Limited open reduction and elastic intramedullary nailing for mid-shaft clavicular fractures

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Background

Elastic intramedullary nailing (EIN) of displaced mid-shaft clavicular fractures is a minimally invasive technique, which was reported to be a simple procedure with low complication rate and good functional results. Other studies, however, report on specific problems with this technique. This prospective study reports on EIN in displaced mid-shaft clavicular fracture. We hypothesized that restoration of clavicular length is the primary goal of EIN.

Patients and methods

Between January 2008 and January 2012, 36 patients with simple, wedge or comminuted mid-shaft clavicular fractures were treated with EIN.Clavicular shortening was determined after trauma and after osseous consolidation on true clavicle anteroposterior radiograph with a 20° cephalic tilt with the patient in a standing position. Radiographic union was assessed every 4 weeks. Patient satisfaction was assessed at final follow-up after 1 year.

Results

Among the 36 patients, 34 fractures healed, and each underwent a planned procedure for nail removal. Complications included two nonunions, one delayed union, two nail migrations and one deep-wound infection. EIN led to restoration of clavicular length in simple and wedge fractures. We were not able to restore length in comminuted fractures through the EIN technique. Patient satisfaction at a mean follow-up of 29.5 months was significantly correlated with the lesser post-traumatic and posthealing shortening, quicker fracture healing and early implant removal.

Conclusion

Intramedullary nail fixation for acute simple or wedge-type mid-shaft clavicular fractures provides a safe and predictable treatment option. In comminuted fractures, however, EIN does not provide the needed stability to restore clavicular length.

Keywords:
clavicle, fracture, intramedullary nailing, shortening

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Introduction

Fractures of the clavicle are common, accounting for 3–5% of all fractures in adults, with mid-clavicular fractures accounting for 70–80% of all clavicle fractures; more than half of these fractures are displaced [1,2]. It is most often caused by a simple fall on the outstretched hand or a direct impact on the shoulder. They usually affect active and healthy people during sports activities or road traffic accidents. These patients are asking for a quick and full recovery. Until now, treatment was usually conservative for mid-clavicle fractures. However, many recent papers pointed out long-term deficits following conservative treatment for clavicle fractures, leading more surgeons to propose surgical treatment to their patients. In summary, nonoperative treatment of acute mid-shaft clavicle fractures result in an overall nonunion rate of 5.9%. The nonunion rate for displaced fractures is 15.1% [3].

Until the mid 1990s, many authors reported on good outcomes for fracture healing and restoration of function after nonoperative treatment of clavicle fractures, whereas the patients' complaints were thought to be of cosmetic concern only. However, there is growing evidence and awareness that the outcome of such treatment is not as satisfactory as was previously thought. In one of the first papers to highlight the limits of conservative treatment, Hill *et al.* [4] showed a high rate of nonunion (15%) and unsatisfactory results (31%). McKee *et al.* [5] evaluated 30 patients at a mean of 55 months and showed that after conservative treatment strength of the involved shoulder was reduced to 75% compared with the uninjured shoulder.

Conservative treatment is a good option for nondisplaced or minimally displaced fractures. Grossly displaced mid-shaft clavicle fracture is an indication for surgery to lower nonunion rate and to minimize cosmetic and functional sequelae. Advocates for plating point out the quality of reduction and the rigid fixation with improved rotational stability. However, plating is associated with soft-tissue stripping, big scar and discomfort with such superficial plates. Advocates for intramedullary fixation point out the easy procedure, the limited exposure, the good cosmetic results and the satisfactory union rate [3].

The use of titanium elastic nails in the treatment of mid-shaft clavicular fractures was first introduced by Jubel *et al.* [6]. Excellent clinical results encouraged us to take advantage of this technique to treat displaced mid-shaft clavicular fractures. The purpose of this prospective study was to evaluate the use of elastic intramedullary nailing (EIN) with limited open reduction in the management of fully displaced mid-shaft clavicular fractures and to compare our results with those reported in the literature. We hypothesized that restoration of clavicular length is the primary goal of EIN.

Patients and methods

Between January 2008 and January 2012, 36 consecutive patients with simple, wedge or comminuted mid-shaft clavicular fractures were treated with EIN at Mansoura University Hospitals, Egypt, and prospectively evaluated.

