Chapter

Intramedullary Fixation of Midshaft Clavicle Fractures

Martin D. Richardson and Louise M. Richardson

Abstract

Midshaft clavicle fractures are a common orthopaedic upper limb injury in young athletes and in trauma. While non-operative care has traditionally been the preferred therapeutic approach, surgical intervention is becoming more popular, to improve patient outcomes and speed the return to function. Intramedullary screw fixation has developed as a successful surgical treatment for midshaft clavicle fractures, in recent years, giving greater stability and encouraging early mobilisation. This chapter provides an overview of the efficacy, complications, and clinical outcomes of intra-medullary screw treatment for midshaft clavicle fractures. According to current research, intra-medullary screw fixation has various advantages over standard non-operative therapy, including increased fracture stability, lower non-union rates, and improved functional outcomes. Complications from this procedure, such as implant migration or discomfort, are often minor and controllable. However, careful patient selection, preoperative preparation, and surgical expertise are required to achieve the best results.

Keywords: midshaft clavicle fracture, intramedullary fixation, common upper limb injury, significantly displaced, shortened

1. Introduction

Clavicle fractures are very common, accounting for 2.6–4% of all fractures [1, 2]. The majority of these, greater than 80%, occur in the midshaft [3]. They are commonly associated with athletic activities such as contact sports (such as football), cycling, and snow sports, and occur typically in a younger male patient group [2]. Undisplaced fractures are usually treated non-operatively, but indications for operative treatment have led to a general consensus that displacement and/or shortening of greater than 20 mm leads to a higher mal-union and non-union rate and is a stronger indication for operative treatment. Zlowodzki et al. [4] reported a 15.1% non-union rate for non-operatively treated displaced clavicle fractures. They identified factors associated with nonunion including displacement, comminution, female sex, and increased age. Postacchini et al. [2] noted 48% of fractures in their study were displaced and 19% were comminuted. This chapter outlines a surgical approach for intramedullary fixation of midshaft clavicle fractures using a cannulated intramedullary screw. A recent systematic review supported a lower incidence of nonunion and symptomatic malunion in patients who underwent operative fixation of displaced midshaft clavicular fractures compared to conservative management [5].

Furthermore, there is mounting evidence that intramedullary fixation achieves similar or superior functional outcomes to plate fixation, but with lower complication rates [6]. The decision to proceed with operative management will be patient specific and will be affected by factors such as: deformity, disability, patient choice, the local health care system, implant cost and availability, and the overall relative cost/benefit of the procedure. For instance, operative fixation for a tradesperson, dependent on upper limb use, may allow substantially more rapid return to work and reduced off-work costs.

2. Variety of intramedullary devices

Numerous implants have been used to fix midshaft clavicular fractures by an intra-medullary technique.

2.1 Kirschner wires

There have been accounts of successful K-wire stabilisation of clavicle fractures since the early 1940s [7]. However, Lyons and Rockwood [8] cautioned that Implants around the shoulder girdle that have the potential to migrate and end up in cerebral or intrathoracic structures can have severe adverse effects.

2.2 Titanium elastic nails (TENs)

TENS were originally developed to manage paediatric long bone fractures without causing damage to the epiphyses and have been used to manage midshaft clavicular fractures, with one benefit being a MIPO approach that minimises surgical scars [9]. The inability to manage the implant's length and rotation are potential drawbacks of this method. This restricts their application to more simple configurations, such as transverse or short oblique fractures with minimal comminution [10]. Significant radiation from the C-arm is required to handle the implant with an image intensifier (fluoroscopy), exposing both patient and operators to increased radiation exposure. Additionally, Jubel et al. [11] reported a 15 mm loss of length in the post-operative period following comminuted fracture fixation. Frigg et al. [12] reported a complication rate of 70% and 36% revision rate, using this approach. In this group 44% of the fractures were comminuted. Randomised controlled trials comparing TENs to plate fixation [13, 14] showed high union rates (96–100%) but also significant complication rates (over 60%).

2.3 Hagie pins

The San Antonio -based Rockwood team described the use of a Modified Rockwood-Hagie pin for treating midshaft clavicular non-unions [15]. This device has been used successfully by a number of groups, with union rates ranging from 91.4 to 100% [16–20]. Mudd et al. [21] reported less favourable results in a small study, with an 83.3% (15/18) union rate. All authors reported that irritation from the prominent lateral end of the implant necessitated removal.

In our experience with this device, the inability to have the length less than 120 mm resulted in prominence of the nuts on the lateral side and often protrusion of the medial end of the screw anteriorly, causing subcuticular irritation, requiring implant removal. We have since chosen devices with more length options that can be made completely intra-osseous, avoiding a second operation to remove the implant. This is also a common problem when plates are used. As the clavicle lies in a subcutaneous plane with little soft tissue and muscular coverage, extra-osseous implants will frequently cause irritation and necessitate a second procedure for removal.

2.4 Knowles pins

Knowles pins are solid threaded nails used to repair midshaft clavicular fractures [22]. Unfortunately, due to their length, one or both ends of the pin frequently protrude from the bone, causing irritation requiring removal after fracture healing.

