity and function of the acromio-clavicular joint.

Due to studies where the outcome following non-operative treatment was followed systematically and in larger patient populations, it became obvious that non-union and sequelae following midshaft clavicula fractures were fare more common than previously reported. Fracture types such as the Z-fracture were associated with a high risk for sequelae (Fig. 1). The present level of knowledge therefore shows that nonoperative treatment of midshaft clavicle fractures is associated with a higher rate of nonunion and functional sequelae than previously known [7–9].

In 2007 the Canadian Orthopedic Trauma Society published a multicenter randomized study where in displaced midshaft clavicula fractures plate fixation proved to be superior compared to nonoperative treatment. Plate fixation resulted not only in a lower rate of malunion and nonunion but also in improved functional outcome when compared with nonoperative treatment [10]. Based on this pivotal study, and supported by later studies with similar favorable results with surgery, the pendulum shifted rapidly from a conservative attitude towards surgery with internal fixation as the preferred treatment option for a substantial part of clavicula fractures. However, the attractive results in favor of surgery might have led to an over treatment with internal fixation. In more recent papers complications are frequent and thus a more reluctant and critical attitude with respect to the indications for plating of clavicular fractures is evident [11–14]. In a recent meta-analysis by Devji et al. (2015) based on 15 randomized controlled trials the authors concluded that the current evidence did not support the routine use of internal fixation for the treatment of displaced midshaft clavicle fractures [15]. The meta-analysis revealed that nonoperative treatment did not differ from operative treatment in the risk of secondary operation or rate of complications. Regardless of type of treatment there was an average of 25% of patients having a complication. Ban et al. (2016) considered the present frequent use of surgical intervention for displaced midshaft clavicle fractures as an overtreatment [16].

There is a need to define more precise indications where surgery might be beneficial in the treatment of midshaft clavicula

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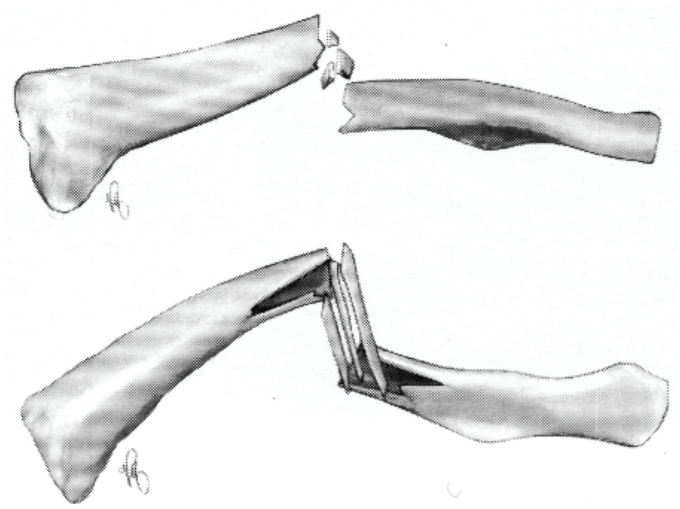

Fig. 1. Z-fracture associated with high proportion of sequelae when treated non-operatively.

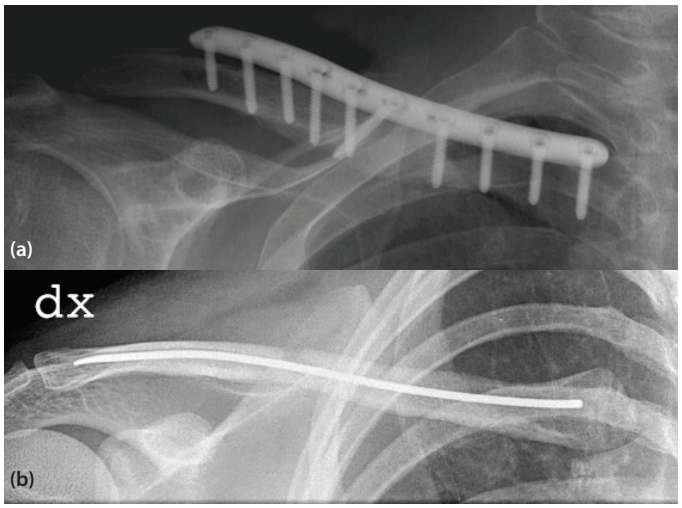

Fig. 2. (a) Displaced clavicular fracture fixed with a pre-contoured plate. (b) Displaced clavicle fracture fixed with an elastic nail.

fractures. Several ongoing studies are therefore aiming at different subpopulations and fracture types to elucidate when surgery might be beneficial as well as subgroups of midshaft clavicula fractures where nonoperative treatment will give a similar or even better result.