Inclusion criteria were (i) isolated, unilateral, displaced mid-shaft clavicular fractures with no cortical contact between the main fragments, and (ii) age between 18 and 60 years. Exclusion criteria were (i) fractures of the medial or lateral third of the clavicle, (ii) pathological or open fractures, (iii) neurovascular injury and (iv) additional shoulder girdle fractures.

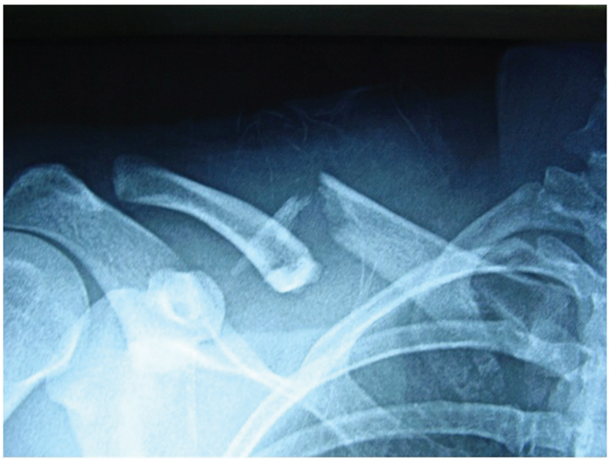
Fracture type and post-traumatic clavicular shortening were determined on true clavicle anteroposterior radiograph with a 20° cephalic tilt with the patient in a standing position. Fractures were classified according to the Orthopaedic Trauma Association system. Simple shaft fractures were coded as 15B1, wedge fractures as 15B2 and complex fractures as 15B3.

Clavicular shortening was determined after trauma and after osseous consolidation in millimetres, with the uninjured side serving as a control for the clavicular length.

Surgery was performed within 3 days after trauma under general anaesthesia. Single dose of antibiotics was given preoperatively, and antibiotics were continued for 3 days postoperatively. The 2.0–3.5-mm elastic titanium nails were used. A 1-cm skin incision was made over the sternal end of the clavicle ~1 cm lateral to the sternoclavicular joint. The anteroinferior cortex of the clavicle was drilled with a 2.7-mm drill-bit. The hole was widened with an awl, and the elastic titanium nail was advanced to the fracture site through oscillating movements under fluoroscopic control. Another limited 1-cm incision was made over the fracture site for direct manipulation of the main fragments, leaving the other fragments untouched. This was done with the help of fluoroscopic control.

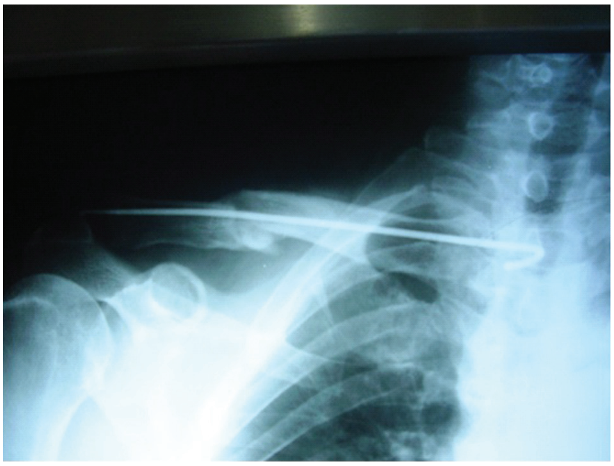
Postoperatively, the arm was put in a shoulder sling. Pendulum exercises and pain-dependent passive mobilization were started immediately, and the range of shoulder motion was gradually increased but kept within 90° during the first 4 weeks after surgery. Active range of motion rehabilitation exercises were allowed after 4 weeks postoperatively. Heavy load bearing was not recommended until osseous consolidation. Once

Figure 1



Preoperative radiograph.

Figure 2



Postoperative radiograph.

Figure 3

Radiograph after hardware removal.

fracture union was achieved, nail removal was done for all patients (Figs 1–3).

Radiographic union was assessed every 4 weeks. Radiographic union was defined as complete cortical bridging between the medial and lateral fragments. Clavicular shortening was determined again after osseous consolidation. Patient satisfaction was assessed at final follow-up after 1 year. Patients were asked about pain, cosmetic appearance, ability to return to work and overall satisfaction [7].

Complications included (i) two cases of symptomatic nonunions after 24 weeks requiring revision surgery, (ii) one patient with symptomatic malunion with pain and easy fatigability requiring corrective osteotomy, (iii) two cases with telescoping and medial nail migration and protrusion with subsequent clavicle shortening who needed cutting the nail under local anaesthesia and (iv) one case with deep infection who responded to early surgical lavage and the appropriate antibiotics.