2.5 Echidna pins

Echidna pins (**Figure 1**) were developed to aid rotational and length stability [23, 24]. The retractable spikes on this intramedullary device can be deployed once in position to achieve fixation in the proximal and distal fragments. While experimental studies have demonstrated good biomechanical performance, this device has not been clinically trialled.

2.6 Solid intra-medullary screws

Khalil [25] described a medial to lateral approach that made use of a solid 6.5 mm screw, but the prominent medial head caused significant discomfort and additional surgery was needed for implant removal. Abo El Nor [26] used a similar device with

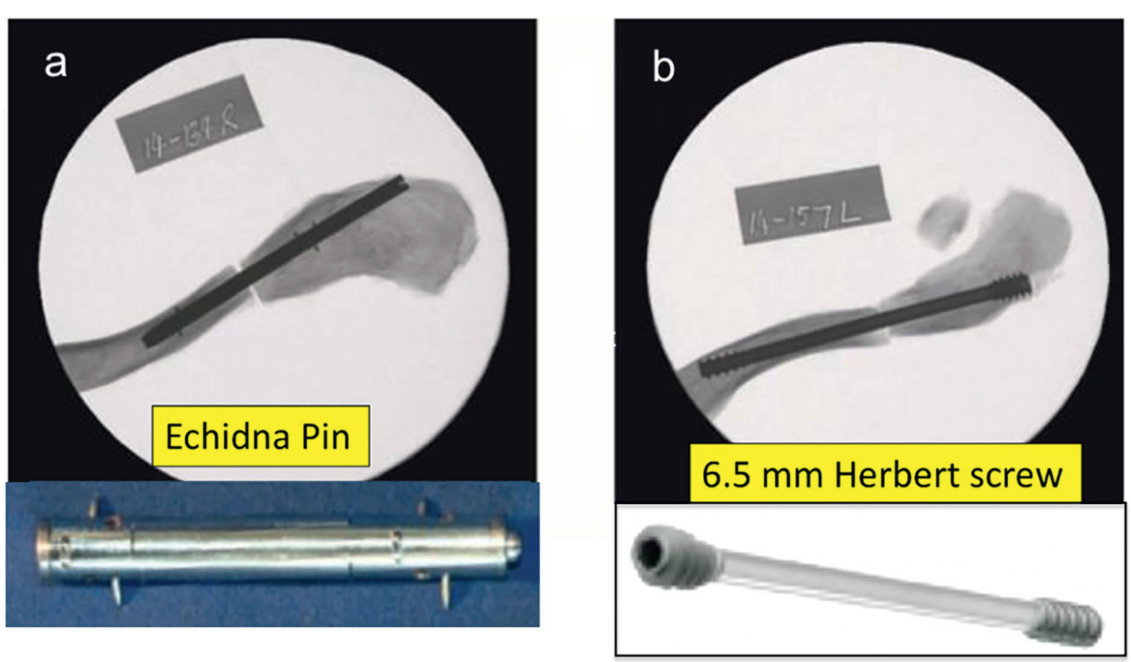

Figure 1.
Fluoroscopy images showing intramedullary Echidna pin (a) and Herbert. Screw (b) use to manage a midshaft clavicular fracture.

a lateral to medial insertion after retrograde drilling of the lateral fragment and achieved a 100% union rate while avoiding the medial head prominence.

2.7 Cannulated intra-medullary screws

Our intra-medullary fixation preference is now a cannulated intra-medullary screw (**Figure 1**) with differential threads at either end. Originally, we used 4.5 mm diameter Herbert screws for females and adolescent males and the 6.5 mm Herbert screws for most adult males. Unfortunately, these have been discontinued recently. We successfully have variants on this theme with different diameters and lengths. Typically, 70–100 mm lengths have been suitable. The advantage of this design is that temporary reduction can be made over a guide wire before definitive placement of the cannulated screw. The screw can be made completely intra-osseous reducing the likelihood of hardware irritation and the need for subsequent removal. The differential threads at either end of the screw provide length and rotational control (**Figure 2**).

3. Risks

Numerous sensory supraclavicular nerves run over the clavicle, supplying skin over the anterior chest down to the level of the nipple. The area of numbness created by the surgical approach to the clavicle is directly related to the size of the incision. Plating techniques typically require larger incisions than intramedullary approaches, resulting in a higher risk of numbness or dysthaesia.

It has been demonstrated that both the subclavian artery and vein lie very close to the inferior surface of the clavicle bone (12.2 mm and 8.3 mm, respectively) [27, 28] and are at risk of damage if a drill bit is plunged or an excessively long screw is used when plating midshaft clavicle fractures. The brachial plexus is also intimately related to the midshaft of the clavicle (within 8.3 mm). Bain et al. [29] have documented a pseudo aneurysm of the axillary artery after plating of a midshaft clavicular fracture. These findings resulted in the conclusion that an anterior approach is potentially safer than a superior plating approach. The apex of the lung is also just deep to

Figure 2.
Well reduced clavicle fracture with intra medullary cannulated screw with differential threaded Herbert styled screw threads to aid with fracture stabilization, compression and rotational control.

the neurovascular structures and may be at risk, with resultant pneumothorax, if damaged.

