# Evaluation and Management of Mid-Shaft Clavicle Fractures in Adolescents

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**Abstract:** The rate of operative fixation for completely displaced mid-shaft clavicle fractures in adolescents has been increasing yearly over the last decade, largely driven by studies of adult populations in whom the rate of nonunion is approximately 15% with nonoperative treatment. However, nonunion and symptomatic malunion in younger populations remain rare. Recent studies suggest that functional outcomes are similar between conservative management and operative fixation in adolescents, with higher rates of complications and slightly decreased time to return to sport with operative fixation. Implant-related symptoms remain an important consideration that lead to implant removal. Additionally, the cost of operative fixation is significantly higher than that of nonoperative management. The aim of this review is to summarize the salient historical and more recent literature regarding displaced mid-shaft clavicle fractures in order to better understand treatment considerations and the natural history of these fractures in the adolescent.

**Key Concepts:**

- The standard of care treatment for minimally displaced mid-shaft clavicle fractures is nonoperative treatment, yet there is controversy regarding the optimal treatment of completely displaced adolescent clavicle fractures.
- The rates of operative treatment for displaced adolescent clavicle fractures is rising despite low rates of nonunion and symptomatic malunion following nonoperative treatment (<1% and <5%, respectively).
- Evidence is emerging that patient-reported upper extremity function, pain, quality of life, and satisfaction are similar between operative and nonoperative treatment of displaced mid-shaft clavicle fractures in adolescents, while operative treatment may result in an increased rate of complications and unexpected surgery.

## Introduction

Clavicle fractures account for 8-15% of all skeletal injuries[1,2] in the pediatric (<10 years) and adolescent (10-19 years) populations. Mid-shaft clavicle fractures specifically account for approximately 90% of all clavicle fractures in adolescents,[3] with distal clavicle and sternoclavicular injuries being rarer. Although the peak incidence of clavicle fractures across the entire population occurs between the ages of 10-19 years,[4-7] decision-making regarding the treatment of mid-shaft clavicle fractures has mostly been driven by adult-based studies.[8]

Prior to 2000, indications for operative treatment of mid-shaft clavicle fractures in all age groups were primarily open/impending open fractures, those with neurovascular compromise, those with other serious injuries (polytrauma and floating shoulder), and

nonunions.[9-11] The vast majority of clavicle fractures, including those completely displaced and shortened, were treated nonoperatively in the form of a sling or figure-of-eight bandage. Studies in the late 1990s and mid-2000s emerged to suggest that operative fixation in the adult population was associated with higher rates of union, faster return to activity, improved functional outcomes, and greater patient satisfaction.[12-14]

The impact of such studies was significant, with the pendulum swinging towards a new standard of operative treatment for displaced fractures in adults. Over the subsequent decade, there were few studies to confirm that this was appropriate for younger patients. Nevertheless, although the incidence of clavicle fractures increased significantly in this sub-population likely due to increasing youth sports participation and the popularity of more extreme sports, the rate of operative fixation increased to a disproportionally high degree.[15-17] A POSNA survey of surgeons in 2011 revealed that 48% considered the adult literature to be amongst the greatest influences on their treatment decisions.[8]

The purpose of the current review is to describe emerging evidence and concepts regarding the management of displaced mid-shaft clavicle fractures in the adolescent population, exploring the controversy over changing indications for surgery.

## Anatomy

The clavicle has the distinction of being the first bone in the body to begin ossification around the 5$^{th}$-6$^{th}$ weeks of gestation. It grows steadily from birth to early adolescence at a rate of 8.4 mm/year.[18] Although the majority of growth occurs before age 9 in girls and 12 in boys, 20% of lengthening takes place during adolescence and into the young adult years.[18] Remarkably, the clavicle is also the last bone in the body to complete ossification, with the lateral physis closing by around 19 years of age and the medial physis closing around 22-25 years of age.[10,19] Due to this substantial late growth, the clavicle may retain an underappreciated healing and remodeling potential through late adolescence.