The SPSS version 16.0 (SPSS Inc., Chicago, Illinois, USA) was used for statistical analysis. Metric scaled data are reported as arithmetic mean±SD and categorical data as absolute frequency and percentage distribution. Depending on the distribution form, a *t*-test for independent samples was used. For paired samples, a *t*-test was used. The analysis of bivariate correlation was performed by using the Pearson correlation coefficient. The probability level was set at P value of less than 0.05.

Results

Demographic data are shown in Table 1.

Table 1 Demographic data, mechanism of injury and fracture classification

Age	31.25±7.1 (18–44)
Sex	
Male	22
Female	14
Mechanism of injury	
Fall	20
RTA	6
Sports injury	10
Fracture classification	
15B1	15
15B2	9
15B3	12

RTA, road traffic accidents.

Table 2 Time to union in weeks

Time to union	Mean±SD	Count
All fractures types	9.294±5.277	36
15B1 (simple)	5.6±2.028	15
15B2 (wedged)	11.111±3.333	9
15B3 (comminuted)	13.2±6.546	12

Time to union in weeks is shown in Table 2. It was 9.3 ±5.3 weeks for the whole sample. It was especially shorter in the simple fracture type.

Post-traumatic shortening and shortening after union are shown in Table 3. We observed a significant improvement of shortening for the simple and wedge fracture types (P=0). In the comminuted fracture subgroup, there was no significant improvement of shortening (P=0.13).

Complications are listed in Table 4. Nonunion occurred in two cases with comminuted fracture type. Telescoping and nail migration occurred in one patient with comminuted fracture type and another patient with a wedge-type fracture.

Patient's satisfaction is shown in Table 5. At a mean follow-up of 29.5 months (range: 12–48 months), we had 77.8% satisfaction rate. Patient's satisfaction with significantly correlated with post-traumatic shortening, fracture healing in weeks, posthealing shortening and earlier implant removal (Table 6).

Discussion

The clavicle has an S-shaped configuration with medial and lateral flat ends, a tubular middle and a very small medullary canal. These considerations explain that plates or rigid nails are relative unsuitable implants [3]. The clavicle acts as a bone strut to maintain the width of the shoulder and

Table 3 Clavicular shortening after trauma and after union

Fracture types	Initial shortening	Shortening after union (mm)	*P* value
All fracture types	16.81 (7.289)	13.08 (10.346)	0
15B1 (simple)	11.53 (5.927)	4.33 (5.876)	0
15B2 (wedged)	16.56 (4.953)	12.78 (6.241)	0
15B3 (comminuted)	23.58 (4.295)	24.25 (5.276)	0.13

Table 4 Complications

All complications	*n*
Nonunion	2
Malunion	1
Nail migration	2
Infection	1
Total	6

Table 5 Patient's satisfaction

	n
Satisfaction	
Satisfied	28
Unsatisfied	8
Reasons	
Pain and easy fatigability	2
Ugly scar	7
Skin irritation	4

therefore provides the power and stability to the arm-trunk mechanism; thus, shortening after clavicle fractures may have an effect on shoulder function. This might be a specific problem with the use of intramedullary nailing with telescoping and nail protrusion [8]. Clavicular shortening leads to static changes in the shoulder girdle. The sternoclavicular joint angle increases, and the resting position of the scapula and the preload of the muscles of the shoulder girdle change. This might lead to limitations in the overhead motion and symptoms such as pain, weakness and easy fatigability [9]. Restoration of clavicular length was therefore stated as a primary goal of EIN [6].

Traditionally, conservative treatment has been the major treatment of clavicular fracture. In two landmark studies from 1960s by Neer [10] and Rowe [11], nonunion rates were relatively low when conservative treatment was applied. Neer [10] reported nonunion in only three out of 2235 mid-shaft clavicular fracture patients treated conservatively, whereas Rowe [11] reported four nonunions out of 566 patients. These findings have dominated the clinical approach for displaced clavicular fractures for a long time. However, more recent studies showed much higher nonunion rates and unsatisfactory functional outcomes [2,4,8,12,13].

