Distal Clavicle Fixation in the Skeletally Immature

S. Clifton Willimon, MD, Henry B. Ellis, MD, and Peter J. Millett, MD, MSc

Abstract: Distal clavicle fractures in adolescent patients may benefit from surgical intervention depending on fracture pattern, age of the patient, and other variables. Less-invasive techniques allowing earlier mobilization, decreased pain, and no requirement for hardware removal are attractive. A technique of double-button suture fixation is useful for the treatment of distal clavicle fractures in the skeletally immature.

Key Words: distal clavicle fractures, adolescent, skeletally immature patients

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Clavicle fractures are common in skeletally immature patients, but distal clavicle fractures are relatively rare, comprising only 10% to 20% of clavicle fractures in the growing population.[1] Variations exist in this age group as chronological age may not correlate with skeletal age. Some children, specifically those whose age is greater than 15 years, may sustain an adult type of injury pattern.[2] Knowledge of both skeletally mature and immature clavicle fractures is thus useful when caring for the adolescent population.

Displaced distal third clavicle fractures in children, as opposed to adults, retain the integrity of the coracoclavicular (CC) ligaments. The proximal attachment of the CC ligament to the periosteum and the distal attachment to the conoid tubercle of the coracoid are important intact attachments that allow for cortical button fixation in this age group. A displaced clavicle with a CC disruption, as in adults, concerns an orthopedic surgeon with not only a stable fixation of the clavicle but also the biological fixation of the CC ligament. The lack of stable biological fixation of the CC ligament in the skeletally mature patient has thought to be a source of failed repairs in these injuries.[3,4] This is not the case in the pediatric patient with a similar injury who has intact CC ligaments with a disrupted periosteum and abundant innate biological healing capabilities.

A double-button suture fixation technique has been utilized to improve fixation, avoid the need for hardware removal, and allow earlier mobilization of adolescent patients with distal clavicle fractures. The purpose of this study is to describe a surgical technique for the management of adolescent distal clavicle fractures.

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Reprints: Peter J. Millett, MD, MSc, Steadman Philippon Research Institute, 181 West Meadow Drive, Suite 1000, Vail, CO 81657 (e-mail: drmillett@steadmanclinic.com).

CLASSIFICATION

In 1968, Neer[5] originally classified lateral third clavicle fractures in 3 types, which was later expanded by Rockwood.[6] This classification, as in acromioclavicular (AC) separations, focuses on the integrity of the CC ligament. Skeletally immature fractures of the distal third of clavicle displace by disrupting the periosteal sleeve leaving the CC ligaments intact and attached to the remaining periosteum (Fig. 1). This injury in a child is typically a physeal or metaphyseal fracture and may radiographically appear very similar to an AC separation because the ossification center of the distal clavicle is not present until the age of 18 or 19.

Proposed classification systems have described these injuries by the amount of displacement[8,9] or by fracture pattern.[8] A recent proposed classification by Nenopoulos et al[8] uses displacement and age of patient (above 8 y old) for surgical indication, but this has yet to be validated and well accepted. More commonly the Dameron and Rockwood[9] classification is used to describe injuries of the distal clavicle and AC joint in children. The various types are listed below and in Figure 1:

Type I—mild strain of the AC ligaments with no disruption of the periosteal sleeve. Clinical examination reveals a stable, nondisplaced clavicle, and tender AC joint. Radiographs are normal.

Type II—partial tearing of the distal, dorsal periosteal sleeve with mild clinical instability of the AC joint. Radiographs show no change in the CC interval but slight widening of the AC joint space.

Type III—more extensive disruption of the distal, dorsal periosteal sleeve with superior displacement of the distal clavicle. Clinical examination reveals instability of the distal clavicle. Radiographs show 25% to 100% displacement superiorly and often Salter-Harris type I fracture of the distal clavicular epiphysis, thus a pseudodislocation.

Type IV—similar to type III but due to increased force of injury, the distal clavicle is button-holed through the trapezius muscle and fascia. Clinical examination is significant for an incompletely reducible distal clavicle due to interposed trapezius muscle tissue. Radiographs show less superior migration than type III injuries but axillary radiographs reveal posterior displacement.

Type V—identical to type IV, except complete rupture of the distal clavicle through the trapezius muscle into the subcutaneous tissue.

Type VI—subcoracoid dislocation of the distal clavicle.[10]

Many distal clavicle and AC injuries, including Dameron and Rockwood types I, II, and III in children[9] are routinely treated nonoperatively with success. Some distal clavicle injuries, including types IV, V, and VI patterns, are prone to failure from nonunion, malunion, clavicular duplication, and shoulder dysfunction. Fractures that are prone to fail or have known poor outcomes in adolescents may be treated effectively with operative intervention. In addition, cosmetic deformity, pain associated with unstable fractures, skin breakdown, or malunion may be additional indications to proceed with surgical intervention. After a discussion with the patient and their family, we give them the option of pursuing surgical treatment during the acute phase of the injury.

