Management of displaced midshaft clavicle fractures in adolescent patients using intramedullary flexible nails: A case series

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ABSTRACT

Introduction: Clavicle fractures are common injuries in adolescent patients. In this study we present our technique and results for treating non-comminuted displaced midshaft clavicle fractures using flexible intra medullary nails.

Methods: A retrospective review of prospectively collected data using the electronic medical record was performed. Adolescent patients presenting to a level one pediatric trauma center with acute displaced non comminuted clavicular shaft fractures who were treated with intra medullary flexible nails were included in this study.

Results: Seven adolescent patients with non-comminuted displaced mid shaft clavicle fractures were treated with flexible nails over a period of five and half years with an average follow up time of 10 months. The average age was 14.6 years (range 14–16), and a 2 mm nail was used in all cases. Closed reduction was obtained in five cases with only two cases needing open reduction to pass the nail. One patient had skin breakdown over the nail entry and had the nail removed in clinic two months after surgery, all other patients healed with no complication. Sports and full shoulder activity were allowed when radiographic healing was seen at an average 8 weeks. Implant removal was performed four of the seven patients.

Conclusion: Flexible intramedullary nailing is an effective minimally invasive method for the treatment of displaced midshaft clavicle fractures in the adolescent population. The surgeon should be aware that a 2 mm nail is likely the optimal diameter, and the nail is difficult to pass beyond the lateral 2–3 cm of the distal segment due to canal narrowing, but passage further than this is not necessary to achieve stability and union. Following these pearls will allow the surgeon to successfully perform the procedure.

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1. Introduction

Clavicle fractures are common injuries in children, representing about 15% of all pediatric fractures, with more than 90% of these fractures located in the midshaft.^{1–3} Traditionally non operative treatment has been the gold standard treatment in children, as the clavicle has excellent remodeling potential due to late medial and lateral physeal closure. Another reason for popularity of non operative treatment is that non union is extremely rare in pediatric patients, with only few case reports in the pediatric literature.^{2,4,5}

Recently, however, this thinking has been questioned as 80% of total clavicle growth is already achieved by the age of 9 in girls and 12 in boys and thus the remodeling potential after adolescence is less than previously thought.^{2,5–8} This, along with recent literature in the adult population, that supports operative treatment of displaced clavicle fractures, has caused interest in the surgical treatment of displaced clavicle fractures in adolescents.^{1,9,15}

Traditionally, operative treatment of clavicle fractures in adult and adolescent populations alike has been achieved by plate and screws.^{9,10,11} However, some of the complications of plate fixation include a prominent symptomatic implant frequently requiring a secondary surgery for removal, concern for refracture after implant removal, and poor cosmesis due to scar from the surgical incision.^{4,7,10,12–14} Recently, there has been an increased interest in intramedullary fixation in the literature surrounding clavicle fixation in adults.^{7,10,12,14}

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In this article, we describe our technique for using flexible nails in the management of mid shaft, displaced, non-comminuted fractures of the clavicle in the adolescent population. We describe the specific details related to this subset of the population. These details were not described before and are crucial to be able to fix these fractures using flexible nails. We also present our results in this patient category using this form of treatment.

2. Patients and methods

After Institutional Review Board approval, a retrospective electronic medical record review of prospectively collected data was performed from January 2010 to December 2015. A total of seven adolescent patients with clavicle fractures were treated using a flexible titanium nail. Inclusion criteria were mid shaft, completely displaced (no overlapping), non comminuted fractures in adolescent patients (Fig. 1). Exclusion criteria included patients older than 18 years, late (>2 weeks) presentation, open technique to pass nail without trial of closed reduction, and comminuted fractures. The families were counseled regarding the advantages and disadvantages of operative versus non operative treatment. Patients' age, complications, time to union, time to previous activities, and clinical follow up were assessed.

