



Adolescent Clavicle Fractures: Is There a Role for Open Reduction and Internal Fixation

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Abstract

Purpose of Review Over the past ten years, there has been a change in the management of adolescent clavicle fractures. Utilizing data from the adult population, clinicians have become more aggressive in terms of surgical fixation. The purpose of this paper is to critically analyze the recent literature in regard to adolescent clavicle fractures, and to determine the role of open reduction and internal fixation.

Recent Findings Although there have been many case series that demonstrate that open reduction and internal fixation can be done safely and with predictable healing, studies which compare operative versus non-operative intervention suggest there may not be functional outcome differences between the two treatment options.

Summary Further study is necessary to determine the specific indications for fixation of clavicle fractures in the adolescent population. Shared decision-making between patient, family, and clinicians is essential to determine the specific fracture patterns and patients who might benefit from fixation to improve functional outcome.

Keywords Adolescent · Clavicle · Fracture · Plate fixation · Reduction · Function · Radiographs

Introduction

The treatment of clavicle fractures in the orthopedic community has experienced dramatic shifts over the past several decade or so. This trend has been seen in both adult and pediatric orthopedic practices. As the demands placed on the growing skeleton of youth athletes have seemingly increased with the rise in single-sport specialization and year-round sporting activity (combined with parent and patient expectation of rapid return of function), there has been a trend towards increasing operative fixation of fractures in the growing population. Yet, there is a dearth of high-quality studies which compares either the potential complications of treatment or the functional outcomes of operative versus non-operative management. This is perhaps best exemplified by the treatment of clavicle fractures in the adolescent population.

Historical Perspective

In the absence of an open fracture, neurovascular injury, or polytrauma, the vast majority of pediatric and adolescent clavicle fractures were treated non-operatively before the twenty-first century. Due to the high rate of union, the operative indications were sparse and very limited literature existed as to the outcomes after open reduction and internal fixation [1]. A treatment shift occurred in 2007 with the Canadian Orthopedic Trauma Society (COTS) multi-center, randomized, prospective trial, in which 132 adult patients were treated with either plate fixation or a sling for their mid-shaft clavicle fractures [2]. The authors found improved functional outcome and lower rates of non-union and malunion with plate fixation, compared to non-operative treatment. Additional studies at this time also presented results which shed a favorable light on the fixation of mid-shaft clavicle fractures [3–5]. This trend towards fixation of these injuries then began to shape the treatment of adolescent clavicle fractures.

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Changing Treatment Trends

The results of a Pediatric Orthopedic Society of North America (POSNA) e-mail survey found that surgeons

demonstrated a trend towards increased fixation in older adolescents and more severe fracture patterns, with the results of adult literature representing the greatest influence on treatment choices among pediatric caregivers [6]. This trend was also shown by Heyworth et al. in their single-institution analysis over a 12-year period from 1999 to 2011, which demonstrated not only an increase in the number of mid-shaft clavicle fractures seen, but also an increase in the percentage of mid-shaft clavicle fractures being treated operatively [7•]. Yang et al. confirmed this trend using the Pearl Driver database, finding a significant increase in operatively treated adolescent clavicle fractures from 2007 to 2011, particularly in the 15 to 19-year-old age group [8].

The increase in fixation of these injuries occurred with very limited pediatric- and adolescent-specific evidence that demonstrated improved functional outcomes and a similar complication profile compared to non-operative treatment. As with other fracture patterns in this age group (i.e., medial epicondyle fractures, open forearm fractures, comminuted femur fractures), more aggressive operative treatment indications were implemented prior to literature which supported the shifting trend [9••]. This treatment trend must be examined critically such that the appropriate management is made using evidence as the basis of care delivery. If not, surgical treatment options may become commonplace without a critical analysis of the risks and benefits in the context of historical, non-operative treatment options.