If internal fixation is to be used there are two major alternatives, plate or intramedullary fixation, to consider. Both options have advantages and drawbacks (Fig. 2a and b). In a Cochrane review by Lenza and Faloppa (2015) a fair number of trials where plate fixation was compared with intramedullary fixation were assessed [17]. They concluded that only limited evidence is at present available on the effectiveness of different methods of surgical intervention of midshaft clavicle fractures. With no difference in outcome between clavicula fractures treated with intramedullary rods compared with plates. A meta-analysis by Hussain et al. (2016) came to a similar conclusion with no difference in long-term functional outcomes following intramedullary nailing compared with plating although plating was associated with a higher risk for complications [18]. In contrast, a meta-analysis by Houwert et al. (2016) revealed more frequent refractures and major re-interventions after implant removal when using plates compared with intramedullary rods [19].

Whenever plate fixation is being used for treatment of midshaft clavicula fractures there are several considerations that should be addressed including e.g. patient characteristics, fracture type, associated injuries, surgical approach, plate position and type of implant to be used. In fact, plate fixation of clavicula fractures present several unique demands including a complex bone geometry and a subcutaneous location of the bone that must be addressed to achieve an adequate fixation.

Complications following plate fixation

Complications when using plates as internal fixation often tends to be related to the actual procedure or the hardware. Wound infection, anterior chest wall numbness and plexus symptoms represent soft tissue complications frequently reported that usually are related to the procedure. While mechanical failure during the course of healing or local irritation of hardware after healing are frequent hardware related complications that often lead to implant removal with a risk for refracture through the screw holes after removal. In the Canadian study [10] the overall complication rate when using plate fixation was 37% while the reoperation rate, including plate removal, was 13%. Across eight studies assessed in a meta-analysis there were 23% complications and a reoperation rate of 11% [15].

Horizontal or vertical approach

A transverse or horizontal incision along the clavicula is commonly used when plating midshaft clavicula fractures as it allows good exposure and is easy to extend if needed. One problem with this incision is the frequent risk of damaging branches that belongs to the supraclavicular nerve as these branches cross the clavicula at an almost perpendicular angle along the lateral two-thirds of the bone [20]. Anterior chest wall numbness due to injury to the supraclavicular nerve branches when using an open transverse approach for reduction and plating of midshaft clavicula fractures is therefore a frequent and often permanent complication. Although there are reasons to believe that this complication is not reported to the full extent of its presence after surgery. Even though numbness is frequently surrounding surgical incisions in general, the negative effect of anterior chest wall numbness might be more pronounced than numbness in other parts of the body. Chest wall numbness might have a truly negative impact on clothing, use of shoulder straps and introduce a risk for pressure soars when carrying heavy loads as the protective skin sensation is affected. Even when attempting to identify and protect the anterior chest wall cutaneous supraclavicular nerve branches during the surgical procedure the occurrence of numbness is frequent [21]. In 83% of the patients some degree of anterior chest wall numbness was present at two weeks after surgery using a transverse incision even when a nerve sparing technique was used. Over time the occurrence as well as the size of the numbness area decreased although at one year after surgery approximately 50% of the patients still experienced numbness with the average area of numbness being 15 cm^2.

As an alternative to horizontal incision a vertical incision can be readily used for midshaft fractures although the need for appropriate soft tissue mobilization and retraction to gain adequate access to the fracture area is obvious. Numbness seems to be more commonly associated with open transverse incisions due to the direction of the incision being perpendicular to the nerve branches compared with vertical incisions that runs parallel to the branches of the supraclavicular nerve. In a retrospective study by Wang and others (2010) the likelihood of experiencing numbness following plate fixation was significantly less when using a vertical compared to a transversal incision [22].