The preparation of a midshaft clavicle fracture for fixation with an intramedullary screw is done entirely within the plane of the clavicle, protecting the nearby neurovascular structures.

4. Operative technique

We have developed an operative technique which exposes the fracture directly, allowing mobilisation of the fractured ends of the midshaft clavicle and preparation of the intramedullary canal of the main shaft elements, which are essentially straight. The lateral end of the clavicle curves anteriorly to become the acromio-clavicular joint, thus lateral reaming deliberately perforates the posterior cortex behind the acromio-clavicular joint. A straight guide pin can then be directed posteriorly to allow a percutaneous incision to be made through which the pin can be pushed. The fracture can then be reduced over the pin and advanced medially into the medial fragment. The intramedullary device can be further advanced to achieve reduction and fixation of the fracture akin to similar fixations in other long bones fixed with intramedullary devices, like a midshaft tibia or femoral fracture.

If the fracture is comminuted as in the Xray in **Figure 3**, the butterfly fragments can be carefully pushed to the side maintaining their periosteal soft tissue attachments and (thus their vascularity) and sutured back into place around the reduced fracture. Bone graft can be harvested from the drill bits used to open the medullary canal, which can then be used to primarily bone graft the fracture site, promoting earlier fracture healing. The wound can then be closed in layers, first with muscular sutures and then with dermal and subcuticular dissolvable sutures to re-cover the clavicle.

Elements of the operative technique are illustrated in **Figures 4–11**, and **Figure 12** provides a stepwise diagrammatic representation of the procedure.

A more detailed demonstration video of the procedure can be accessed at Vumedi.com [30].

Figure 3.
Plain radiograph of a comminuted midshaft clavicular fracture, shortened and displaced more than 20mm.

Figure 4.
Positioning of patient supine with their head on a donut ring, at the edge of the bed and secured to the table with head strapping. A rolled towel or litre bag of saline placed under scapula aids fracture reduction and arm is positioned on arm board.

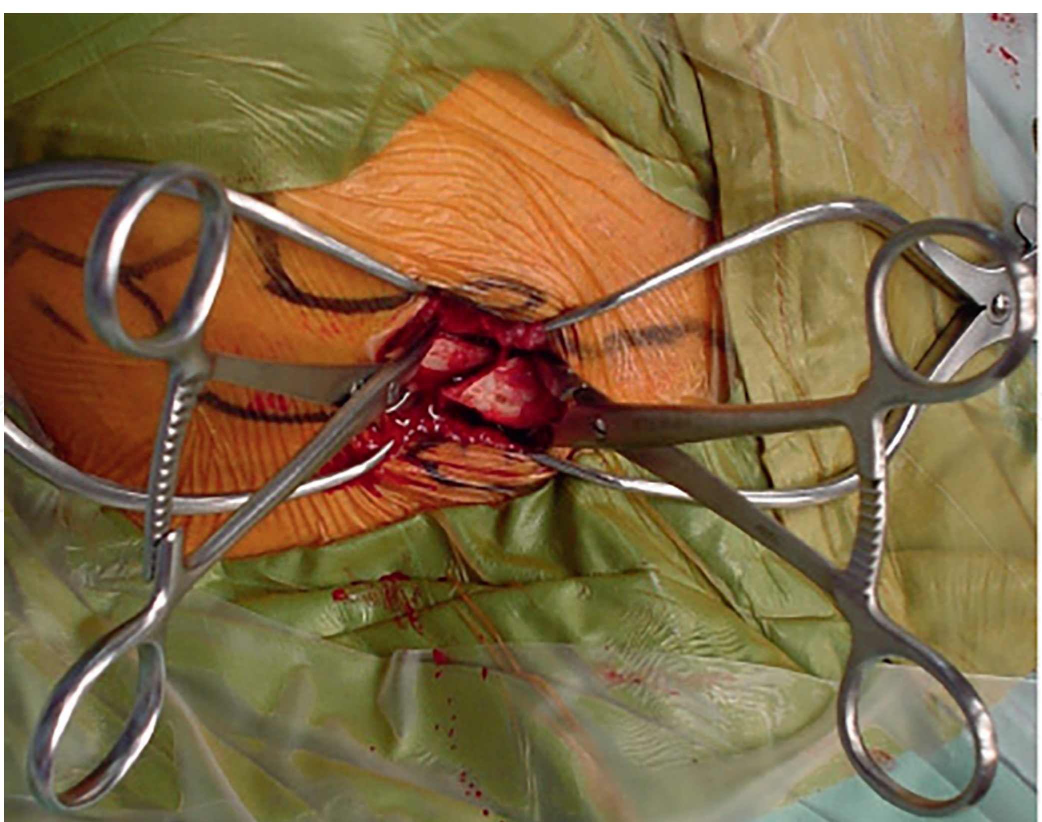

Figure 5.
Manipulation of medial and lateral shaft fragments with small fragment bone clamps to allow preparation and ultimate bony reduction.

