Surgical fixation of displaced clavicle fracture in adolescents: a review of literature

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Abstract

The literature available on patient-orientated outcomes of operative management for clavicle fractures in adolescents is fairly limited. Open surgical treatment of displaced mid-shaft fractures of the clavicle continues to be a topic of controversy. Traditional treatment of clavicle fractures has been via non-operative methods in both children and adults. Management in adolescent patients remains controversial, and rightly so, as the traditional experience from non-operative methods has been regarded as satisfactory, while the literature on the more recent approach towards fixing some of these fractures is evolving. We present a review of relevant literature.

Introduction

Open surgical treatment of displaced mid-shaft fractures of the clavicle continues to be a topic of controversy. Traditional treatment of clavicle fractures has been via non-operative methods in both children and adults.[1-6] The scientific literature has increasingly questioned the patient-orientated outcomes in recent years. Many reports point out higher rates of complications – such as shortening, non-union, deformity, and unsatisfactory patient-derived outcomes – in cases of adult displaced mid-shaft clavicle fractures.[7-14] Two recent randomized controlled studies have demonstrated superior results in favour of the operative treatment in those cases of completely displaced clavicle fractures in the adult population.[15,16] Definitive indications for internal fixation of closed clavicle fractures in adult patients are still debatable.

Skeletally immature patients with clavicle fractures represent a special cohort of patients known to have a high rate of fracture healing and good remodelling potential.[4,17-20] However, as these patients transition into adolescence, their activity level and functional expectations rise rapidly and may in fact outweigh the activity expectations of most adults. Thus, they may have relatively greater functional impairment from residual disability at their age compared with young or older adults. Despite these concerns, the literature currently available on true patient-orientated outcomes of operative and non-operative management of clavicle fractures in adolescents is fairly limited, and as such, most of the data are extrapolated from the adult literature. Although clavicle fractures in adolescents have traditionally been treated non-operatively, the positive outcomes achieved from fixation of displaced clavicle fractures in young adults could challenge this classical treatment philosophy. Sports and trauma subspecialty orthopaedists are increasingly being obligated by patients and by parents of highly functional and active adolescents to fix these fractures.

The purpose of this review is to discuss the literature relevant to this subject, and to outline our personal approach in dealing with these cases as well as our preferred surgical technique and postoperative management.

Our approach

We discuss the options of both conservative and operative fixation in older teenagers with clavicle fractures that are completely displaced and shortened by more than 15 mm, a fracture affecting the dominant arm in a high-end athlete, a comminuted fracture – including a z-shaped configuration with a central segmental fragment/butterfly – irrespective of the amount of shortening (Figure 1), and tenting of the skin associated with fracture (impending open fracture) and in patients with clavicle fracture and polytrauma. After the parent/patient has made an informed decision, having weighed the pros and cons of surgical versus non-surgical fixation, and if surgical intervention is decided upon, our current approach for further management (senior author HH) is discussed.

In these select cases, surgical treatment is performed using a standard positioning and a similar surgical technique (described below) on a Jackson radiolucent flat table (Mizuho OS, Union City, USA) for optimal intraoperative radiographic assessment with the patient in the supine position and a bump between the scapulae for optimal positioning and intraoperative fracture reduction. An appropriate clavicular implant (side-appropriate) is utilized for fixation in all cases.

Postoperatively, all patients undergo a standardized protocol until full recovery is achieved. In the immediate postoperative period the patient is placed in a shoulder immobilizer with a bulky dressing and discharged home on postoperative day 1 or 2. All patients come back for an initial postoperative check at 7-10 days. Following wound check they are allowed to start gentle oscillatory movements and pendulum exercises while placing the arm back in the shoulder immobilizer. A second follow-up in all cases is at 3-4 weeks from initial surgery and includes repeat radiographs. The shoulder immobilizer is discontinued and a sling is provided for support (for a week more). Range-of-motion (ROM) exercises (active and active-assisted) are started at this stage. Overhead activities and weight lifting (>1 kg) are specifically avoided. Patients are brought back at 6-7 weeks and repeat radiographs are performed. At this time overhead activities are permitted (with continuation of increasing ROM) and strengthening exercises are started. At 12 weeks post-surgery, the patients are allowed to return to full sporting activity – including contact sports – if radiographs do not reveal any abnormalities and the clinical exam remains normal with full recovery of strength.