Initial Non-Plating Adolescent Studies

Several early studies demonstrated the outcomes, albeit in small numbers, of the operative fixation of these injuries. Kirschner wires [10], clavicle pins [11], and flexible nails [12–14] were all described in the literature as leading to successful radiographic outcomes in this age group. Yet, issues with potential hardware migration, need for hardware removal, and technical difficulty have limited the large-scale utilization of these fixation modalities, particularly in the adolescent population. The vast majority of studies examining operative fixation in this age cohort has concentrated on open reduction and internal fixation utilizing plate fixation, either standard compression plating or pre-contoured clavicle plates.

Early Plate Fixation Studies

There were several initial studies in the literature examining the outcomes of plate fixation in the pediatric and adolescent age group. Although many of them presented excellent results, study design limited their ability to meaningfully contribute to the question of what should be the indications for fixation in these sub-populations.

In 2009, Mehlman et al. retrospectively reviewed 24 patients with a mean age of 12 years and 8 months who

underwent plate fixation for their injuries [15]. All patients healed, and 87% of patients returned to unrestricted sports activities. Of note, *all* patients required a 2nd operation to have hardware removed. Namdari et al. also retrospectively reviewed a cohort of skeletally immature patients who underwent fixation for their clavicle fractures [16]. Their series consisted of 14 patients (mean age of 12.9 years) who underwent plate fixation and had a mean pre-operative fracture shortening of 14.4 mm. The authors found that all patients had achieved radiographic healing by a mean of 3 months, and the minimum 2-year follow-up telephone survey revealed a mean QuickDASH score of 7.0, but only seven patients (50%) were completely pain-free. Four patients (28.6%) had undergone hardware removal, and 8 (57%) complained of numbness at the surgical site.

Finally, Vander Have et al. performed one of the first studies comparing operative versus non-operative fixation of mid-shaft clavicle fractures, albeit in a retrospective fashion with different degrees of shortening between the two groups [17]. Forty-two patients (25 non-operative and 17 operative; mean age 15.4 years) were analyzed with a higher degree of shortening (27.5 mm vs 12.5 mm) in the operative group. The authors found no non-unions in either group but a slighter faster time to union as well as return to activity in the operatively treated group. One of the most surprising results of this study was that symptomatic malunion actually developed in five patients who were treated non-operatively, a much higher rate of symptomatic malunion that had/had been reported in the literature. Four patients underwent corrective osteotomy.

As a result of these studies combined with recent adult literature, a strong push towards operative fixation of these injuries in pediatric and adolescent patients was made. For many surgeons, these studies demonstrated that open reduction and internal fixation of clavicle fractures was a relatively safe operation with predictable healing rates, rapid return to activity, and a moderate need for a second operation to remove symptomatic hardware.

More Questions Arise

Amidst the changing trends of clavicle fracture management, many members of the pediatric orthopedic community questioned if the results of studies which consisted largely of adult patients should be applied to the adolescent population in the context of pediatric and adolescent studies with small sample sizes and low levels of evidence. The function after adolescent clavicle trauma and surgery (FACTS) multi-center study group and prospective cohort study were developed at Boston's Children's Hospital in an attempt to address this deficit in the literature. Pooling data from several high-volume children's hospitals across the country, this group compared non-operative versus operative treatment of adolescent clavicle fractures in a prospective, age-matched, pattern-

matched, parallel group comparison. This study group has led to several publications (which will be outlined below) and has sought to comprehensively look at differences in outcomes, not only in relation to healing, but also complications and functional outcomes.

Concurrent with the work of this study group has come a new volume of literature both in the adult and adolescent population which has helped to change the current indications for fixation of these injuries.

New Treatment Paradigms

Despite several previous studies suggesting superiority of operative treatment, other authors studying adult populations developed conflicting findings. For example, Tamaoki et al. found no difference in limb function between non-operatively and operatively treated adult patients with mid-shaft clavicle fractures in their prospective randomized controlled study [18•]. Further, Woltz et al. also performed a multi-center randomized clinical trial comparing plate fixation to non-operative treatment for displaced mid-shaft clavicle fractures [19••]. They found that although plate fixation improved the chance of bone healing, no difference was found between groups in terms of functional outcomes as measured by constant or DASH scores. Similarly, in their meta-analysis of randomized controlled clinical trials, Woltz et al. found that although plate fixation decreased the rate of non-union, it did not lead to a clinically relevant change in functional outcome as measured by constant and DASH scores [20].