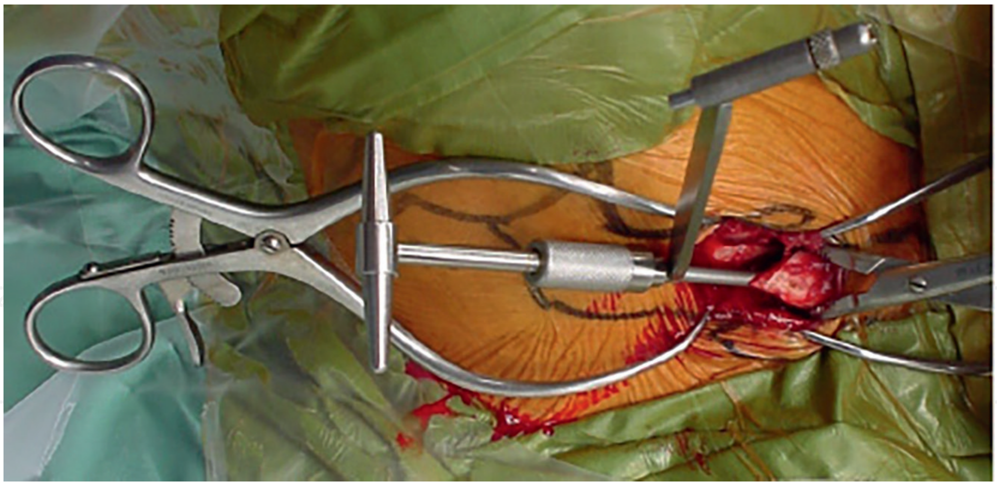

Figure 6.
Preparation of intramedullary canal with handheld drill bits.

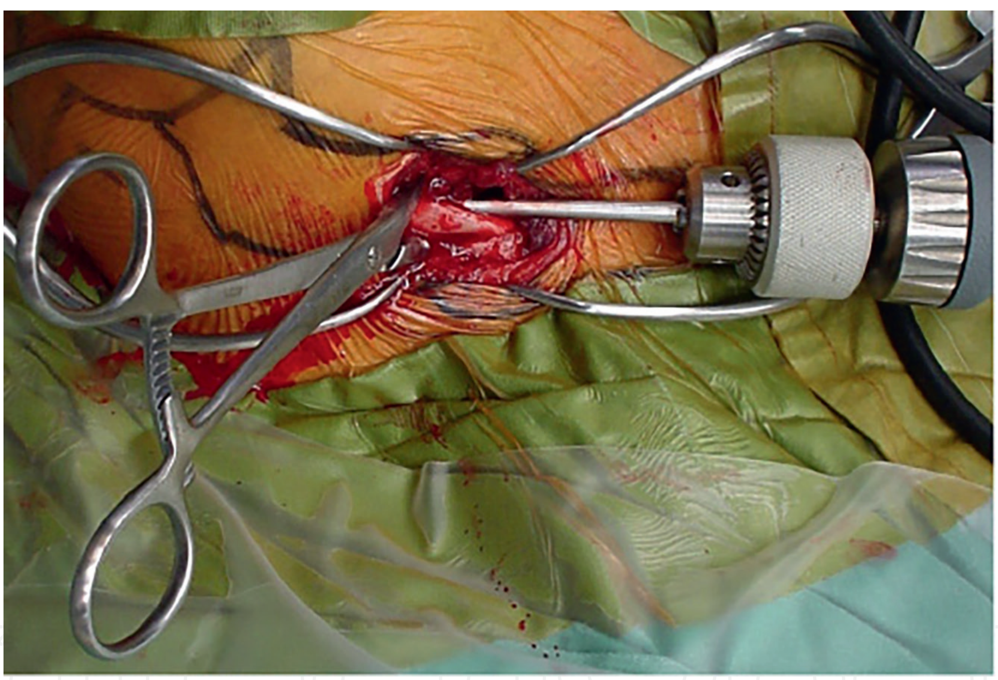

Figure 7.
Preparation of lateral fragment, initially by hand, and ultimately perforation of postero-lateral cortex with power.

5. Clinical results

Xie et al. [31] performed a systematic review of eight overlapping meta-analyses comparing the results of plate versus intra-medullary fixation of displaced midshaft clavicular fractures. While the functional or non-union outcomes did not differ between the two treatment groups, they did document a higher reintervention and refracture rate after implant removal of plate implants.

We reported on 114 of our own cases, with a 2.6% non-union rate [32]. The reoperation rate was also low (1.7%).