3. Surgical technique

The patient was positioned supine on a radiolucent flat top table with a small bump in the back between the scapulae (Fig. 2). The clavicle/sternum/anterior shoulder area was prepped and draped in standard sterile fashion, and the head of the patient was rotated opposite of the operative side. A small, 1.5 cm, incision was made at the junction of the medial third and middle third of the clavicle. Intra operative fluoroscopy (C-arm) was brought in from the contralateral side. The c-arm can then be tilted caudally and cranially to give orthogonal views of the clavicle. A 2.7 mm drill bit was used to create an opening in the anterior cortex of the clavicle

with the drill bit initially perpendicular to the clavicle, then gradually lowering the hand medially to aim the drill in a lateral direction, and finish with an oblique hole in the anterior clavicle. A 2 mm titanium flexible nail is introduced (using a T-handle) from the hole and hammered inside the intramedullary canal until it reaches the medial fracture end (Figs. 3 and 4). The surgeon must maintain good control on the T-handle and nail as the nail will tend to bend at the interface between the nail and handle. Passage of the nail inside the canal is not an easy task due to the small nature of the canal (Fig. 5). Minimal to no additional bend of the nail is required as the tip is pre-bent. Sizes of 1.5 mm or 2.5 mm were never successful in our experience, as the 1.5 mm nail was very flimsy and the 2.5 mm nail was too big to pass through the small medullary canal. Very strong blows from the hammer are required to pass the nail. If despite this, the nail is not advancing, the C-arm should be used to alternate between two views to assess the direction of the nail tip. If the built-in tip of the nail is found to be hitting against the cortex, 90–180° turns are done using the T-handle to rotate the tip of the nail away from the cortex to allow for passage.

A towel clip in the distal lateral fragment is used to obtain reduction. If this fails, another towel clip is used to better control the medial fragment. This can be aided by external pressure of the fragments with the hammer or other flat instrument such as an army navy retractor. In our experience, closed passage of the nail across the fracture is not an easy task; however, it can be done in the vast majority of cases using the “two towel clips” technique. The surgeon should know that this step will usually require some time and considerable number of trials judged by intra operative fluoroscopy in two perpendicular views (with increased exposure to radiation). If closed reduction cannot be obtained with these maneuvers, a small one inch incision is created, centered over the fracture, and two towel clips or bone forceps are used to bring the fracture ends together. One of the authors of this article prefers to pass the nail across the fracture by open technique (rather than fighting long time with considerable radiation exposure) (please

Fig. 1. 14 years old male with left mid shaft clavicle fracture. A) XR clavicle showing the fracture. B) intra operative arrangement of the prepping, draping and fluoroscopy machine. C and D) intra operative and fluoroscopy pictures showing the use of “two-towel clips” technique. E and F) two intra operative fluoroscopy views showing the reduction and the passage of the nail. G) intra operative fluoroscopy three months after initial surgery showing fracture healing and removal of the implant. Mid shaft, completely displaced (no overlapping), non comminuted fractures in adolescent patients.

Fig. 2. Patient positioning.

Fig. 3. During introduction of the elastic nail medially.

Fig. 4. Intraoperative fluroscopy during reduction and introduction of Elastic pin.

note that these cases were excluded from the study). The nail is then advanced into the distal (lateral) fragment, using hammer blows on the T handle. In most cases, the nail cannot be advanced more than three cm distal to the fracture as the medullary canal size decreases in the lateral part of the clavicle. The nail is cut very short using the wire cutter. In our experience the flexible nail cutter found in the set usually results in a longer residual stump of nail left behind as the cutter cannot be pushed flush against the bone due to the small size of the entry wound.

Post operatively, the patient is placed in a simple sling for comfort. Patients are instructed to remove the sling once pain subsided. Shoulder range of motion is not restricted, however, no sports were allowed until radiographic evidence of healing.

4. Results

Seven adolescent patients were treated with flexible nails over a period of five and half years with an average follow up time of 10

Fig. 5. Fluoroscopic appearance after passage of elastic nail the fracture site.

months. The average age was 14.6 (range 14–16). The majority of injuries were due to falls associated with sports or athletic participation such as football and skateboarding. Patients were offered the option of intramedullary nail fixation as well as non operative treatment and the benefit of each was discussed in detail with the patient and their family. A 2 mm nail was used in all cases. Mean fluoroscopy time was 138.3 s (2.3 min).

Closed reduction was obtained in five cases. Two cases required open reduction to pass the flexible nail. The two cases which required open reduction had their surgery seven and nine days after injury.

All the patients except one (who was performed 9 days after injury) healed with no complications and regained full activity without limitation, thus accounting for the short follow up period. The mean time to radiographic union for these five patients was 8.75 weeks. Sports and full shoulder activity were allowed when radiographic healing was seen at 6–8 weeks.