Additionally, the immature clavicle is invested by a thick periosteum. The strength of this periosteum may limit the displacement of fractures, provide relative stability in the face of complete displacement, and provide a higher potential for secondary bone healing and remodeling when compared to similar fractures in older age groups.[9,10] This is particularly relevant given that more than half of mid-shaft clavicle fractures are displaced,[3] though this rate may be lower in 10-13 year-olds compared to older adolescents.[20]

Late physeal closure and the thick periosteum distinguish the skeletally immature clavicle in children and adolescents from that of the mature clavicle seen in adults. This has important implications on relative fracture stability, healing, and remodeling, which may explain the evolving elucidation of outcomes-based distinctions between adolescent and adult studies.

## Classification Systems

Numerous classification systems have been used to describe clavicle fractures. The Allman, Neer, and Craig classifications include mid-shaft clavicle fractures but do not differentiate the mid-shaft fractures any further. The AO classification describes specific fracture patterns, with group A being simple fractures, B being wedge fractures, and C being complex fractures. The Edinburgh classification distinguishes between aligned fractures, displaced fractures, and comminuted fractures. The Robinson classification system describes Type 1 fractures as involving the medial 1/5$^{th}$ fractures, Type 2 as middle 3/5$^{th}$, and Type 3 as lateral 1/5$^{th}$. Type 1 and 3 are further subdivided by displacement and intra/extra articular, while Type 2 fractures are subdivided by A: cortical alignment fractures, and B: displaced fractures. Type 2A fractures are divided into 2A1: non-displaced, and 2A2: angulated. Type 2B fractures are divided into 2B1: simple fractures or wedge comminution, and 2B2:

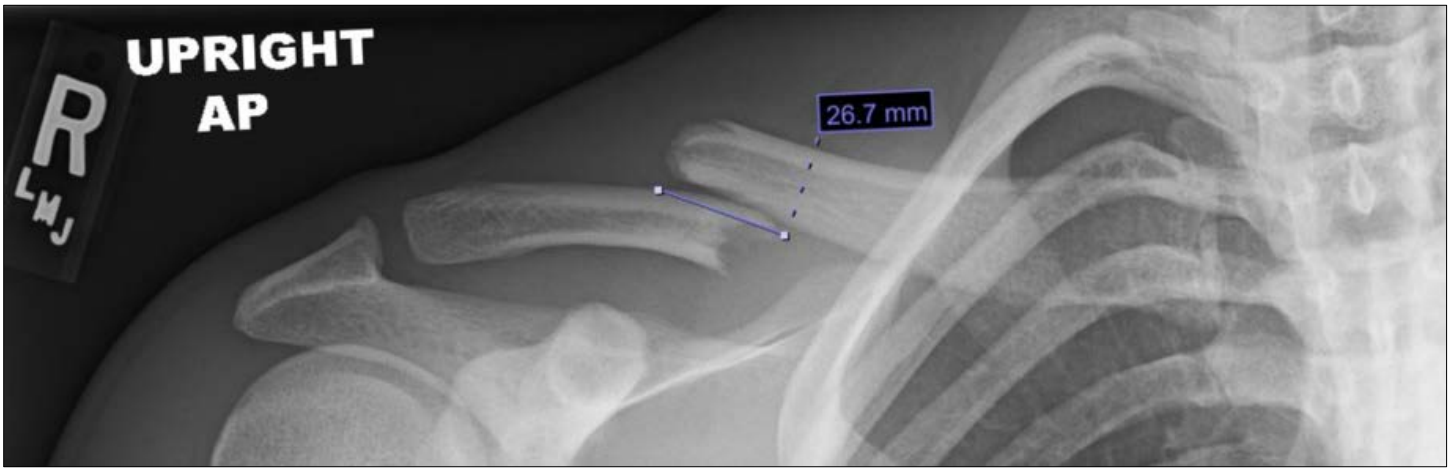


***Figure 1a.*** *The end-to-end measuring technique for evaluating shortening in a mid-shaft clavicular fracture in an 18-year-old male. This method of measurement may overestimate the true amount of shortening.*