Surgical technique: our preferred method

Cases are selected on the basis of the indications mentioned above. In addition to these indications, patients with polytrauma also present relative indications for clavicle fracture fixation as mentioned, particularly with ipsilateral floating shoulder or upper-extremity trauma.

We do not use the beach-chair position for

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performing this surgery. Patients are typically positioned on a radiolucent flat-top Jackson table (Mizuho OS, Union City, USA). Muscle relaxation is specifically requested in our cases for ease of reduction. A well-padded adequately sized bump is placed between the scapulae, and the head is tilted to the opposite side. The ventilation tube is carefully placed coming out from the angle of the mouth on the opposite side so as to be further away from the surgeon and assistants. The forehead is then taped to the Jackson table using a 5-cm silk tape for stabilisation, with appropriate headrest elevation so as not to hyperextend the head during positioning. A separate arm board is used and placed parallel to the Jackson table on the side of surgery for resting the freely prepped upper extremity during surgery. Parts are painted, prepared, and draped in the standard sterile orthopaedic fashion. A stockinette is utilized to cover the upper extremity and is stopped short at the level of the upper arm; Ioban (3M, St Paul, USA) surgical drapes may be used to cover the axilla during surgery. Both bipolar and unipolar bovies are utilized during exposure and dissection.

Surgical incision is typically an oblique incision extending to the inferior border of the clavicle on the medial side of the fracture (about 2.5-3.0 cm medial to the fracture) and extending to the superoposterior border of the clavicle on the lateral side of the fracture about 2.5-3 cm laterally to the fracture. Following the initial 5-6-cm incision, subcutaneous and deeper dissection is carefully performed with the help of sharp and blunt dissection. A medial window is created so that dissection is continued right up to the periosteum and bone on the medial part of the clavicle (medial to the fracture). Subperiosteal elevation is performed so as to comfortably place small Hohmann retractors. A small retag piece of gauze is now placed in the medial window and attention is directed to the lateral end of the incision. Similarly deeper dissection is performed up to the periosteum of the lateral part of the clavicle, and Hohmann retractors are placed. A blunt freer is now used to gradually deepen and dissect the central part of the incision over the fracture site while protecting the nerve branches as well as important veins. A bipolar bovie is very helpful in this dissection.

Once the dissection has exposed the fracture, both ends of the bone are held with lobster clamps for ease of control. The fracture site is now cleaned, the haematomata are evacuated, and the fracture edges are cleared with curettes and a dental pick. Care is taken not to break any bone spikes that would provide rotational stability. Irrigation is now performed with copious amounts of saline and the fracture is reduced. The importance of muscle relaxation for ease of reduction cannot be over-emphasized. Once the fracture is well reduced, the appropriate length (and side) of the clavicular plate is selected and placed on the bone. Fluoroscopy imaging confirms the adequacy of length as well as the potential need for any change in plate configuration; we have never had to bend or manipulate the currently available Synthes clavicle plating system (LCP Superior Anterior Clavicle Plate, Paoli, USA). The plate fixation is then achieved using 3.5-mm cortical fully threaded screws in the compression mode. Although locking screws can be placed through these holes, we have not felt the need to use locking screws in healthy adolescents with good bone quality and strength. One should be careful intraoperatively while drilling the holes for the screw placement as excessive inadvertent plunging can lead to pleural injury and has the potential to cause pneumothorax.

Following the placement of the plate, fluoro images are obtained again to confirm the adequacy of reduction as well as the screw lengths; we prefer to not have more than two screw threads beyond the far cortex in these cases (Figure 2). Upon satisfactory radiographs, the wound is irrigated, the incision is closed in layers, and a bulky foam-tape dressing is applied. We do not give regional blocks in these cases because they make the immediate postoperative neurological examination more difficult. Patient-controlled analgesia (PCA) or oral pain medications may be used in these cases.

