Displaced Clavicle Fractures in Adolescents: Facts, Controversies, and Current Trends

Abstract

There is an increasing trend toward stabilization and fixation of markedly displaced midshaft clavicle fractures in adolescents. Recent studies in the adult literature have shown a greater prevalence of symptomatic malunion, nonunion, and poor functional outcomes after nonsurgical management of displaced fractures. Fixation of displaced midshaft clavicle fractures can restore length and alignment, resulting in shorter time to union. Symptomatic malunion after significantly displaced fractures in adolescents may be more common than previously thought. Adolescents often have high functional demands, and their remodeling potential is limited. Knowledge of bone biology and the effects of shortening, angulation, and rotation on shoulder girdle mechanics is critical in decision making in order to increase the likelihood of optimal results at skeletal maturity. Selection of fixation is dependent on many factors, including fracture type, patient age, skeletal maturity, and surgeon comfort.
healing and remodeling. However, as they enter adolescence, children become more active than adult patients, lose the ability to remodel, and theoretically may have greater functional impairment resulting from residual disability.

**Anatomy**

The clavicle is an S-shaped bone whose medial end is connected to the axial skeleton via the sternoclavicular joint and whose lateral end is connected to the scapula via the acromioclavicular joint. Phylogenetically, it has played a critical role in avian species, bipeds, and quadrupeds. As mammals evolved into an erect species, the clavicle continued to be a critical bone, attaching and suspending the entire upper extremity and scapular blade to the thoracic girdle. It is the first bone to ossify in the fifth week in utero. Initial growth (≤5 years) occurs from the ossification center in the central portion of the clavicle, whereas continued growth occurs at the medial and lateral epiphyseal plates. During childhood, approximately 80% of clavicular growth occurs at the medial physis. The medial growth plate is the last physis to close, generally at age 23 to 25 years.

Several fascial layers and muscles attach to the clavicle and help to create the predictable deformity seen with fractures. Midshaft fractures are the most common type (Figure 1). These fractures occur in the middle third of the clavicle and include all fractures lateral to the sternocleidomastoid muscle and medial to the coracoclavicular ligaments. The medial fragment is pulled superiorly and posteriorly by the sternocleidomastoid muscle. The lateral segment sags forward and rotates inferiorly because of the weight of the upper extremity and, to a lesser extent, the pull of the pectoralis muscle on the humerus. More complex fracture patterns can also occur, as seen in Figure 2.

**Effect of Clavicle Malunion on Scapular Kinematics**

The normal clavicle undergoes complex three-dimensional motion. Clavicular motion is linked directly to the surrounding motion of the scapula via attachment to the acromioclavicular joint and to the surrounding motion of the sternum via attachments to the sternoclavicular joint. During elevation of the arm and with respect to the thorax, the clavicle generally undergoes elevation of 11° to 15°, retraction of 15° to 29°, and posterior long-axis rotation of 15° to 31°. The magnitude of motion varies by subject and plane of motion.

Although nonsurgically managed clavicle fractures typically heal with some degree of deformity, functional results have been considered to be generally acceptable. However, more recent studies have highlighted the importance of clavicle shortening and displacement in determining healing potential and functional outcomes, which has created interest in the role of clavicle malunion on shoulder girdle kinematics. Changes in the resting position of the scapula can lead to scapular dyskinesia and pain on arm movement. Additionally, scapular malrotation may change the orientation of the glenoid relative to the humeral head, which...
could lead to altered joint reactive forces. In an experimental cadaver model, Andermahr et al.12 demonstrated that healing of clavicle fractures with bony shortening leads to a ventromedial caudal shift in the position of the glenoid fossa. They hypothesized that this malposition can result in functional deficits in abduction, particularly overhead motion. Most recently, in a cadaver study evaluating the effect of shortening deformity of the clavicle on scapular kinematics, Matsumura et al.13 found that posterior tilting and external rotation of the scapula significantly decreased with ≥10% shortening.

Although it is clear that clavicle shortening leads to alteration in the normal scapular position, the clinical influence of these changes has not been extensively studied. Ledger et al.11 evaluated the impact of clavicle malunion (ie, 15 mm of shortening) on anatomic and functional outcomes in 10 patients. They noted a reduction in muscular strength for adduction, extension, and internal rotation of the humerus as well as reduced peak abduction velocity in the injured shoulder. In a larger clinical study of mostly adult patients, Lazarides and Zafiropoulos14 reviewed 132 patients with united fractures of the middle third of the clavicle after nonsurgical management at a minimum follow-up of 1 year. Of these, 25.8% reported overall dissatisfaction with the result of their management. Final clavicular shortening of >18 mm in male patients and >14 mm in female patients was significantly associated with patient-reported overall dissatisfaction with nonsurgical treatment (P < 0.001 for each). The study included 93 males with a mean age of 25.4 years (range, 16 to 72 years) and 39 females with a mean age of 34.2 years (range, 15 to 77 years).