segmental or multi-fragmentary fractures.[1] The Function After Clavicle Trauma & Surgery (FACTS) adolescent clavicle fracture study group has described Type 1 fractures as non-displaced or minimally displaced, Type 2 as partially displaced or angulated, and Type 3 as completely displaced, which are further divided into comminuted or non-comminuted.[21] Despite this array of systems, a descriptive classification alluding to displacement, comminution, and shortening remains the most commonly used approach. The degree to which each of these three factors may dictate treatment and outcomes remains incompletely studied in adolescents.

## Evaluation

Mid-shaft clavicle fractures can occur after direct or indirect trauma to the clavicle, most commonly after a fall onto the shoulder with an adducted arm. Sports injuries are most common in all age groups and responsible for 45-66% of mid-shaft clavicle fractures in adolescents.[1,6-7] Fractures occur commonly in contact sports such as football, rugby, lacrosse, and ice hockey, but fractures can also occur from soccer, cycling, and horse riding.[1,7] Non-sport related mechanisms include car accidents, horseplay, and falls from height.[4,22-23]

In addition to a thorough history and physical examination, an anteroposterior (AP) radiograph is most often obtained for initial evaluation of the injury. In the adult population, significant radiographic shortening of a completely displaced clavicle is frequently used as an indication for operative management.

Various treatment algorithms have been proposed, with many recommending that completely displaced mid-shaft fractures with shortening of over 15-20 mm be managed operatively to prevent symptomatic malunion or nonunion.[19,24] Plain radiographs have been shown to provide unreliable measurements of true shortening in adults.[25,26] In adolescents, a method in which shortening is measured according to the cortex of a fracture end and correlated with the corresponding cortex of the other fragment on an anteroposterior projection has shown excellent intra- and inter-rater reliability (Figure 1).[27] Because clear indications for surgery in the adolescent age group based on shortening, comminution, angulation, or displacement have yet to be established, the intricacies of the radiographic measurements or views at the time of injury or initial follow-up may not have great clinical significance. Currently, the clearest indications for surgery in this younger population include open fractures, skin-based signs of impending open fractures, such as severe skin tenting with hypovascular skin, severe polytrauma, a 'floating shoulder' with concomitant humerus fracture, and