Open, mini-open or minimal invasive approach

By using a mini open plating technique Beirer et al. (2015) described a significantly reduced area with anterior chest wall

numbness when compared with conventional open plating [23]. By reducing the average transverse incision length from about 94 to 61 mm, centered over the fracture area, the average area of chest wall numbness was reduced from 26 to 7 cm^2. In order to preserve the enveloped soft tissue and the periosteal blood supply without exploring the fracture area, and to reduce anterior chest wall numbness, a minimally invasive plating technique has also been described where no soft tissue opening is done at the fracture site [24]. The fracture is reduced through the use of indirect means followed by plate insertion using small incisions on each side of the fracture area and screw placement through stab wounds. When in a retrospective series results were assessed when using this technique, a significant reduced occurrence of skin numbness was observed when compared with open plating. While there was no difference in rate of healing, malunion and functional outcome using the Constant score and the UCLA score [25].

Superior or anterior-inferior plate position

Implant related problems are frequent when using plates for fixation of midshaft clavicular fractures. One obvious reason being the subcutaneous location of the clavicular bone that limits the soft tissue envelope. The bone being curved might also present a challenge especially when dealing with reduction following a comminuted fracture. Lack of proper reduction to restore the curvature might lead to mismatch between bone and plate causing protrusion of hardware even when using precontoured plates, as well as lengthening of the bone if the natural curve is not restored. With a superior plating position, the limited thickness of the soft tissue coverage will make the plate prominent leading to a risk for implant irritation and subsequent need for plate removal [26]. With an anterior-inferior plate position a better soft tissue coverage can be achieved. There is also a potential benefit with the use of longer screws due to the oblique form of the medial and lateral aspect of the clavicula that might contribute to improved mechanical fixation strength when using the anterior-inferior plate position (Fig. 3) [27–29]. Another potential benefit of an anterior-posterior plating position is that the direction of the drilling and screw placement should reduce the risk for damaging the underlying neurovascular bundle. In a retrospective study a comparison was made with respect to implant-related irritation and proportion of plate removal in patients with midshaft clavicular fractures undergoing plate fixation by an anterior-inferior or superior approach [30]. The study revealed that an anterior-inferior plate position was associated with significantly less patients reporting implant irritation compared with patients being fixed with a plate on the superior aspect of the clavicle. However, there was no difference in implant removal due to implant-irritation between the two groups.

Type of plate

There are a number of options to consider when choosing a plate system that will be most suitable for fixing a midshaft clavicula fracture. For a simple fracture in a patient with good bone quality the challenge that has to be met by the implant until healing is quite different compared with a comminuted or segmental fracture especially when combined with poor bone quality. For instance, size and plate length needs to be considered as well as the potential use of a precontoured plate or not and whether a locking plate-screw system will be preferable [31].

Based on the dimension of the clavicula the plate sizes usually employed are either 2.7- or 3.5-mm plating systems. In a clinical study by the use of 2.7-mm or 3.5-mm non-locking reconstruction plates inserted using an anterior-inferior approach were compared in midshaft clavicula fractures. There were no differences in time to healing or healing rate between groups. However, the 2.7-mm group had a lower reoperation rate and a higher rate of cosmetically good results with less plate prominence due to the lower profile [32].

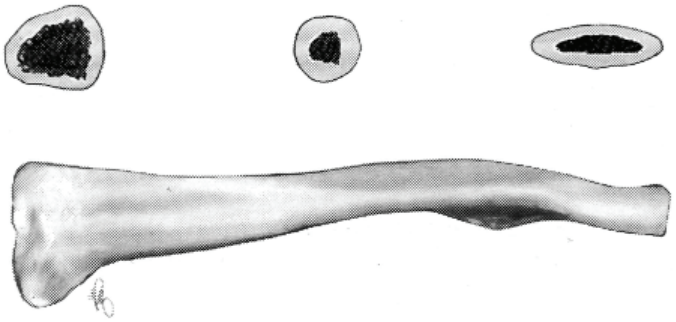

Fig. 3. Cross section of different parts of the clavicle.

In a biomechanical study the properties of the same type of plates, i.e. non-locking reconstruction plates sized 2.7 mm or 3.5 mm were compared when placed in an anterior-inferior position using a synthetic clavicula bone model [33]. The specimens were subjected to axial compression, torsion and four-point bending. In both axial and torsional stiffness, the 3.5-mm plate provided a significantly stiffer construct as well as a higher bending rigidity. Although the 2.7-mm plate also revealed mechanical strength well above the properties of an intact clavicle. No fatigue testing was performed.