Four patients underwent implant removal. One patient elected to remove it without any complaint related to the nail (was done 13 months after surgery). Two patients decided to have the implant removed due to discomfort related medial end of the nail (one patient 10 weeks after implantation and the other 12 weeks after implantation). The fourth patient had prominence of the nail beneath the skin causing skin break down, requiring removal which was done in the clinic.

The patient with implant prominence beneath the skin had his surgery nine days after fracture. Closed reduction could not be obtained even after multiple attempts. Open reduction was necessary in which considerable amount of callus had to be excised to allow reduction of the bone ends and restoration of length. This patient had backing out of the nail through the skin and the flexible nail was removed in the clinic two months after surgery. The patient did not displace the fracture after nail removal.

5. Discussion

Adolescent clavicle fractures are common injuries with increasing surgical versus conservative management. While most surgeons continue to treat adolescent clavicle fractures non operatively, the improved outcomes reported in recent adult literature, have swayed some surgeons from classic non operative conservative management, to surgical fixation, especially in older adolescents.¹⁵ It is important to note that our hospital is a “level one” trauma center with very busy orthopedic trauma service, despite this, we only performed this procedure less than ten times in five and half years indicating that non operative treatment for adolescent clavicle is by far still our preferred method of treatment. For cases that we decide on surgical treatment, the choice between flexible nail versus plate fixation will depend on the degree of

comminution and the location of the fracture. Flexible nails are only suitable for mid shaft non comminuted fractures.

The Canadian Orthopedic Trauma Society reported improved functional outcomes and increased union rates with open reduction internal fixation in the adult population, with multivariate analysis of the study finding that non union was the only independent predictor of functional outcome.^{1,9} While non union in the pediatric/adolescent population is thought to be extremely rare due to excellent remodeling potential, thus placing this subgroup of patients at a very low risk for dysfunction, newer data suggests that the remodeling potential may not be as prominent as previously thought.^{5,16} Males reach 80% of their clavicle length by age 12 while females do so at age 9, with some studies suggesting that children as young as 10 years old have pain and dissatisfaction with non operative treatment.^{2,5–8} Reasons for unsatisfactory outcomes in the pediatric/adolescent population are multifactorial. Malunion with associated shortening changes the biomechanics of shoulder function can be symptomatic with much less shortening than expected compared to adult patients. Shortening and malunion, to some degree, is inherent with non operative management, as 71% of fractures have some degree of shortening with 56% having >2 cm.⁴ This amount of shortening in the coronal plane causes muscular imbalance of the shoulder girdle and leads to fatigue.^{4,17} Adolescent males with as little as 18 mm and females with 14 mm of shortening have been found to be dissatisfied with their final outcome.¹⁷ Although the exact amount of shortening associated with a poor outcome in skeletally immature individuals has yet to be determined, due to smaller anatomy, relative shortening should be taken into consideration.¹⁷ Some authors favor consideration for surgical management in patients with relative shortening of 14–15% of the total clavicle length compared to an absolute amount of 15–20 mm in the adult clavicle.^{6,17} Multiple pediatric/adolescent studies have demonstrated that although final functional outcome scores tend to be good with non operative treatment, motion analysis has demonstrated functional deficits, as patients have decreases in endurance strength which leads to continued pain and dissatisfaction, with up to 80% electing to undergo corrective osteotomies.^{4,5,13,16,19,20} Another issue of concern with non operative treatment of these fractures is a high risk of refractures.¹⁸ Studies evaluating the surgical management of adolescent clavicle fractures have found good results, with faster time to union and activity, and excellent ability to return to previous sports.^{4,11,21} As stated in the previous paragraph, the vast majority of adolescent clavicle fracture in our pediatric trauma center are still managed non operatively. We only offer operative treatment as an option for treatment for adolescent patients (older than twelve) who have completely displaced and shortened clavicle fracture.