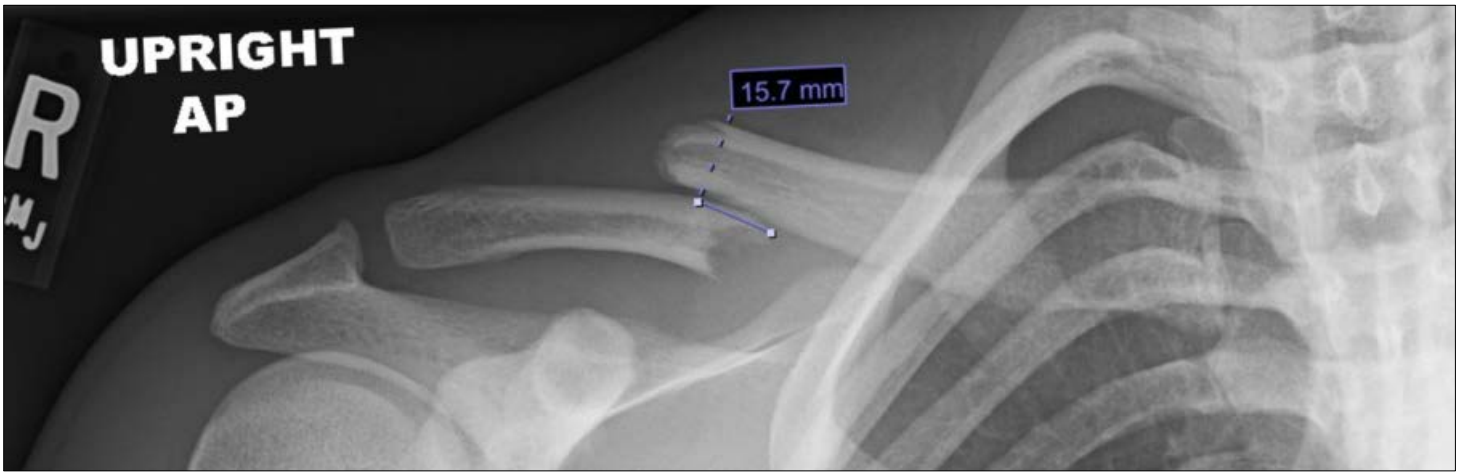


***Figure 1b:*** *A cortex to corresponding cortex measurement technique may provide a more accurate assessment of shortening, showing that the above fracture does not meet a common indication (>20mm shortening) for surgical management in adults.*

neurovascular compromise.[10,11] Simple or mild skin tenting and bony prominence, which are particularly common in comminuted fractures, have not been shown to be associated with nonunion, poor outcomes, or symptomatic malunion in adolescents. These findings may, therefore, be monitored closely in the early stages of nonoperative treatment.

## Nonoperative Management

Nonoperative management consists of temporary immobilization and pain control. Of historical interest is the use of a figure-of-eight style brace, in which a bandage or strap was used to retract the shoulders. By providing tension across the fracture, this brace could theoretically reverse the shortening effect of a bayoneted, completely displaced fracture. However, the lack of clear evidence of the effectiveness of this technique, coupled with increased discomfort compared to the use of a regular sling,[28-30] has led these figure-of-eight braces to generally fall out of favor. Upper extremity slings are currently the most common early treatment, and young patients may have decreased discomfort with the use of a waist strap attached to the sling or with the addition of a swathe bandage around the arm and torso in the early stages following a fracture. This relative immobilization is typically maintained for 2-6 weeks after clavicle fracture, after which the patient may begin active motion.[31-34] Contact sports are generally avoided for 3 months after injury for completely displaced fractures,[35] but the risk of refracture depends on the quality of fracture healing, which is largely guided by radiographic imaging. Therefore, it is recommended to follow the patient until union is achieved, and the physical exam returns to near normal.

## Surgical Management

Operative treatment of displaced clavicle fractures has been increasing in all age groups over the last two decades.[8,16-17] Common techniques include the use of plate osteosynthesis and intramedullary nail/rod constructs.

Open reduction and internal fixation with plate and screw constructs (Figure 2) remain the most frequent choice of operative fixation. There is ongoing investigation[36-41] into optimal plate location (superior vs. anteroinferior), screw type (locking vs. nonlocking), screw placement (unicortical vs. bicortical), screw number (4 cortices vs. 6 cortices), plate number (single vs. dual-plating), and plate size (2.7 mm vs. 3.5 mm), with minimal rigorous comparisons in the pediatric and

adolescent literature. Manufacturer pre-contoured specialty clavicle plates may lead to decreased plate prominence and subsequent lower rates of implant removal.[42-45] This may be particularly relevant to the smaller clavicle size of some adolescents, in whom smaller (2.7 mm) plates, shorter plates (with 4-cortices fixation),[19] and thoughtful plate bending may improve surgical outcomes.

Intramedullary fixation may allow for a relatively small incision with less soft tissue dissection and increased load sharing[46] compared to plate fixation. However, their use may be limited in certain fracture patterns, such as those with significant comminution. Implant types have included k-wires, Hagie pins, Rockwood pins, titanium elastic nails (TENs), and other locking or nonlocking intramedullary constructs. In many cases, it is necessary to remove intramedullary constructs after radiographic healing to prevent future implant-related complications such as migration,[19] thus making this approach less desirable than plate constructs to some. Randomized controlled trials, systematic reviews, and meta-analyses have shown little difference, overall, in outcomes of intramedullary versus plate fixation.[47-49]

***Figure 2a.*** *An injury radiographic of a mid-shaft 4-part, segmental, comminuted clavicle fracture with skin tenting in a 17-year-old male.*