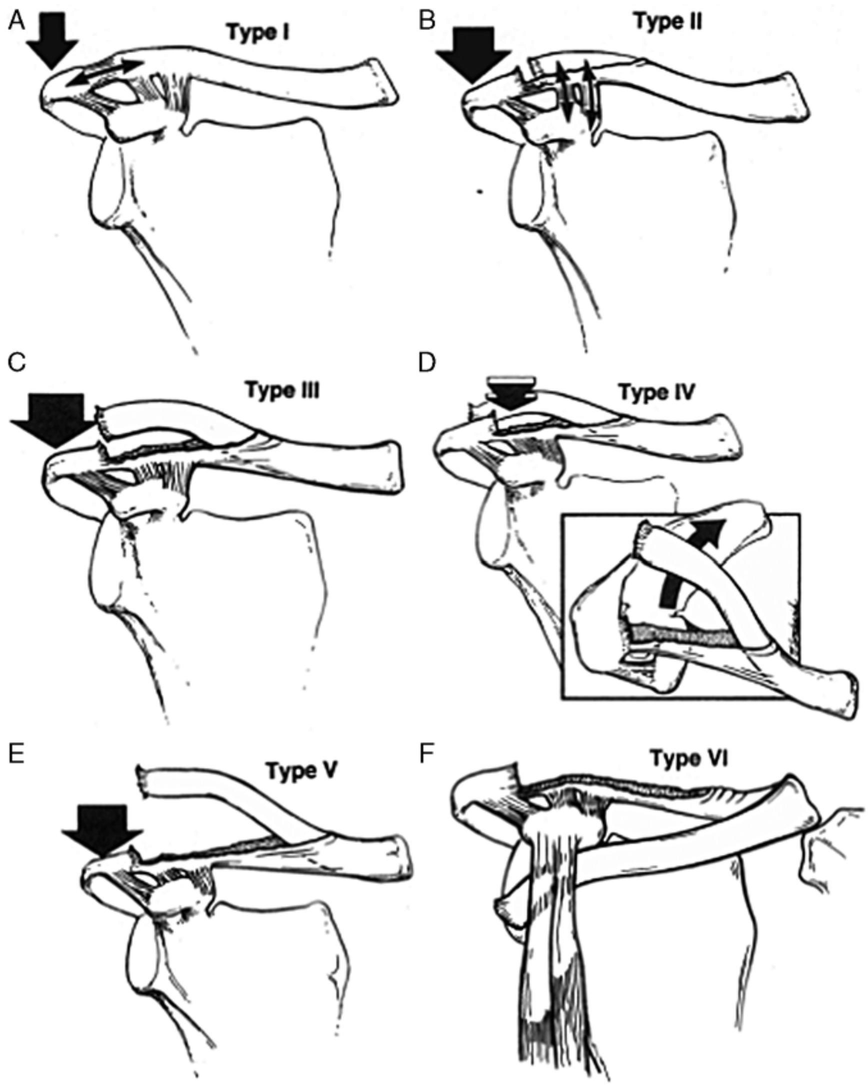

FIGURE 1. Rockwood classification of distal clavicle injuries in children. Adapted from Sarwark et al.[7]

TECHNICAL PROCEDURE

After having a suspicion of a clavicle fracture in a skeletally immature child, a thorough physical examination must be performed to evaluate for an open fracture or compromised skin that may require urgent operative attention. A detailed neurovascular examination is necessary to identify potential vascular or neurologic injury. Adequate imaging is the key to establishing the diagnosis and location of the injury. In addition to standard clavicular radiographs, we recommend using a Zanca view (10 degrees cephalic angle with one-third less penetration) to evaluate the AC joint.[11] An axillary view is helpful to visualize anterior or posterior displacement of the fracture.

Absolute indications for surgical intervention include open injuries or compromised skin. Surgical intervention of displaced distal third clavicle injuries is individualized, as there has been no functional difference found between conservative and operative management. Surgical indication should include significant pain in the acute or subacute setting or lack of acceptance of cosmetic deformity. With a diagnosis of a displaced distal third clavicle fracture in the skeletally immature patient, a thorough discussion of operative and nonoperative treatment is undertaken. Informed consent is completed with the patient and family.