Once the decision has been made to proceed with operative fixation, many of these fractures are treated with open reduction and internal fixation (ORIF) using plates and screws, however this is not without complications such as poor cosmesis due to scar, scar sensitivity, prominent implant, anesthesia surrounding the incision and concern for re-fracture after implant removal.^{4,7,10,12–14} Elastic stable intramedullary nailing (ESIN) has been reported as the method of choice in the treatment of pediatric/adolescent/adult clavicle fractures, it is minimally invasive with less blood loss, and patients are found to have less pain and improved cosmesis, with no functional differences.^{2,7,10} The adult literature on the use of ESIN is controversial as some studies have shown this to be a minimally invasive technique with little risk of complications, while others have shown a 70% complication rate, a 36% risk of reoperation, and >50% conversion to open reduction.^{7,12,14} Advantages of elastic nailing over other intramedullary devices such as clavicle pins, Rush pins, or Kirschner wires, is the tension created by the nail blocks itself in the curved shaped clavicle and prevents migration.^{2,14} While this technique has successfully been studied and implemented in other long bone fractures, there is very little literature dedicated to the specific technique and use of ESIN in pediatric/adolescent clavicle fractures.¹⁴ In addition, the specifics of the technique of using flexible intra-medullary in adolescent patients have never been explained adequately in the literature. We found that there are very important tricks that the surgeon needs to know otherwise he or she will not be able to perform the procedure.

Currently published studies in both adults and pediatrics report a high rate (>50%) of conversion to an open reduction when using ESIN.^{7,14} In our small cohort only two of seven patients required conversion to an open reduction. We believe we were more successful in achieving closed reduction in our cohort of acute cases because of our use of the two towel clip technique described above. Our average use was just over two minutes compared to greater than eight minutes reported in other studies.¹⁴ The closed reduction and flexible nail passage in cases of mid shaft clavicle fractures in adolescent is not an easy task (compared to other bones like tibia, femur, radius or ulnar), nevertheless, it is still can be done using our “two towel clips technique” with many trials required that need to be judged by intra operative fluoroscopy.

With regard to optimal nail size, Rapp et al.⁷ used 2–2.5 mm nails in a study of 24 adolescent patients, Frigg et al.,¹⁴ used 2–3 mm nails in a study of 34 patients, however, the study done by Frigg included both adult and adolescent patients, while the frequently quoted study by Kubiak and Slongo² does not mention the size of nails used. In a similar study of intramedullary fixation, Frye et al.,¹² used 2.8–4.5 mm intramedullary clavicle pins in their study of 17 adolescent patients. In our experience, 2 mm nails were the most convenient size to use in adolescent patients as they provided a good balance between rigidity to allow for passage, and intramedullary fit. Larger diameter nails (2.5 mm and 3 mm) were much harder to pass in the narrow medulla, conversely, with hammering, smaller diameter nails start to bend at the point where they are anchored to the T handle.

A crucial learning point in our technique is the narrowing of the lateral medullary canal which prevents the passage of the nail more than 2–3 cm past the fracture site. Although we did not have any cases of lateral perforation, this observation was also noted by Frigg et al.,¹⁴ as they recommend advancing the nail just lateral enough to bridge the fracture in order to prevent this complication. Regardless of the narrowing of the lateral medullary canal and the obstruction to passage of the nail it causes, we found no lateral displacement of the fragment or failure of the nail construct. This “short distance” of nail distal to the fracture was not found to be a cause of loss of fixation.

We had one case of medial skin penetration by the nail. This may be due to cutting the nail too long at the insertion site, the

nail backing out, or due to a “telescoping” event, caused by fracture shortening, as has been previously described.⁷ The patient presented approximately two months after the initial surgery with continued soreness in his left upper extremity and upon physical examination the pin was noted to be penetrating the skin. After discussion with the patient and family about potential solutions for this problem, the patient elected to have the pin removed in clinic and this was done uneventfully. Concern for telescoping events or nail backout is usually associated with shortening and comminution, which prevents stability provided by cortical apposition. Since the fracture was not comminuted and no shortening was noted, prominence of the hardware was likely due to leaving the pin proud at the insertion site. Removal of the pin did not cause displacement of the fracture. While comminution is considered a contraindication to flexible nailing, due to the reasons stated above, Frigg et al.,¹⁴ in their study of 34 patients ages 16–74 were able to restore and maintain length despite comminution. While we did not use flexible nailing in comminuted fractures, the successful use by Frigg et al.,¹⁴ in fractures with comminution begs for further research, and may likely be associated to their use of an end cap. In our series we did not use an end cap as we did not perform this procedure in comminuted fracture.