Discussion

Surgical intervention for clavicle fractures in adolescents and young adults is increasingly considered to be an acceptable line of treatment.[21-25] Closed clavicle fractures in children are well known for their high potential for remodelling and healing despite their degree of displacement or angulation.[4,17-20] Therefore, they are traditionally treated non-operatively and seem to do well with time. In contrast to the young paediatric population, several studies involving adult patients have reported fairly moderate outcomes related to conservative (non-operative) treatment.[7-14] On the other hand, there are some reports of potentially favourable results following operative management in adults with satisfactory patient-derived outcomes and fewer rates of non-union.[15,16]

Hill *et al*. have noted unsatisfactory patient-orientated outcomes in 16 out of 52 adult patients (31%) for the conservative treatment of displaced mid-shaft clavicle fractures.[10] Somewhat moderate results for the non-operative treatment were also reported by Nordqvist *et al.* who noted unsatisfactory patient-orientated outcomes in 22 out of 68 patients (32%).[12] Of note, a multicentre randomized comparative study in adult patients between the non-operative treatment and open reduction, internal fixation (ORIF) revealed superior functional outcomes and a lower rate of malunion and non-union for the operative treatment of displaced mid-shaft clavicle fractures compared with conservative management.[15] This is in keeping with a recent systematic review of 2144 clavicular fractures in 22 case series reporting that the rate of non-union for displaced mid-shaft clavicle fractures was 2.2% (10 of 460 patients) after internal fixation compared with 15.1% (24 of 159 patients) after non-operative treatment.[26] This represents a relative risk reduction for non-union of 86% if surgical reduction and internal fixation is performed. This review further outlined advantages of the primary plate fixation compared to non-operative treatment.

The literature on outcomes of operative versus non-operative management of clavicle fractures in adolescents is evolving, and as such, definitive indications for internal fixation are currently not well established. Our clinical experience is in agreement with previously reported studies. Kubiak and Slongo conducted a retrospective review of 15 children (14 boys, 1 girl; mean age: 13.1 years, age range: 9.3-15.6 years) who underwent surgical treatment of clavicle fractures between 1989

Figure 1. 45° cephalic tilt (Serendipity view) radiograph of the left clavicle demonstrating a mid-shaft fracture with z-shaped configuration and central segmental fragment.

Figure 2. Intraoperative fluoro image confirming the anatomic reduction as well as the appropriateness of screw lengths.

Figure 3. Advanced imaging with three-dimensional computed tomography (3D-CT) that allows reconstruction of the fractured clavicle for accurate assessment of the pattern of injury, displacement, shortening, rotation and/or angulation of the fracture.

and 2000.[21] This series included intramedullary stabilisation (n=5), external fixation (n=2), osseous suture (n=3), k-wire fixation (n=4), and/or screw fixation (n=2) in eight mid-shaft clavicle fractures, two medial fractures, and five lateral fractures. One fracture occurred in combination with a true disruption of the acromioclavicular joint. As in our experience, there were no major complications. All patients had reached full ROM at a mean follow-up of 88 days. These workers concluded that indications for operative treatment of clavicle fractures in children are rare. However, if surgical treatment is conducted, satisfactory results without major complications may be expected.

Mehlman *et al.* have reported their results on operative treatment of completely displaced clavicle-shaft fractures in children.[22] This retrospective study involved 24 children (mean age: 12 years and 8 months, range: 7-16 years) whose displaced clavicle shaft fractures were treated through ORIF. The healing rate, complication rate, and radiographic and functional variables were assessed. The mean follow-up was 2 years and 2 months. Similarly to our case series, no infections and no non-unions were observed, and 21 of 24 patients (87%) returned to unrestricted sports activities. All fractures healed and all orthopaedic implants were later electively removed. Complications included scar sensitivity in two patients and transient ulnar nerve neuropraxia in one patient related to the initial injury. The authors concluded that the ORIF procedure for displaced clavicle shaft fractures in children can be performed safely. Furthermore, they noted that growth and remodelling in the adolescent/teenage clavicle (i.e. close to skeletal maturity) is not as predictable and may resemble that of an adult rather than that of a young child, as most of the clavicle length is reached at a relatively early age. In consideration of the age group, high functional demand, thinner periosteal tube, limited potential for complete remodelling, and a need to return to athletic activities as quickly as possible, we also believe that adolescent clavicle fractures represent a unique injury.