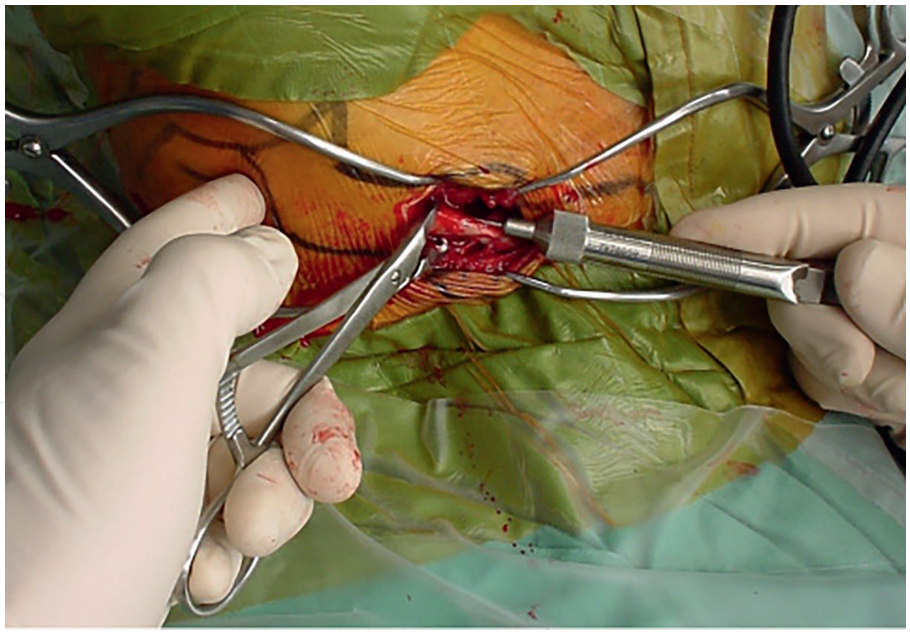

Figure 8.
Measurement of length of intramedullary fragments both medial and lateral to determine length of intramedullary device.

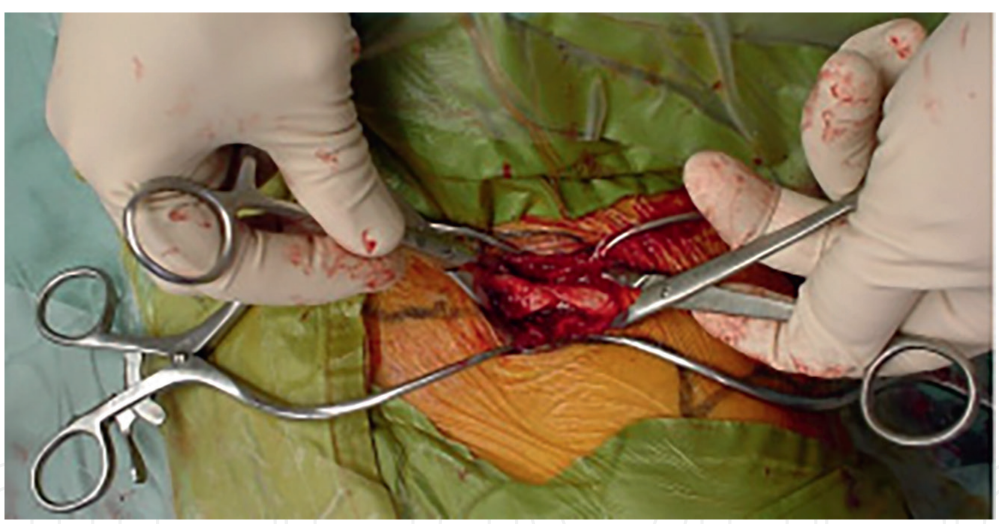

Figure 9.
Final reduction of fracture over intramedullary pin, the intramedullary device can then be inserted from the lateral percutaneous incision medially across the reduced fracture.

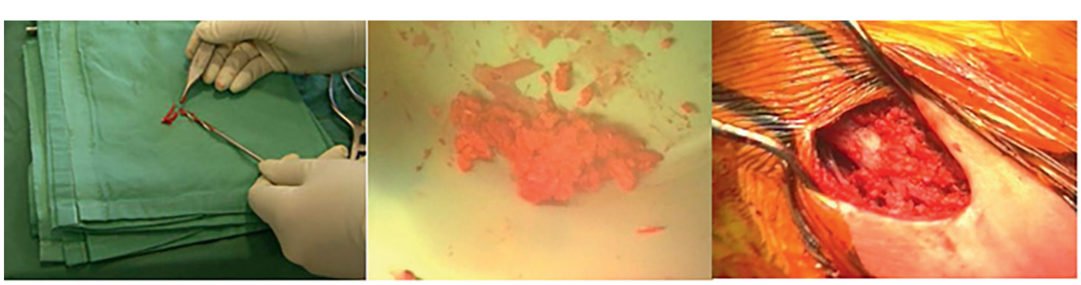

Figure 10.
Care taken to harvest reamings, from the intramedullary drills, yields abundant bone graft to be placed as primary bone graft to promote fracture healing.