6. Conclusion

Elastic stable intramedullary nailing for displaced clavicle fractures in children is a viable alternative to plate fixation. This method avoids the complications specific to plate fixation without sacrificing functional outcomes. There are very critical technical points that the surgeon needs to know in order for him/her to be able to perform the procedure. Closed reduction can be achieved in most cases of acute fractures without the need for conversion to open reduction. Using two towel clips can facilitate the closed reduction. The surgeon should expect multiple trials before succeeding in nail passage. In our experience a 2 mm nail is the most suitable size to use in adolescent patients. Bigger nail are harder to pass and smaller ones are not rigid enough. Passing the nails require more force that the most surgeon would anticipate. It is important to remember the nail cannot be advanced into the lateral fragment for more than 2–3 cm as the medullary canal narrows in this area, however, this short distance is not a risk for fixation failure. The medial end of the pin should be cut very close to point of entry in the clavicle to prevent symptomatic implant prominence.

Conflict of interest

The authors have none to declare.

References

1. Yang S, Werner B, Gwathmey FJ. Treatment trends in adolescent clavicle fractures. *J Pediatr Orthop*. 2015;35(3):229–233.
2. Kubiak R, Slongo T. Operative treatment of clavicle fractures in children: a review of 21 years. *J Pediatr Orthop*. 2002;22(6):736–739.
3. Kotb A, Yong T, Abdelgawad A. A posteriorly displaced distal metaphyseal clavicular fracture (Type IV AC joint dislocation-like) in children: a case report and literature review study. *Case Rep Orthop*. 2016;2016:4015212.
4. Vander Have K, Perdue A, Caird M, et al. Operative versus non operative treatment of midshaft clavicle fractures in adolescents. *J Pediatr Orthop*. 2010;30(4):307–312.
5. Assafiri I, Sraj S. Adolescent displaced midshaft clavicle fracture. *J Hand Surg Am*. 2015;40:145–147.
6. Fanter N, Kenny R, Baker C, et al. Surgical treatment of clavicle fractures in the adolescent athlete. *Sports Health*. 2015;7(2):137–141.
7. Rapp M, Prinz K, Kaiser M. 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):608–613.

8. Caird M. Clavicle shaft fractures: are children little adults. *J Pediatr Orthop*. 2012;32:S1–4.
9. Society COT. 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.
10. Wang X, Cheng L, Guo W, et al. Plate versus intramedullary fixation care of displaced midshaft clavicular fractures a meta analysis of prospective randomized controlled trials. *Medicine (Baltimore)*. 2015;94(41):21792.
11. Mehlman C, Yihua G, Bochang C, et al. Operative treatment of completely displaced clavicle shaft fractures in children. *J Pediatr Orthop*. 2009;29(8):851–855.
12. Frye B, Rye S, McDonough E, et al. Operative treatment of adolescent clavicle fractures with an intramedullary clavicle pin. *J Pediatr Orthop*. 2012;32(4):334–339.
13. Luo T, Ashraf A, Larson A, et al. Complications in the treatment of adolescent clavicle fractures. *Orthopedics*. 2015;38(4):287–291.
14. Frigg A, Rillmann P, Perren T, et al. Intramedullary nailing of clavicular midshaft fractures with the titanium elastic nail: problems and complications. *Am J Sports Med*. 2009;37(2):352–359.
15. Carry P, Koonce R, Pan Z, et al. A survey of physician opinion: adolescent midshaft clavicle fracture treatment preferences among POSNA members. *J Pediatr Orthop*. 2011;31(1):44–49.
16. Bae D, Shah A, Kalish L, et al. Shoulder motion, strength, and functional outcomes in children with established malunion of the clavicle. *J Pediatr Orthop*. 2013;33(5):544–550.
17. Pandya N, Namdari S, Hosalkar H. Displaced clavicle fractures in adolescents: facts, controversies, and current trends. *J Am Acad Orthop Surg*. 2012;20(8):498–505.
18. Masnovi M, Mehlman C, Eismann E, et al. Pediatric refracture rates after angulated and completely displaced clavicle shaft fractures. *J Orthop Trauma*. 2014;28(11):648–652.
19. Hagstrom L, Ferrick M, Galpin R. Outcomes of operative versus nonoperative treatment of displaced pediatric clavicle fractures. *Orthopedics*. 2015;38(2):135–138.
20. Schulz J, Moor M, Roocroft J, et al. Functional and radiographic outcomes of nonoperative treatment of displaced adolescent clavicle fractures. *J Bone Joint Surg Am*. 2013;95(13):1159–1165.
21. Namdari S, Ganley T, Baldwin K, et al. Fixation of displaced midshaft clavicle fractures in skeletally immature patients. *J Pediatr Orthop*. 2011;31(5):507–511.