Functional outcomes after ORIF of displaced, closed mid-shaft clavicle fractures in skeletally immature patients have been recently published by Namdari *et al.*[23] This study involved a cohort of 14 adolescents (mean age: 12.9 years, range: 10.6-15.3 years). Demographic and radiographic indices as well as radiographic and functional outcomes were assessed using the disabilities of the arm, shoulder and hand (DASH) questionnaire, the simple shoulder test (SST), and additional binary questions at a mean follow-up of 37.9 months (range 24.1-115.7 months). In their series, patients treated operatively performed well on the DASH and SST at follow-up, and all patients treated operatively achieved union. Of note, there was an increased rate of painful hardware and residual incisional numbness at the site of injury and/or surgery.

Clavicle fractures are common. An epidemiological study involving 535 patients (mean age for the entire cohort of patients: 29.3±22.0 years) revealed that clavicle fractures account for 2.6% of all fractures and 44% of those in the shoulder girdle.[27] Fractures of the middle third of the clavicle were noted to be the most common (81%). This is related to the fairly thin junction between the middle and the lateral third and the lack of stabilising ligamentous or muscular attachments.

Deforming forces on the mid-shaft clavicle fracture – such as the upward and backward pulling of the medial fragment by the sternocleidomastoid muscle and the downward dragging of the lateral fragment related to the weight of shoulder girdle and upper extremity – may eventually cause multifaceted three-dimensional (3D) mal-alignment of the fracture.[28] Additionally, the trapezoid muscle pulls the lateral third medially, causing shortening of the shoulder girdle. In the study of Postacchini *et al.*, 88.2% of all clavicle fractures occurred in the first decade of life, with 55% being non-displaced.[27] In adults, the incidence of displaced fractures was higher than that of non-displaced fractures. Regarding the middle third of the clavicle, fractures were displaced in 48% of cases and comminuted in 19%. Interestingly, in our personal experience involving adolescent patients, we note that the z-variant is the most common variant of comminution.

In order to assess the pattern of injury, displacement, shortening and/or angulation, radiographs in two projections are traditionally obtained in fractures. Clavicle fractures are routinely studied with single biplanar radiographs of the involved clavicle or shoulder. However, there is considerable lack of consistency related to measurements based on this biplanar film, and reproducibility of these measurements is relatively low, which can lead to misinterpretation of overlapping fragments.[29] Although not indicated in all routine cases, advanced imaging such as computed tomography (CT), which allows reconstructions of the clavicle in three dimensions, may overcome this barrier (Figure 3). Furthermore, measurement of the true total clavicle length is more accurate in these images. At our institution we have compared standard clavicle radiographs with CT scans, including the 3D reconstructions, and have noted that the standard clavicle films remarkably underestimate the degree of displacement, and thus cannot be used to accurately assess all the components of the deformity, including shortening or translation, angulation, rotation, and shoulder-girdle changes. Therefore, in our practice, for patients who meet the inclusion criteria for surgical intervention (or are on the cusp) we may sometimes obtain CT scans for 3D assessment to further evaluate total length, shortening, and comminution. Of note, CT scanning has its own disadvantages, such as cost and radiation exposure. Furthermore, correlation between supine CT scan measurements of clavicle-fracture shortening and standing plain radiograph measurements has not been well studied.

Conclusions

In conclusion, anatomical reduction with internal fixation and early mobilisation of adolescent displaced clavicle fractures remains a viable treatment option with predictable results and no major complications in reliable hands. There is no doubt that several clinicians and centres, including our own practice, continue to treat clavicle fractures conservatively most of the time after informed decision-

making with patients and parents. We certainly need further prospective, controlled, randomised studies, probably multicentre-based, that involve a sufficient number of cases and power in order to determine whether operative fixation may be preferred to non-operative fixation and for which specific types of clavicle fractures in adolescents.

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