The operation is performed under general anesthesia in a beach chair position within 3 weeks of the injury. The head and neck are well padded and secured. The contralateral arm is placed in an anatomic position with a foam pad underneath the elbow. The injured extremity is secured with a Spider arm holder (Tenet Medical Engineering, Calgary, Canada). After patient positioning, a C-arm fluoroscope is strategically placed to ensure adequate imaging without compromising the surgeon's ability to perform the operation (Fig. 2). The ideal position for the fluoroscopic device is exactly perpendicular to the coracoid process (Fig. 3). This view allows one to visualize both medial and lateral cortices of the coracoid and is vital to ensure the success of the procedure. Proper placement of the drill holes in the coracoid is essential. Ensuring adequate fluoroscopic views is necessary before prepping and draping the patient.

A curvilinear incision along Langer's lines is made approximately 2 to 3 finger breadths (3 to 5 cm) medial to the AC joint. The incision should allow exposure of the anterior

FIGURE 2. Surgical beach chair position with fluoroscopy. Position of C arm allows for adequate images without compromising surgical space. It is important to ensure the imagine before draping. Ideal image is to view distal clavicle, acromioclavicular joint, and be perfectly perpendicular to the tip of the coracoid process.

and posterior aspects of the clavicle. After dividing the subcutaneous tissues, a horizontal incision is made through the deltopectoral fascia, and full thickness flaps are created off the clavicle in a subperiosteal manner. Care must be taken to identify and preserve the AC capsule and CC ligaments.

The thick periosteum in this age group is usually intact and attached to the acromion, medial clavicle, and intact CC ligaments. Before reduction, the periosteum should be identified as it is typically folded over onto itself. To obtain an anatomic reduction, the periosteum must be exposed and mobilized to allow reduction of the clavicle within the thick periosteal sleeve.

A small cortical button can be used to obtain CC fixation (Mini Tightrope or Biceps button fixation system, Arthrex, Naples, FL). This type of fixation system maintains anatomic reduction while allowing clavicular bone healing. Once anatomic reduction is achieved, blunt dissection to the coracoid is performed. Although protecting the surrounding soft tissue with a 3.5-mm soft tissue guide, a 1.1-mm Kirschner wire is drilled through both cortices in the center of the coracoid, and the position is confirmed by fluoroscopy. The pin should be placed 2 cm posterior to the coracoid tip or, if palpable, just anterior to the junction of the coracoid and the glenoid neck (Fig. 4). After placement of the Kirschner wire, a cannulated 3.5-mm drill is used to drill through the coracoid. Care must be taken to protect the surrounding soft tissues and prevent plunging of the drill bit in this location. A 2.6-mm oblong cortical fixation button (biceps button with inserter) is inserted through the hole created in the coracoid from superior to inferior. When the inserter is pulled back, the cortical fixation button is subsequently flipped and locked in place. The #2 permanent nonabsorbable sutures (Fiberwire, Arthrex) that were preloaded onto the cortical button are then passed through the clavicle. These will be used to maintain the reduction through the clavicle. The clavicle fixation is performed by drilling a 3.5-mm hole in the center (sagittal plane), and the sutures (#2 Fiberwire) are shuttled through the clavicle using a suture passing instrument or a small hemostat. While again maintaining the reduction, the sutures are tied over a low-profile cortical button.

Previous anatomic studies have reported anatomic positions of the origin of the CC ligaments in relation to the distal clavicle.[12] In skeletally immature patients these measurement will likely lead the surgeon too medial with their clavicle fixation. In the acute setting, the CC ligaments will be palpable and therefore the fixation should be in the center of the ligaments. If the CC ligaments are not palpable, then we recommend fixation to be located in the clavicle in line with the coracoid.

After anatomic reduction is confirmed with both direct visualization and fluoroscopy, a running #1 braided absorbable suture is used to repair the periosteum circumferentially over the clavicle. The AC ligaments are inspected and repaired if necessary. If there is herniation of the clavicle through the deltoid, trapezius, or pectoralis major, then repair of the fascia should also be performed with a #1 braided absorbable suture in a figure-of-eight fashion. The wound is then copiously irrigated before closure. The wound is closed in a layered manner with a 2-0 absorbable suture in the subcutaneous layer followed by a running subcuticular stitch. A sterile surgical dressing is then applied.

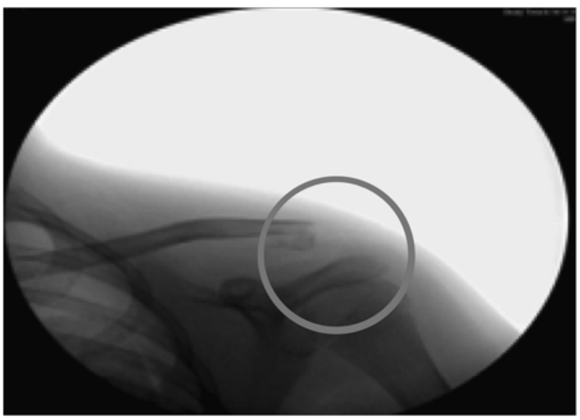

FIGURE 3. Ideal fluoroscopic view for fixation of a distal third clavicle fracture. Note the tip of the coracoid is perpendicular to the imaging device (highlighted gray).