The question naturally arises: how should this evolution in the adult literature, or pendulum swing back towards non-operative treatment since the initial 2007 Canadian study affect our perspective on adolescent clavicle fractures, particularly as adolescent patients may have the highest levels of participation in high-demand activities? Are the goals of operative fixation to prevent non-union, malunion, or delayed union? Are the goals of treatment to improve shoulder function and/or to allow quicker return to sport?

Given the high rate of healing of fractures in this population, an emphasis on the impact of treatment on shoulder function is critical, as is the potential complications of treatment, whether it be operative or non-operative. Only assessment of all of these factors can allow us to more definitively answer if open reduction and internal fixation is indicated in this age group. Several recent age-specific studies have emerged, which have helped tremendously in answering these questions.

New Literature Focusing on Function and Complications

Schulz et al. examined the functional and radiographic outcomes of adolescent patients with complete, displaced,

shortened mid-shaft clavicle fractures who were treated non-operatively, using the non-injured limb as a control [21]. The authors found that regardless of the fracture type, age, or level of athletic involvement, there was no difference between the limbs in terms of pain, strength, shoulder range of motion, or outcomes scores (SANE, QuickDASH, and Constant scores), even with 100% of these fractures healing in a significantly shortened position compared to the contralateral side. Parry et al. similarly found that when comparing their cohort of operatively versus non-operatively treated adolescent patients, no differences in range of motion, isometric strength, or abduction fatigue were found between groups [22•]. Even patients with established malunion were shown by Bae et al. to not developed any clinically meaningful loss of shoulder motion or abduction/adduction strength [23].

With limited evidence demonstrating a functional benefit, the complication profile must also be taken into consideration. Lou et al. examined a cohort of 153 adolescent clavicle fractures and found a 21.7% complication rate of surgically treated fractures including refracture, implant prominence/removal, and non-union [24••]. Li et al. also examined 36 operatively treated adolescent clavicle fractures and found an 86% complication rate: 59% with implant prominence or irritation, 16% with anterior chest wall numbness, 5% with superficial wound dehiscence or infection, 3% with refracture adjacent to the plate, and 3% with refracture after implant removal [25••]. Fifteen of the patients in their cohort (41.7%) underwent hardware removal.

These studies demonstrating potentially limited functional benefit, combined with a high complication rate, raise the following question: what are the *specific* indications for plate fixation of mid-shaft clavicle fractures in the adolescent population?

Identifying Cases for Fixation

It is important to identify the patients who may benefit from plate fixation compared to a non-operatively cohort. Utilization of a mean value of shortening may not be beneficial, as this has not been shown to be a consistent factor in determining treatment outcome, even with varying clinicians demonstrating good to excellent intra- and inter-rater reliability in regard to measuring shortening [26•]. In terms of non-union risk, the FACTS study group found over a 10-year period at 9 pediatric hospitals and 25 non-unions with a mean age of 14.5 years [27••]. The majority of these fractures occurred in male patients with displaced fractures, many of whom had a prior history of an ipsilateral clavicle fracture. Furey et al. also reported on a series of three patients who suffered a refracture of their clavicle due to angular malunion in the absence of displacement; indicating perhaps another group at risk for a complication related to healing [28•]. Although these specific patients may benefit from operative

fixation, it is important for the clinician to realize that the overall non-union risk is likely exceedingly low. Further study which looks at the non-union risk in a large cohort of patients is necessary to determine the importance of these, and potentially other, risk factors which may influence treatment decisions.