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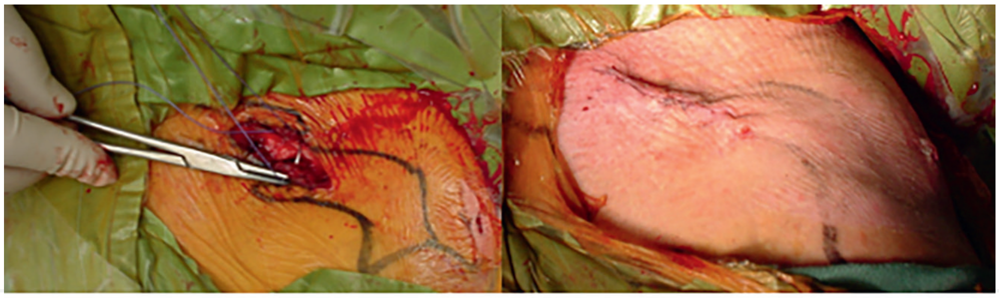

Figure 11.
Suturing of periosteal soft tissue attachments of butterfly fragments back into place around reduced fracture.

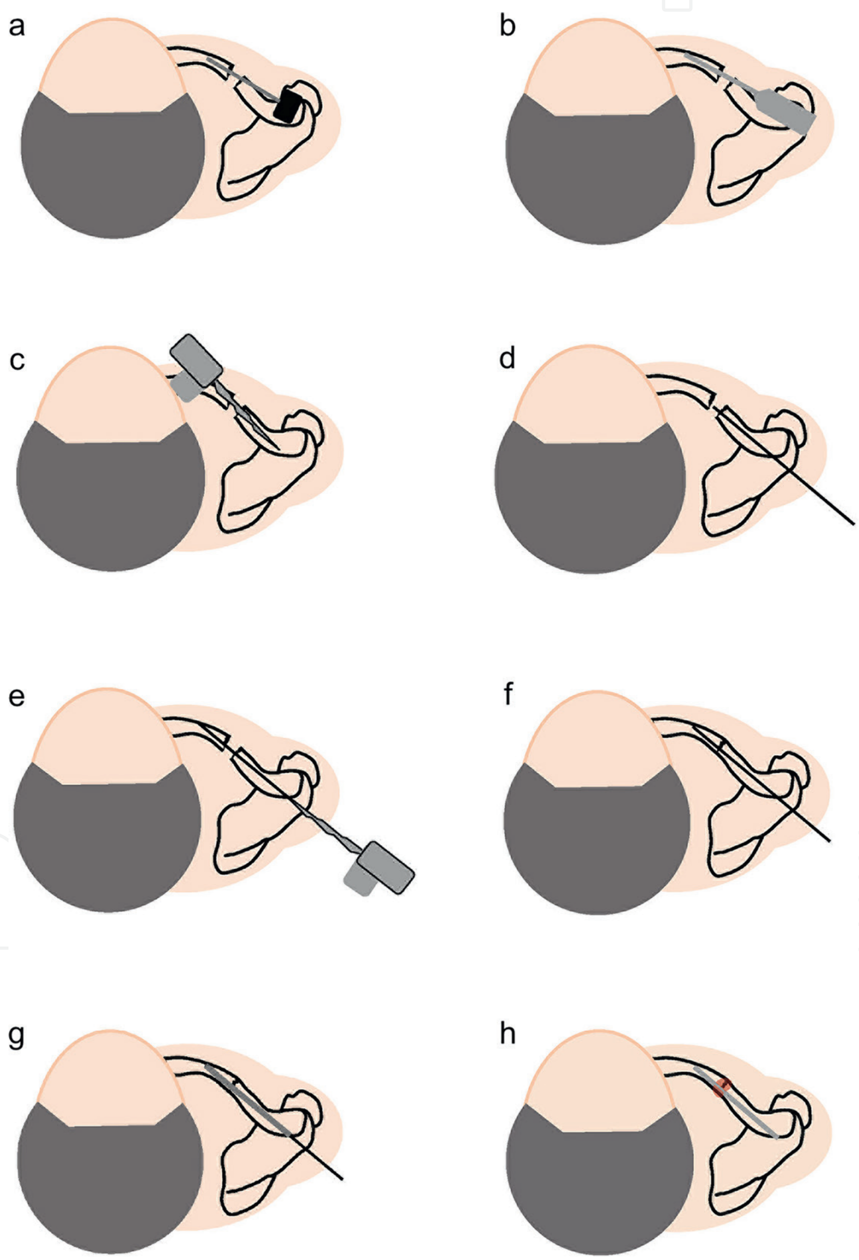

Figure 12.
Diagrammatic representation of the operative procedure. (a) Hand-drilling the intramedullary canal of the medial fragment. (b) Tapping the intramedullary canal of the medial fragment. (c) The intramedullary canal of the lateral fragment was power drilled. (d) The guide wire is introduced in retrogradely. (e) The posterolateral cortex is drilled out using a step drill. (f) Reinsertion of the guide wire and fracture reduction. (g) Placement of a cannulated Herbert screw at the fracture site. (h) Implantation of harvested bone graft around the fracture site.