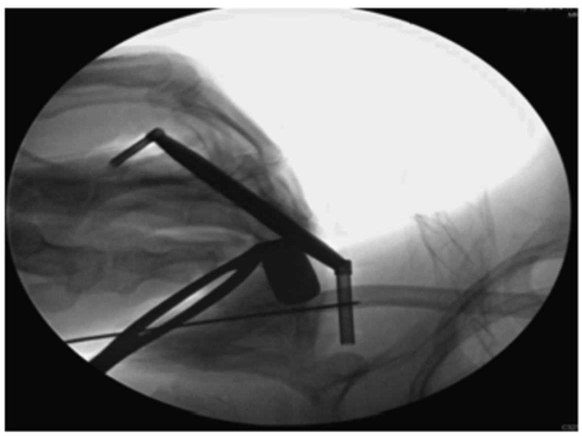

FIGURE 4. A drill guide used to protect the soft tissue while driving a 1.1-mm Kirschner wire through the center of the coracoid. An attempt should be made to place drill guide 2 cm posterior to the tip of the coracoid.

Because of the variable size of the anatomy in this age group, we typically use a single cortical button fixation system with 2 sutures and 2 buttons to obtain fixation from the coracoid to the clavicle. In the older adolescent, the surgeon may consider 2 sources of fixation between the coracoid to the clavicle to reproduce both the conoid and trapezoid arms of the CC ligament (Fig. 5). This technique is ideal in the acute setting (<3 wk). Other techniques should be considered if surgical intervention occurs >3 weeks from the injury.

The postoperative protocol consists of protection in a sling for 6 weeks. Full passive range of motion of the shoulder commences at 2 weeks and active motion at 6 weeks if there is radiographic evidence of healing. We recommend strengthening exercises to start at 12 weeks beginning with isometric exercises. The patient can return to contact sports at 4 to 5 months (Fig. 6).

DISCUSSION

Distal clavicle fractures in skeletally immature patients are traditionally metaphyseal or physeal fractures and mimic AC separation.[7] These fractures are sometimes referred to as pseudodislocations of the AC joint.[13,14] Although nondisplaced fractures are typically treated nonoperatively, the treatment of displaced distal third clavicle fractures in the skeletally immature is more controversial.[1,2,15,16] The displaced fracture usually leaves a thick periosteal sleeve distally that remains attached to intact CC ligaments (Fig. 5). Although children have abundant osteogenic capabilities, adolescents nearing skeletal maturity may lack adequate remaining growth for sufficient remodeling.[8] Reports of duplicate clavicle deformity exist due to this phenomenon.[8,14]

Many surgical procedures have been described to address the unique challenges of distal clavicle fractures, which include anatomic limitations for plating necessitating fixation across the AC joint, adjacent neurovascular structures, and deforming muscular forces. Reports of transacromial fixation with Kirschner wires,[17,18] cerclage wiring,[17] hook plates,[19–22] and CC screw fixation[23,24] exist in the literature. Transacromial fixation with hook plates has several disadvantages including the need for hardware removal, inability for early mobilization due to poor fixation, and the potential for hardware migration.[18,19]

FIGURE 5. Dual-cortical button fixation in a skeletally mature adolescent. Inset: arthroscopic image confirming double-button fixation on the inferior aspect of the coracoid process.

FIGURE 6. Six-week follow-up after coracoclavicular fixation of a distal third clavicle fracture in a 12-year-old boy.

Double-button suture fixation has been reported in the literature with success in the treatment of AC injuries.[25,26] Advantages include an earlier return to activities, no requirement for hardware removal, and improved cosmesis. CC fixation using a double-button suture fixation system also has published complications including coracoid and clavicular fracture and hardware failure.[27,28] A thorough understanding of the anatomy and methods for coracoid exposure and placement of coracoid and clavicular tunnels is necessary to minimize the risk of complications. The use of fluoroscopy assists with coracoid tunnel placement and prevents eccentric tunnel placement.

Suture fixation with cortical buttons for adolescent distal clavicle fractures is a reliable technique for the treatment of this challenging injury. We have not observed any complications related to this technique; however, clavicle and coracoid fractures have been reported with this technique in other populations. A clinical evaluation of this technique is currently underway at our institution.

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