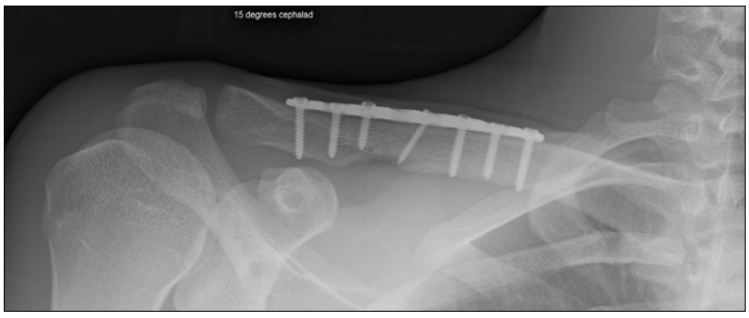


***Figure 2b.*** *A postoperative radiograph demonstrating superior plating with three bicortical screws medially and distally and one interfragmentary screw. The patient returned to sports at 3 months postoperatively with no complaints or functional limitations.*

## Outcomes

*Complications*

The primary complications following nonoperatively treated clavicle fractures include: nonunion, symptomatic malunion, and refracture. Nonunion was historically thought to be rare after conservative management, with Neer et al. reporting a rate of 0.13% in 1960.[50] However, more recent retrospective studies and randomized controlled trials have revealed that nonunion rates in adults may be significantly higher than previously reported, ranging from 5% to as high as 26%,[2,13,23,51] with larger meta-analyses and systematic reviews estimating approximately 15%. Pediatric and adolescent clavicle nonunions, however, remain very rare. A systematic review in 2018 found only 21 cases of reported clavicle fracture nonunions in patients between the ages of 4-17 years.[52] A multicenter retrospective study found only 25 nonunion cases across nine pediatric institutions over an 11-year period.[53] More recent prospective work has estimated the rate of nonunion to be around 0.4% in adolescents.[54] Therefore, while operative indications and techniques honed in adult populations have been increasingly applied to adolescents, the primary justification for performing surgery may not be applicable in this younger age group.

Symptomatic malunion after conservative management has similarly been more deeply explored in the last 1-2 decades. Shortening, in particular, has been suggested to

correlate with decreased range of motion, scapular dyskinesis, and decreased functional scores in adults, though controversy remains as to the degree to which shoulder function is truly affected.[55-59] Malunion has been associated with increased risk of refracture in young adults[60] but likely requires further analysis in children and adolescents. Skeletally immature patients with clavicle fracture malunions do not appear to develop clinically significant loss of shoulder motion, strength, or discomfort.[61] Perry et al. investigated a series of adolescents with significant shortening (>15mm) and with minimum 2-year follow-up, and found no limitations in function.[62] Overall, malunions may impose fewer symptoms in adolescents, particularly over time, due to remodeling potential (Figures 3, 4), which may extend into young adulthood. More research on this concept is warranted.

Common complications of plate fixation include implant-related symptoms, sensory deficits, wound infections, and nonunion.[63-65] In adults, 5.6-25% of patients may require a secondary operation for implant removal due to irritation.[63, 66-67] Intramedullary fixation may result in irritation at the entry site due to the protruding end of the nail.[46,68-70] Smooth pins without locking mechanisms should not be used due to the potentially dire complication of pin migration.[71]

While to date many prospective, comparative studies and randomized trials have been conducted in adults, there is minimal comparative literature in pediatric and adolescent populations for mid-shaft clavicle fractures. Vander Have et al. reported on a series of adolescents, 17 of whom underwent plate fixation, and 25 of whom were treated nonoperatively; they reported that the operative group had shorter time to union while five of the nonoperative group developed a symptomatic malunion.[72] While three operative patients underwent secondary surgeries for implant removal, no long-term follow-up or patient-reported functional outcome measures were included. In addition, the similarity of the two treatment groups was not elucidated, raising the question of comparability of the study cohorts. Subsequent studies have found that operative management may, in fact, result in significantly higher