6. Biomechanics

Smith et al. [33] demonstrated superior strength of clavicles fixed with an intramedullary device after removal of hardware compared to plates, raising the concern of refracture for plate fixation.

7. Treatment of delayed, mal-unions and non-unions

Treatment of midshaft clavicular fractures is easier if performed within 28 days of the fracture as much of the dissection of the fracture ends has been done by the trauma. Union rates are higher in the acute group, while complications are lower, implying that the decision to operate should ideally be made in the first month [34]. When treating a mal- or non-united mid shaft clavicular fracture, caution is required because the anatomy is likely to be distorted and adhesions may increase the risk of damage to neuro-vascular structures when osteotomizing a mal union or mobilising and debriding a non-union. Our technique of using intramedullary reamings aids the healing of these cases. A small curette is an excellent tool to locate and develop the medullary canal safely for implant insertion.

8. Conclusion

Midshaft clavicle fractures are common upper limb injuries that generally affect younger active males. The natural history of conservatively treated displaced fractures is characterised by a high mal- and non-union rate. Intra-medullary fixation of midshaft clavicle fractures provides a safe consistent method of managing these fractures, allowing early return to function in both the sporting arena and workplace.

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References

[1] Nordqvist A, Petersson C. The incidence of fractures of the clavicle. Clinical Orthopaedics and Related Research. 1994;**300**:127-132

[2] Postacchini F, Gumina S, De Santis P, Albo F. Epidemiology of clavicle fractures. Journal of Shoulder and Elbow Surgery. 2002;**11**(5):452-456. DOI: 10.1067/mse.2002.126613

[3] McKee M. Clavicle fractures. In: Bucholz R, Court-Brown C, Heckman J, editors. Fractures in Adults. Lippincott: Williams & Wilkins; 2010. pp. 1106-1141

[4] Zlowodzki M, Zelle B, Cole P, Jeray K, McKee M. Treatment of acute midshaft clavicle fractures systematic review of 2144 Fractures_On behalf of the evidence-based orthopaedic trauma working group. Journal of Ortho Trauma. 2005;**19**(7):504-507

[5] Amer K, Smith B, Thomson JE, Congiusta D, Reilly MC, Sirkin MS, et al. Operative versus nonoperative outcomes of middle-third clavicle fractures: A systematic review and Meta-analysis. Journal of Orthopaedic Trauma. 2020;**34**(1):e6-e13. DOI: 10.1097/BOT.0000000000001602

[6] Hoogervorst P, van Dam T, Verdonschot N, Hannink G. Functional outcomes and complications of intramedullary fixation devices for midshaft clavicle fractures: A systematic review and meta-analysis. BMC Musculoskeletal Disorders. 2020;**21**(1):395. DOI: 10.1186/s12891-020-03256-8

[7] Murray G. A method of fixation for fracture of the clavicle. JBJS A. 1940;**22**(3):616-620

[8] Lyons F, Rockwood C. Current concepts review: Migration of pins used in operations on the shoulder. JBJS A. 1990;**72A**(8):1262-1267

[9] Fuglesang HFS, Oksum MA, Wikeroy AKB. Mini-invasive intramedullary fixation of displaced midshaft clavicle fractures with an elastic titanium nail. JBJS Essential Surgery Technology. 2018;**8**(2):e16. DOI: 10.2106/JBJS.ST.18.00001

[10] Chung HJ, Hong KJ, Kim DS. Biomechanical properties of titanium elastic nail applied to a cadaveric clavicle model. Orthopaedics & Traumatology, Surgery & Research. 2015;**101**(7):823-826. DOI: 10.1016/j.otsr.2015.06.023

[11] Jubel A, Andermahr J, Schiffer G, Tsironis K, Rehm K. Elastic stable intramedullary nailing of midclavicular fractures with a titanium nail. CORR. 2003;**408**:279-285. DOI: 10.1097/01.blo.0000048131.30533.81

[12] Frigg A, Rillmann P, Perren T, Gerber M, Ryf C. Intramedullary nailing of clavicular midshaft fractures with the titanium elastic nail: Problems and complications. The American Journal of Sports Medicine. 2009;**37**(2):352-359

[13] Andrade-Silva F, Kojima K, Joeris A, Santos SJ, Mattar R. Single, superiorly placed reconstruction plate compared with flexible intramedullary nailing for midshaft clavicular fractures: A prospective, randomized controlled trial. The Journal of Bone and Joint Surgery. American Volume. 2015;**97**(8):620-626

[14] van der Meijden O, Houwert R, Hulsmans M. Operative treatment of dislocated midshaft clavicular fractures: Plate or intramedullary nail fixation? A

randomized controlled trial. The Journal of Bone and Joint Surgery. American Volume. 2015;**97A**(8):613-619

[15] Boehme D, Curtis R, DeHaan J, Kay S, Young D, Rockwwod C. Non-union of fractures of the mid-shaft of the clavicle. Treatment with a modified Hagie intramedullary pin and autogenous bone-grafting. JBJS A. 1991;**73 A**(8):1219-1226