Precontoured plates have been introduced for fixation of clavicula fractures. The proposed benefits when compared with straight plates, being contoured during the procedure, include a design that will act as a form when restoring the shape of the fractured clavicle into an anatomic natural shape. Especially when dealing with a comminuted fracture the precontoured plate can be used as a model. Thereby reducing the risk for straightening and thereby also lengthening the clavicula due to inability to reconstruct the full S-shape of the natural clavicula. In a retrospective clinical study by VanBeek et al. (2011) the results following use of precontoured and noncontoured 3.5-mm plates were compared in displaced midshaft clavicle fractures. In the noncontoured group 64% complained of prominent hardware and only 32% in the precontoured group. Removal of hardware was 21% in the noncontoured plate group and only 11% among patients treated with a precontoured plate. There were no differences in postoperative ROM and functional outcome variables between groups [34]. In another similar study by Rongguang et al. (2016) the complications and outcome were compared when using precontoured plates with noncontoured. In the precontoured group 28% reported hardware prominence while in the noncontoured group 54% of patients reported problems with hardware prominence. The difference between groups was statistically significant. Patients complaining of hardware prominence had a significant lower BMI compared with patients reporting no hardware problems for both groups, indicating the importance of soft tissue coverage to reduce the risk for hardware prominence. Plate removal was significant more frequent among patients being treated with a noncontoured plate compared with the group treated with a precontoured plate [35].

With the increased use of locking plates for many fractures there is a question on whether such a concept will improve the mechanical stability and the outcome in the fixation of clavicula fractures. In a biomechanical study by Celestre et al. (2008) synthetic clavicles with a midshaft transverse fracture model were fixed with 3.5-mm plates with or without a locking system (Locked CDCP) [36]. In axial compression the locked plate system was significantly stiffer than the non-locked construct and in bending the locked plates demonstrated greater failure strength than non-locked plates. Torsional stiffness was also higher for the locked plates but only when placed in the superior position while placement in the anterior-inferior position favored non-locked plates.

In a retrospective case-controlled study by Lai and others (2013) patients with midshaft clavicula fractures fixed with either dynamic or locked compression plates were assessed with respect to perioperative course and complications [37]. The only significant difference between groups was a higher request for plate removal in the dynamic compression plate group while there were no differences in the perioperative course or healing. A difference that might be due to the screws in the unlocked system being more pronounced than in the locked plate system and not directly related to whether the system is being locked or not.

Unicortical versus bicortical screw fixation and refracture after removal

Reports on refracture following plate removal has raised concerns on how to avoid such a complication. In a biomechanical study James et al. (2015) examined whether the orientation of screw holes in clavicles will have any effect on the stiffness and load to failure. Clavicles with anterior-inferior directed drill holes had a significant increase in median maximal load to failure and an increase in median stiffness compared with clavicles where superior holes had been made for simulation of superior plating. The diameter of the drill holes as well as the number of screws per length unit is obviously also of importance for the risk of refracture due to local stress rising [29].

Another potential way to reduce the risk for refracture following plate removal might be by using unicortical screws that will leave the opposite cortex intact. Using fresh frozen cadaver clavicle specimen's oblique osteotomies through the midshaft were fixed using precontoured plates with either standard bicortical non-locking screws or unicortical looking screws in a study by Hamman et al. (2011) [38]. Mechanical testing did not reveal any significant differences in terms of axial stiffness or load to failure. Although rotational stiffness varied significantly with bicortical non-locking constructs providing higher torque values. When comparing the biomechanical properties of unicortical versus bicortical locked plate fixation using a synthetic bone model no difference was found between groups in failure load, cantilever bending and cross body stiffness. Authors concluded that unicortical fixation might be an option to avoid complications associated with posterior-inferior hardware penetration [39]. While Little and others using a biomechanical model based on cadaveric clavicles concluded that mono-cortical plating failed at significantly lower loads when compared with bicortical locked and non-locked plating. Based on the findings the authors advised against the use of unicortical fixation in the midshaft fractures of the clavicle [40].

Disclosure

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