***Figure 3a.*** *A 14-year-old male with completely displaced fracture, which was treated with a simple sling.*

***Figure 3b.*** *An 8-month post-injury radiograph demonstrates advanced bony healing and remodeling of a malunion, which was asymptomatic.*

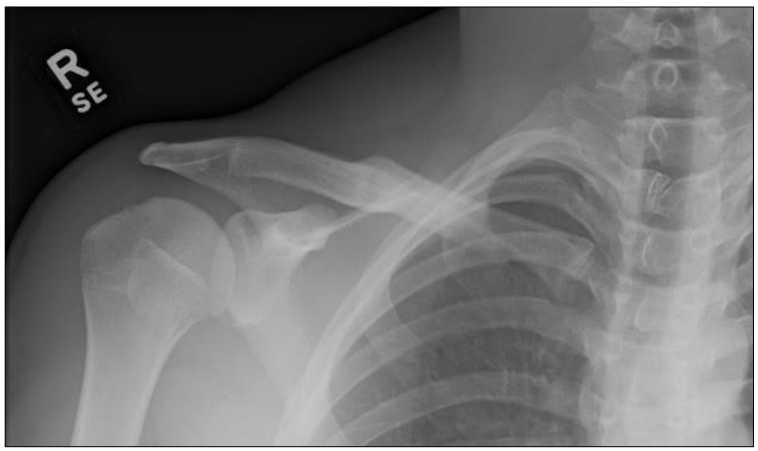


***Figure 3c.*** *A 3-year post-injury radiograph demonstrates advanced remodeling of the malunion. The patient remained asymptomatic throughout this follow-up period.*

complication rates with no improvement in patient satisfaction functional outcome or time to return to activity.[73,74] In recently presented data from the FACTS registry of adolescent clavicle fractures, 40% of 125 operatively treated patients reported at least one complication after surgery.[54]

When nonunions and symptomatic malunions occur with conservative treatment, delayed surgical fixation represents a feasible option without a suggestion of long-term morbidity or disability from the delay. Corrective osteotomy, bone grafting, and plate fixation have led to good clinical outcomes with high patient satisfaction in adult populations.[75-77] In a group of 16 adolescents who underwent surgery for failed nonoperative treatment, including cases of nonunion, delayed union, and malunion, it was demonstrated that plate fixation with or without osteotomy for a symptomatic bony bump led to comparable time to union and complication rates as primary surgical fixation.[78]

***Figure 4a.*** *Injury radiographs of significantly shortened, comminuted, 3-part mid-shaft clavicle fracture in a 16-year-old male who underwent nonoperative treatment.*

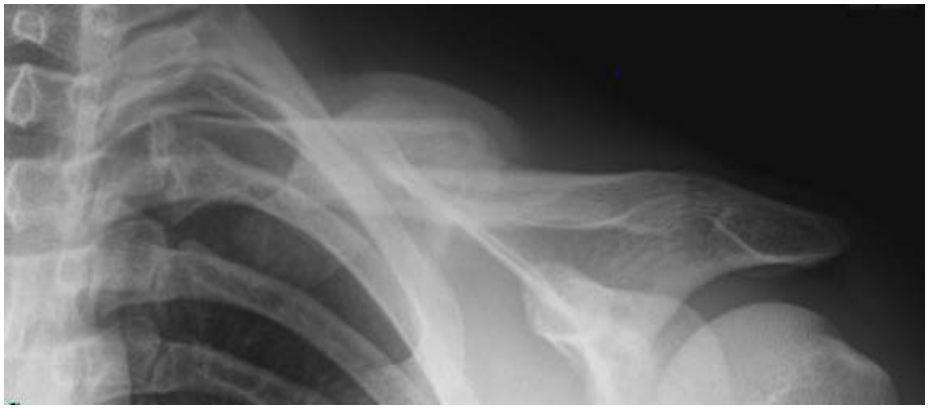

***Figure 4b.*** *Two-month post-injury radiograph demonstrating advanced healing. The patient returned to sports at 3 months with no complaints or functional limitations.*