[16] Ferran N, Hodgson P, Vannet N, Williams R, Evans R. Locked intramedullary fixation vs plating for displaced and shortened mid-shaft clavicle fractures: A randomized clinical trial. Journal of Shoulder and Elbow Surgery. 2010;**19**(6):783-789

[17] Kleweno C, Jawa A, Wells J. Midshaft clavicular fractures: Comparison of intramedullary pin and plate fixation. Journal of Shoulder and Elbow Surgery. 2011;**20**(7):1114-1117

[18] Millett P, Hurst J, Horan M, Hawkins R. Complications of clavicle fractures treated with intramedullary fixation. Journal of Shoulder and Elbow Surgery. 2011;**20**(1):86-91

[19] Payne D, Wray W, Ruch D, Zura R, Moorman C. Outcome of intramedullary fixation of clavicular fractures. The American Journal of Orthopedics. 2011;**40**(6):E99-E104

[20] Strauss E, Egol K, France M, Koval K, Zuckerman J. Complications of intramedullary Hagie pin fixation for acute midshaft clavicle fractures. Journal of Shoulder and Elbow Surgery. 2007;**16**(3):280-284

[21] Mudd C, Quigley K, Gross L. Excessive complications of open intramedullary nailing of midshaft clavicle fractures with the Rockwood clavicle pin. Clinical Orthopaedics and Related Research. 2011;**469**(12):3364-3370

[22] Jou IM, Chiang EP, Lin CJ, Lin CL, Wang PH, Su WR. Treatment of unstable distal clavicle fractures with Knowles pin. Journal of Shoulder and Elbow Surgery. 2011;**20**(3):414-419. DOI: 10.1016/j.jse.2010.08.009

[23] Ackland D, Griggs I, Hislop P, Wu W, Patel M, Richardson M. An intramedullary Echidna pin for fixation of comminuted clavicle fractures: A biomechanical study. Journal of Orthopaedic Surgery and Research. 2017;**12**(1):122. DOI: 10.1186/s13018-017-0623-y

[24] Sidhu N, Huntington LS, Richardson M, Ackland DC. Biomechanical performance of an intramedullary Echidna pin for fixation of comminuted mid-shaft clavicle fractures. ANZ Journal of Surgery. 2019;**89**(10):1308-1313. DOI: 10.1111/ans.15392

[25] Khalil A. Intramedullary screw fixation for midshaft fractures of the clavicle. International Orthopaedics. 2009;**33**(5):1421-1424

[26] Abo El Nor T. Displaced mid-shaft clavicular fractures: Surgical treatment with intramedullary screw fixation. Archives of Orthopaedic and Trauma Surgery. 2013;**133**(10):1395-1399

[27] Galley IJ, Watts AC, Bain GI. The anatomic relationship of the axillary artery and vein to the clavicle: A cadaveric study. Journal of Shoulder and Elbow Surgery. 2009;**18**(5):e21-e25. DOI: 10.1016/j.jse.2009.01.021

[28] Hussey M, Chen Y, Fajardo R, Dutta A. Analysis of neurovascular safety between superior and anterior plating techniques of clavicle fractures. Journal of Ortho Trauma. 2013;**27**(11):627-632

[29] Bain G, Galley I, Keogh A, Durrant A. Axillary artery pseudoaneurysm after plate osteosynthesis for a clavicle nonunion: A case report and literature review. International Journal of Shoulder Surgery. 2010;**4**(3):79

[30] Richardson M. Fixation of midshaft clavicle fracture with an intra-medullary Herbert screw. VuMedi. 2019. Available from: https://www.vumedi.com/video/fixation-of-midshaft-clavicle-fracture-with-an-intra-medullary-herbert-screw/

[31] Xie L, Zhao Z, Zhang S, Hu Y. Intramedullary fixation versus plate fixation for displaced mid-shaft clavicle fractures: A systematic review of overlapping meta-analyses. Medicine (Baltimore). 2018;**97**(4):e9752. DOI: 10.1097/MD.0000000000009752

[32] Richardson M, Asadollahi S, Richardson L. Management of acute displaced clavicular fractures using Herbert cannulated screw: Technique and results in 114 patients. International Journal of Shoulder Surgery. 2013;**16**(7):1-7

[33] Smith SD, Wijdicks CA, Jansson KS, Boykin RE, Martetschlaeger F, de Meijer PP, et al. Stability of mid-shaft clavicle fractures after plate fixation versus intramedullary repair and after hardware removal. Knee Surgery, Sports Traumatology, Arthroscopy. 2014;**22**(2):448-455. DOI: 10.1007/s00167-013-2411-5

[34] Richardson M, Richardson L, Asadollahi S. Delayed surgical treatment of displaced midshaft clavicle fracture using Herbert cannulated screw with intramedullary bone graft. European Journal of Orthopaedic Surgery and Traumatology. 2012;**22**(8):647-653. DOI: 10.1007/s00590-011-0877-8