Role of Return to Sport

Beyond the identification of specific cases for fixation, quicker return to high-impact athletic activity has been a proposed benefit of open reduction internal fixation. Although there has not been a high-quality study in the adolescent population, there are studies in the adult population from which data can be gleaned. In a systematic review of return to sport after clavicle fractures, Robertson et al. found that operatively treated mid-shaft clavicle fractures were able to return to sport 12.1 weeks quicker than non-operatively treated fractures [29]. In their series of 54 patients, Ranalletta et al. found that approximately 90% of patients were able to return to sport in 12 weeks or less, with nearly 17% returning at less than 6 weeks after surgery [30••]. In elite NFL players, Jack et al. found that players who underwent fixation played in a similar number of games per season and had similar career lengths as control subjects [31].

Thus, although a pure adolescent cohort does not exist, a relatively quicker and predictable return to sport may be achieved in adults treated by plate fixation.

Author's Preferred Indications

The indications for the operative treatment of adolescent clavicle fracture must begin with a shared decision-making process with the patient and family. Inherent to this discussion is an understanding that there is a high rate of complications with this procedure, particularly incisional numbness and hardware irritation, as well as potential need for a secondary surgery. In my experience, there is no mean value for shortening or fracture pattern that is indicative of an absolute/relative need for surgical intervention (excluding open fractures, those with neurovascular compromise, or polytrauma patients). As shoulder function has not been shown to consistently improve with either treatment option and there exists high rates of healing, it is important to identify the sub-set of patients who would benefit from surgical intervention. It is also important to weight this benefit against a risk of surgical intervention including a high rate of complications and/or need for secondary procedures. In my practice, such patients may be those at risk for refracture (fractures with severe apex-superior angulation without displacement) or non-union (male patients with a prior history of fracture who present with a refracture). In addition, as quicker return to sport may be shown in future studies to be a predictable outcome for adolescent patients, I

typically reserve plate fixation for collision athletes 14 years of age and above who have injured their dominant hand.

In the cohort of patients managed operatively in the author's practice (via plate fixation), patients are placed in a sling for 7 days after the operation. At their 1-week post-operative visit, physical therapy is prescribed and the sling is discontinued. At 6 weeks, post-operatively, if patients can demonstrate full range of motion and strength (equal to the contralateral extremity) and radiographic healing, patients are allowed to return to full contact sporting activity. This is in contrast to patients managed non-operatively, who are placed in a sling for 4 weeks and then initiate physical therapy. No contact sporting activity is allowed until 3 months after initial injury as long as radiographic healing is present.

Conclusions

The indications for operative fixation of adolescent mid-shaft clavicle fractures have yet to be firmly established. A critical analysis of the literature is necessary for clinicians treating this injury to establish their own indications, as well as share this information with patients and their family, so as to individualize care. Clearly, further multi-center study is necessary to understand and identify the specific adolescent patients and fracture patterns, if any, that would benefit from operative treatment. Current indications are quite variable. Armed with an understanding of historical and current literature, the clinician can optimize care for this extremely common fracture in the sub-population most affected by the injury.

Compliance with Ethical Standards

Conflict of Interest Nirav K. Pandya is a consultant and reports personal fees from Orthopediatrics.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

References

Papers of particular interest, published recently, have been highlighted as:

- Of importance
- Of major importance

1. Weinstein S, Flynn JM, editors. Lovell and Winter's pediatric orthopedics. Philadelphia: Lippincott Williams and Wilkins; 2014.
2. Canadian Orthopedic Trauma Society. Nonoperative treatment compared with plate fixation of displaced midshaft clavicular fractures. A multicenter, randomized clinical trial. *J Bone Joint Surg Am.* 2007;89(1):1–10.