Given a high activity level and an emphasis on rapid return to sports, refracture is also a complication of interest in adolescents. Studies suggest that refracture is uncommon in adolescents and unlikely to occur with any more frequency after nonoperative management compared to surgical management. Luo et al. reported no refractures requiring intervention in 130 adolescents with nonsurgical treatment. In those who underwent primary surgical treatment, there were two refractures (8.7%), one of which required revision surgery.[74] Heyworth et al. described six refractures (2.1%) in a group of adolescents treated nonoperatively, with no subsequent surgery required. In contrast, five patients in the operative group sustained refracture (4%), three of whom underwent subsequent surgery.[54]

*Shoulder Function/Patient-Reported Outcomes*

Recent large series have supported the long-held consensus that mid-shaft clavicle fractures in children and adolescents heal well with nonoperative management. O'Neill et al. reported that all of 190 childhood fractures healed clinically without subsequent need for surgical intervention.[20] Schulz et al. found no difference in pain, strength, range of motion, or subjective outcome scores between the injured and

contralateral limbs of 16 adolescents treated nonoperatively for a displaced, shortened mid-shaft clavicle fracture.[79] Randsborg et al. described good to excellent long-term patient-reported outcomes after nonoperative management of clavicle fractures in children.[80] Overall, studies in children and adolescents suggest predominantly good to excellent outcomes with nonoperative management.[20,79-80]

Rates of union with nonoperative treatment and various operative techniques are all very high in children and adolescents and thereby provide little differentiation. Plate fixation and intramedullary nailing have both been shown to lead to satisfactory results,[11,81-82] and patient-reported outcomes appear to be similar between operative and nonoperative management in children and adolescents.[54,62,73]

*Return to Sports*

In displaced pediatric clavicle fractures, conflicting studies have emerged regarding time of return to sports. While one study suggested faster time to union and return to sports with surgery by several weeks,[72] others have concluded that operative fixation offered no significant improvement in terms of return to activity, time to full active range of motion, or time to radiographic healing.[73]

*Cost*

There remains controversy in the literature as to whether operative or nonoperative management is more expensive in adults. Recent work has indicated that operative management of mid-shaft clavicle fractures in adolescent patients generates costs that are 19 times that of nonoperative treatment.[83]

## Summary

A study that reviewed POSNA and AAOS abstracts in 2013 suggested that the majority of research presented failed to support the documented trend towards increasingly aggressive treatment of pediatric clavicle fractures.[84] The authors suggested a dichotomy between both established and emerging clinical evidence versus the direction of clinical treatment. Mid-shaft clavicle fractures in adolescents appear to fall in this category of fractures that are increasingly undergoing operative treatment despite limited age-based evidence to support this trend.

While surgical management may be considered for select adults with completely displaced clavicle fractures to prevent symptomatic malunion or nonunion, current evidence suggests that these complications remain exceedingly rare in adolescent populations. Operative treatment includes a significant risk of complications and secondary surgery. No studies have demonstrated a long-term benefit over nonoperative treatment in terms of pain, quality of life, patient satisfaction, or shoulder/upper extremity function. Nevertheless, a recent study demonstrated that the rates of operative management for adolescent mid-shaft clavicle fractures at a single institution amongst orthopaedic trauma surgeons (32.6%) was almost triple that of the pediatric orthopaedic surgeons (10.3%), despite similar fracture shortening between patient cohorts.[85] Given the current evolving evidence regarding cost, complications, shoulder function, and patient-reported outcomes of nonoperative and surgical management, it behooves pediatric and adolescent caregivers to provide accurate and up-to-date information to patients and families about the natural history and treatment of these fractures.

## Additional Links

1. Orthokids: https://orthokids.org/
2. POSNA: https://posna.org/Physician-Education/Study-Guide/AC-Joint-Injuries
3. Boston Children's Hospital: https://www.childrenshospital.org/conditions-and-treatments/conditions/f/fractures

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