No study has evaluated kinematics of the shoulder girdle in the setting of clavicular malunion in skeletally immature patients. Furthermore, it is not clear which level of clavicle malunion leads to a clinically significantly altered scapular position and a poor functional result in this patient population. To determine the extent of clavicle shortening, investi-
Radiography

Typically, a standard AP radiograph and a 45° cephalic tilt view are obtained to assess clavicle fracture pattern, displacement, and angulation. Although shortening in clavicle fractures is considered to be an important parameter in selecting a treatment modality, no standardized method of measurement exists. Considerable variability exists in measurement techniques. Shortening may be measured on a standardized 15° tilted radiograph of the clavicle, a 15° uptilted AP panorama radiograph of the shoulder girdle, a standardized PA thorax radiograph, an abduction lordosis view, or clinically with a simple tape measure. Smekal et al assessed the different measurement methods and found that the highest agreement with CT measurements was shown by PA thorax radiographs with the patient standing erect and the clavicles positioned close to the x-ray film. Regardless of technique, the authors noted a relatively low repeatability. They attributed this finding to the limitation of two-dimensional radiographs, which can lead to misinterpretation of overlapping fragments.

Advanced Imaging Studies

CT, which is less commonly used than plain radiography, allows three-dimensional reconstruction of the clavicle. This is important in measuring the true total length of the clavicle independent of its angle in reference to the frontal and sagittal planes and because of the interindividual variability in total clavicle length. No study has evaluated the accuracy of normal clavicular length measurement on plain radiography compared with CT. However, given the variability in radiograph plate and beam angles and distance, it is unlikely that a true length measurement can be obtained in a reproducible manner in two dimensions. In our practice (H.S.H.), we commonly utilize three-dimensional CT to evaluate total length, shortening, and comminution of clavicle fractures for which plain radiographs indicate the need for surgical management.

Drawbacks of CT include cost and radiation exposure. Depending on the machine settings, the organ being studied typically receives a radiation dose of 15 mSv in an adult and 30 mSv in a neonate for a single CT scan, with an average of two or three CT scans in a single evaluation. Children are at greater risk than adults from a given dose of radiation because children are inherently more radiosensitive and because they have more remaining years of life during which radiation-induced cancer could develop. CT is done with the patient in the supine position; theoretically, with the shoulder girdle muscles relaxed and gravity acting as a tension mechanism, the fracture may become reduced. However, the correlation between measurements of clavicle fracture shortening on CT and standing plain radiographs has not been determined, and the clinical significance of patient positioning is unclear.

Management

Historically, pediatric midshaft clavicle fractures have been managed nonsurgically. Recent studies have expanded the surgical indications in the adult population beyond injuries that are open or associated with neurovascular compromise to include fractures with >15 to 20 mm of shortening, 100% displacement, and significant comminution. However, the applicability of these findings to pediatric patients is unclear.

Nonsurgical

Traditionally, excellent outcomes have been achieved with nonsurgical management of pediatric clavicle fractures. Treatment generally consists of 2 to 4 weeks of immobilization in either a figure-of-8 brace or a shoulder sling, followed by range of motion (ROM) activities and a return to sports activities 6 to 8 weeks after the date of injury, provided the fracture site is no longer tender. In a review of 38 pediatric trauma patients with head injury and concomitant clavicle fractures, Wilkes and Hoffer found that all fractures healed and exhibited excellent remodeling. In addition, patients regained full shoulder ROM even without immobilization.

Questions remain regarding the ideal type of immobilization. In a Cochrane review, Lenza et al evaluated the available evidence from two trials comparing the figure-of-8 bandage with an arm sling. The only statistically significant difference in clinical outcome between the two groups was that the patients treated with figure-of-8 bracing had significantly higher pain scores at 15-day follow-up in one trial (mean difference, 0.80; 95% confidence interval,
0.34 to 1.26; visual analog scale, 0 [no pain] to 10 [worst pain]). In the other study, neither healing nor reduction was affected by either method of immobilization. However, 9 of 34 patients treated with the figure-of-8 bandage were dissatisfied (26%), whereas only 2 of 27 patients treated with a sling were dissatisfied (7%) (relative chance of satisfaction for sling treatment, 1.3 [95% confidence interval, 1 to 1.6]; \( P = 0.09 \)). The difference appeared to be associated with discomfort caused by the figure-of-8 brace, including impairment of agility and personal care, sleep disturbance, edema of the arm, and paresthesia.

The available evidence is not sufficient to allow definitive conclusions regarding which intervention is better. Given the ease with which a sling can be placed on pediatric patients as well as the minimal cost, we prefer slings when nonsurgical management is selected.