3. McKee MD, Wild LM, Schemitsch EH. Midshaft malunions of the clavicle. *J Bone Joint Surg Am.* 2003;85-A(5):790–7.
4. Pearson AM, Tosteson AN, Koval KJ, McKee MD, Cantu RV, Bell JE, et al. Is surgery for displaced, midshaft clavicle fractures in adults cost-effective? Results based on a multicenter randomized, controlled trial. *J Orthop Trauma.* 2010;24(7):426–33.
5. McKee MD, Pedersen EM, Jones C, Stephen DJ, Kreder HJ, Schemitsch EH, et al. Deficits following nonoperative treatment of displaced midshaft clavicular fractures. *J Bone Joint Surg Am.* 2006;88(1):35–40.
6. Carry PM, Koonce R, Pan Z, Polousky JD. A survey of physician opinion: adolescent midshaft clavicle fracture treatment preferences among POSNA members. *J Pediatr Orthop.* 2011;31(1):44–9.
7. Suppan CA, Bae DS, Donohue KS, Miller PE, Kocher MS, Heyworth BE. Trends in the volume of operative treatment of midshaft clavicle fractures in children and adolescents: a retrospective, 12-year, single-institution analysis. *J Pediatr Orthop B.* 2016;25(4):305–9 **This study demonstrates the increasing trend towards operative fixation at a high-volume institution.**
8. Yang S, Werner BC, Gwathmey FW Jr. Treatment trends in adolescent clavicle fractures. *J Pediatr Orthop.* 2015;35(3):229–33.
9. Eismann EA, Little KJ, Kunkel ST, Cornwall R. Clinical research fails to support more aggressive management of pediatric upper extremity fractures. *J Bone Joint Surg Am.* 2013;95(15):1345–50 **Although upper extremity fracture management in pediatric patients has become more aggressive there is limited literature supporting this increased treatment trend.**
10. Grażyński J, Wawrzaszek P, Sobczyński S, Adamczak M. Operative treatment of clavicle fractures in children. *Chir Narzadow Ruchu Ortop Pol.* 2003;68(1):19–21.
11. Frye BM, Rye S, McDonough EB, Bal GK. Operative treatment of adolescent clavicle fractures with an intramedullary clavicle pin. *J Pediatr Orthop.* 2012;32(4):334–9.
12. Rapp M, Prinz K, Kaiser MM. Elastic stable intramedullary nailing for displaced pediatric clavicle midshaft fractures: a prospective study of the results and patient satisfaction in 24 children and adolescents aged 10 to 15 years. *J Pediatr Orthop.* 2013;33(6):608–13.
13. Eisenstein ED, Misenhimer JJ, Kotb A, Thabet AM, Abdelgawad AA. Management of displaced midshaft clavicle fractures in adolescent patients using intramedullary flexible nails: a case series. *J Clin Orthop Trauma.* 2018;9(Suppl 1):S97–S102.
14. Kubiak R, Slongo T. Operative treatment of clavicle fractures in children: a review of 21 years. *J Pediatr Orthop.* 2002;22(6):736–9.
15. Mehlman CT, Yihua G, Bochang C, Zhigang W. Operative treatment of completely displaced clavicle shaft fractures in children. *J Pediatr Orthop.* 2009;29(8):851–5.
16. Namdari S, Ganley TJ, Baldwin K, Rendon Sampson N, Hosalkar H, Nikci V, et al. Fixation of displaced midshaft clavicle fractures in skeletally immature patients. *J Pediatr Orthop.* 2011;31:507–11.
17. Vander Have KL, Perdue AM, Caird MS, Farley FA. Operative versus nonoperative treatment of midshaft clavicle fractures in adolescents. *J Pediatr Orthop.* 2010;30(4):307–12.
18. Tamaoki MJS, Matsunaga FT, Costa ARFD, Netto NA, Matsumoto MH, Belloti JC. Treatment of displaced midshaft clavicle fractures: figure-of-eight harness versus anterior plate osteosynthesis: a randomized controlled trial. *J Bone Joint Surg Am.* 2017;99(14):1159–65 **This study demonstrates a change from prior adult studies which demonstrated superior outcomes with operative intervention compared with non-operative intervention.**