**Surgical**

It is important to understand the studies behind the expanded indications for surgical management of midshaft clavicle fractures in adults and their potential applicability to the pediatric population. In a multicenter study, the Canadian Orthopaedic Trauma Society prospectively compared nonsurgical management with plate fixation to manage displaced midshaft clavicle fractures in adults. Surgically managed fractures had significantly improved Constant and Disability of the Arm, Shoulder and Hand (DASH) scores (\( P = 0.001 \) and \( P < 0.01 \), respectively), faster time to radiographic union (16.4 weeks with surgery versus 28.4 weeks without; \( P = 0.001 \)), decreased rate of nonunion and malunion (\( P = 0.042 \) and \( P = 0.001 \), respectively), and improved patient satisfaction (appearance of the shoulder \( P = 0.001 \)); shoulder in general \( P = 0.002 \)). In a systematic review of 2,144 acute midshaft clavicle fractures, Zlowodzki et al\(^\text{21} \) found that comminuted displaced fractures had a higher rate of nonunion and long-term negative sequela with nonsurgical management, with a relative risk reduction of 57% for nonunion when plate fixation was applied.

Participation of pediatric patients in higher-demand activities that place adult-type demands on the shoulder girdle, with resultant fracture patterns that resemble high-energy adult trauma, begs the questions whether surgeons should be more aggressive in the surgical fixation of displaced clavicle fractures in children and whether midshaft clavicle fractures should be surgically fixed in the presence of >15 mm of shortening, 100% displacement, and/or significant comminution.\(^\text{2,9,21} \)

There is a dearth of studies on surgical management of pediatric clavicle fractures. A review of several studies examining surgical interventions may provide a basis on which preliminary recommendations can be made and further studies developed. Kubiak and Slongo\(^\text{26} \) provided one of the first reports on the surgical management of clavicle fractures in the pediatric population. The authors reviewed the outcomes of 939 children who presented with clavicle fracture over a period of 21 years; 924 of these patients were treated nonsurgically. Ten of the patients aged ≥10 years and with displaced clavicle fractures were treated surgically and achieved good functional and cosmetic results as measured by the Constant score and a patient satisfaction questionnaire. The authors concluded that in patients aged ≥10 years, surgical treatment with ESIN can lead to improved pain relief and patient satisfaction, largely resulting from a shorter immobilization time. To our knowledge, no other studies have specifically assessed wire fixation or ESIN in a pediatric population.

Several reports in the adult literature indicate that smooth pins are associated with risk of migration in upper extremity surgery.\(^\text{28,31} \) In addition, intramedullary nailing of clavicular midshaft fractures is technically demanding, with risk of high fluoroscopy and surgical times, cortical perforations, nail breakage, and hardware irritation.\(^\text{25} \) For these reasons, we do not currently perform wire or ESIN fixation of pediatric clavicle fractures.

An examination of adult type implants in the surgical management of pediatric clavicle fractures is also im-
operative, particularly the role of plat- 
ing. Vander Have et al supertively compared the results of 42 adolescent patients who were treated for midshaft clavicle fractures (mean age, 15.4 years). Twenty-five patients were treated nonsurgically with a sling or figure-of-8 brace; the other 17 were treated with nonlocking an- terosuperior compression plating. The surgical group had greater short- ening at the time of injury (27.5 versus 12.5 mm), a quicker time to ra- diographic union (7.4 versus 8.7 weeks), and a faster return to full ac- tivities (12 versus 16 weeks). Al- though the quicker time to radio- graphic union was statistically significant (P < 0.02), we do not be- lieve that this small time difference is clinically relevant. In addition, al- though the authors do not provide statistical analysis to determine whether the 4-week faster return to activity of the surgical group is sta- tistically significant, we believe that it is clinically relevant. No patient in either group developed nonunion. However, symptomatic malunion de- veloped in five of the nonsurgically treated patients (mean fracture short- ening, 26 mm). Four of these five pa- tients elected to undergo corrective osteotomy. In this study, symptom- atic malunion was defined as frac- ture union with shortening or angula- tion and asymmetry, as compared with the uninvolved shoulder, and subjective complaints, including pain with overhead use, weakness, fatiga- bility, and neurologic symptoms. We are unaware of any other reports that specifically address the need for corrective osteotomy to manage clavicular malunion in the pediatric population.

Mehlman et al retrospectively ex- amined the outcomes of 24 adoles- cent patients who underwent surgical fixation of their displaced clavicular shaft fractures. Twenty- two patients underwent plate fixa- tion. The patients achieved a 100% rate of union, a 100% rate of satisfac- tion, and an 87% rate of return to unrestricted sports activities. All pa- tients returned for hardware removal after healing.