19. Woltz S, Stegeman SA, Krijnen P, van Dijkman BA, van Thiel TP, Schep NW, et al. Plate fixation compared with nonoperative treatment for displaced midshaft clavicular fractures: a multicenter randomized controlled trial. *J Bone Joint Surg Am.* 2017;99(2):106–12 **This study demonstrates a change from prior adult studies which demonstrated superior outcomes with operative intervention compared with non-operative intervention.**
20. Woltz S, Krijnen P, Schipper IB. Plate fixation versus nonoperative treatment for displaced midshaft clavicular fractures: a meta-analysis of randomized controlled trials. *J Bone Joint Surg Am.* 2017;99(12):1051–7.
21. Schulz J, Moor M, Roocroft J, Bastrom TP, Pennock AT. Functional and radiographic outcomes of nonoperative treatment of displaced adolescent clavicle fractures. *J Bone Joint Surg Am.* 2013;95(13):1159–65.
22. Parry JA, Van Straaten M, Luo TD, Simon AL, Ashraf A, Kaufman K, et al. Is there a deficit after nonoperative versus operative treatment of shortened midshaft clavicular fractures in adolescents? *J Pediatr Orthop.* 2017;37(4):227–33 **When comparing their cohort of operatively versus non-operatively treated adolescent patients, no differences in range of motion, isometric strength, or abduction fatigue were found between groups.**
23. Bae DS, Shah AS, Kalish LA, Kwon JY, Waters PM. Shoulder motion, strength, and functional outcomes in children with established malunion of the clavicle. *J Pediatr Orthop.* 2013;33(5):544–50.
24. Luo TD, Ashraf A, Larson AN, Stans AA, Shaughnessy WJ, McIntosh AL. Complications in the treatment of adolescent clavicle fractures. *Orthopedics.* 2015;38(4):e287–91 **Nearly 22% complication rate of surgically treated fractures including refracture, implant prominence / removal, and non-union.**
25. Li Y, Helvie P, Farley FA, Abbott MD, Caird MS. Complications after plate fixation of displaced pediatric midshaft clavicle fractures. *J Pediatr Orthop.* 2018;38(7):350–3 **Eighty-six percent complication rate with plate fixation noted in this study; implant prominence most common.**
26. Li Y, Donohue KS, Robbins CB, Pennock AT, Ellis HB Jr, Nepple JJ, et al. Function after adolescent clavicle trauma and surgery (FACTS) multicenter study group. Reliability of radiographic assessments of adolescent midshaft clavicle fractures by the FACTS multicenter study group. *J Orthop Trauma.* 2017;31(9):479–84 **Good reliability in terms of measuring clavicle fracture pattern between clinicians.**
27. Pennock AT, Edmonds EW, Bae DS, Kocher MS, Li Y, Farley FA, et al. Adolescent clavicle nonunions: potential risk factors and surgical management. *J Shoulder Elbow Surg.* 2018;27(1):29–35 **Male patients with history of prior fracture are at increased risk of non-union.**
28. Furey MJ, Zdero R, McKee MD. Clavicular refracture at the site of angular malunion in young athletes. *J Orthop Trauma.* 2017;31(4):e130–2 **Fractures with angular malunion may be at higher risk for re-fracture.**
29. Robertson GA, Wood AM. Return to sport following clavicle fractures: a systematic review. *Br Med Bull.* 2016;119(1):111–28.
30. Ranalletta M, Rossi LA, Piuze NS, Bertona A, Bongiovanni SL, Maignon G. Return to sports after plate fixation of displaced midshaft clavicular fractures in athletes. *Am J Sports Med.* 2015;43(3):565–9 **Quicker return to sport noted after plate fixation of fractures.**
31. Jack RA 2nd, Sochacki KR, Navarro SM, McCulloch PC, Lintner DM, Harris JD. Performance and return to sport after clavicle open reduction and internal fixation in national football league players. *Orthop J Sports Med.* 2017;5(8):2325967117720677.

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