Most recently, Namdari et al retrospectively reviewed 14 skeletally immature patients (mean age, 12.9 years) with closed, displaced, mid- shaft clavicle fractures that were managed with open reduction and internal fixation (ie, plate fixation). Total quickDASH and simple shoul- der test (SST) scores were determined at a minimum follow-up of 24 months. In this study, the mean post- operative total quickDASH score was 7.0, and a mean of 11 questions were answered “yes” on the SST. All fractures healed. However, four pa- tients from the surgical group re- quired a second surgical procedure to remove hardware, and eight pa- tients complained of numbness at the site of injury/surgery.

Hosalkar et al reviewed a series of surgical fixations performed at their institution to address displaced unilateral clavicle fracture in 19 adoles- cent patients (mean age, 14.6 years). Baseline demographic and ra- diographic data were collected pre- operatively, and patients were evalu- ated postoperatively with functional outcomes measures such as the quickDASH and SST as well as additional binary questions. The mean quickDASH score was 4.0 at a mean follow-up of 16 months (range, zero to 35.5 months), and the mean num- ber of “yes” responses on the SST for all surgical patients was 11 (range, 9 to 12). Complete radiologic union was noted in all cases at 3-month follow-up, and all patients returned to full sports participation at a mean of 14 weeks (range, 12 to 17 weeks). Minimal hypertrophic scarring was noted in two patients, and no keloid formation or neuro- vascular deficit was noted. At 15- month follow-up, one patient re- ported implant prominence and complained of occasional discom- fort. This patient elected to undergo implant removal and experienced a complete and uneventful recovery. All patients were satisfied with their decision to undergo surgical treat- ment. These results led the authors to conclude that anatomic reduction with internal fixation and early mo- bilization of displaced clavicle frac- tures in adolescent patients remains a viable treatment option with predict- able results and no major complica- tions when performed by experi- enced surgeons.

Excellent outcomes can be achieved with surgical management. However, patients and families must be counseled regarding the known risks of hardware failure, incisional numbness, and the potential need for a second surgery to remove hardware.

**The Authors’ Preferred Method**

At our institution (H.S.H.), adoles- cents with clavicle fractures that are completely displaced (ie, no cortical contact between the fracture ends) or comminuted, or that contain a trans- verse Z-shaped fragment, are treated surgically. In addition, using as a guide the average length of the clavi- cle and the amount of shortening considered to be a relative indication for surgical intervention in adults (138 and 20 mm, respectively), we consider clavicle shortening of 14% to 15% (20/138) to be another rela- tive indication for surgical interven- tion in adolescent patients. Relative shortening by itself is insufficient to warrant surgical intervention. It must be accompanied by comminu- tion, marked displacement, or skin tenting. Fractures that are open or present with neurovascular compro- mise require surgical management, as well.
The patient is placed supine on a Jackson table, and a bump is placed under the scapula. A nonlocking compression plate is affixed to the superior surface of the clavicle. In the patient with severe comminution or osteopenia, a locking plate is used instead. In general, bone quality is excellent in pediatric patients, and nonlocking screws are preferred. Interfragmentary compression screws are used when the fracture pattern allows.

Postoperatively, the patient is kept in a sling and swath for 3 weeks, after which ROM exercises are begun. Following a progressive ROM and strengthening program and in the presence of clinical and radiographic signs of healing, the patient is allowed to return to sport at 12 weeks after the injury. Patients who are treated nonsurgically are typically placed in a simple shoulder sling for 3 to 4 weeks. A sling and swath is used acutely for 2 weeks in the patient with significant swelling and pain, after which ROM exercises and progressive strengthening are begun. Return to sport is allowed once the patient shows clinical (ie, no tenderness about the fracture site) and radiographic signs of healing.

Outcomes can be achieved with regard to shoulder function, patient satisfaction, and union. However, there is no specific criterion that can be universally and consistently applied to guide clinicians as to what type of fractures (ie, shortening, displaced, comminuted) should be surgically managed in this young population and in which manner.

Issues that remain unresolved include the degree of shortening that is acceptable, the degree of displacement that can be tolerated while still achieving union, the level of comminution that will heal without impairment in shoulder function, and the appropriate fixation method. Prospective comparative studies of larger numbers of pediatric patients may help guide future management of displaced clavicle fractures by determining indications for nonsurgical and surgical management in this active patient population.

References

Evidence-based Medicine: Levels of evidence are described in the table of contents. In this article, references 4, 5, 21, and 24 are level I studies. References 10 and 15 are level II studies. References 27 and 33 are level III studies. References 2, 3, 11, 14, 16, 18, 22, 23, 25, 26, 28-32, 34, and 35 are level IV studies. References 1, 6-9, 12, 13, 17, 19, 20, and 37 are level V expert opinion.

References printed in bold type indicate those published within the past 5 years.

16. Walz M, Kolbow B, Auerbach F: Elastic, stable intramedullary nailing in