Open reduction and internal fixation has gradually been recognized as an effective treatment for displaced or shortened (>2 cm) mid-shaft clavicular fractures [4,12]. Plating has been considered the gold standard for operative treatment of displaced mid-shaft clavicular fractures for decades. Various types of plates are commonly used. Reconstruction plates are easier to contour to fit the irregular curve of the clavicle, which promotes bone healing [14,15]. Plating has advantages of rigid fixation and improved rotational stability that may offer a superior construct for highly comminuted fractures. However, it requires large incisions and extensive soft-tissue dissection, which could cause complications such as infection, scarring and refracture after plate removal [16].

Intramedullary fixation provides an alternative and less invasive technique for plating of mid-shaft clavicular fractures. Various types of pins – for example, screws, Kirschner wires, Rockwood pins, Hagie pins and threaded pins – have been widely studied. The main advantages of intramedullary pinning are less soft-tissue dissection and a more cosmetic scar. However, the main disadvantages of this technique are hardware migration and concerns about early mobilization [8].

In the meta-analysis of Zolowodzki *et al.* [12], the nonunion rate is 5.9% for fractures treated nonoperatively, 2.5% for fractures treated with a plate and 1.6% for fractures treated with an intramedullary pin. Intramedullary nailing was used for a long time with good results. In a prospective nonrandomized study, Lee *et al.* [17] compared 56 patients treated with Knowles pins and 32 patients treated by plate. Shoulder score, union rate and healing time were not significantly different between the two groups, leading the authors to propose pinning rather than plating [17]. Chu *et al.* [18] noted a 100% union rate and a constant score of 97% from 73 cases treated with Knowles pins reported at 1-year follow-up.

Titanium EIN was initially used in the paediatric fracture treatment with good functional results that led to its use for treatment of adult fractures. In contrast to screws, Kirschner wires or pins, the titanium elastic nail is flexible with a curved tip that is fixed in the cancellous bone of the lateral clavicle. This helps it to accommodate the S-shaped contour of the clavicle and adhere tightly to the cortex. From a biomechanical point of view, intramedullary positioning of the implant is ideal. The three-point stabilization and

Table 6 Correlations with satisfactory outcome

	Satisfaction rate	Age (years)	Mechanical rate of injury	Post-traumatic shortening	Fracture healing (weeks)	Posthealing shortening	Implant removal (weeks)
Satisfaction rate							
Pearson's correlation	1	–0.142	0.094	0.451**	0.545**	0.598**	0.484**
Significance (one-tailed)	–	0.204	0.293	0.003	0.000	0.000	0.001
N	36	36	36	36	34	36	36
Age (years)							
Pearson's correlation	–0.142	1	–0.338*	0.180	–0.023	0.201	0.119
Significance (one-tailed)	0.204	–	0.022	0.147	0.448	0.120	0.245
N	36	36	36	36	34	36	36
Mechanical rate of injury							
Pearson's correlation	0.094	–0.338*	1	0.218	0.402**	0.181	0.221
Significance (one-tailed)	0.293	0.022	–	0.101	0.009	0.145	0.098
N	36	36	36	36	34	36	36
Post-traumatic shortening							
Pearson's correlation	0.451**	0.180	0.218	1	0.553**	0.903**	0.612**
Significance (one-tailed)	0.003	0.147	0.101	–	0.000	0.000	0.000
N	36	36	36	36	34	36	36
Fracture healing (weeks)							
Pearson's correlation	0.545**	–0.023	0.402**	0.553**	1	0.694**	0.969**
Significance (one-tailed)	0.000	0.448	0.009	0.000	–	0.000	0.000
N	34	34	34	34	34	34	34
Posthealing shortening							
Pearson's correlation	0.598**	0.201	0.181	0.903**	0.694**	1	0.742**
Significance (one-tailed)	0.000	0.120	0.145	0.000	0.000	–	0.000
N	36	36	36	36	34	36	36
Implant removal (weeks)							
Pearson's correlation	0.484**	0.119	0.221	0.612**	0.969**	0.742**	1
Significance (one-tailed)	0.001	0.245	0.098	0.000	0.000	0.000	–
N	36	36	36	36	34	36	36

*Correlation is significant at the 0.05 level (one-tailed). **Correlation is significant at the 0.01 level (one-tailed).

the curved tip of the EIN could provide a better antibending and antitorsion load and decrease the occurrence of hardware migration [7].

In the series from Jubel *et al.* [6], all fractures treated with elastic stable intramedullary nailing united and the constant score was 98% 1-year after surgery. However, the authors proposed the nail only for transverse or oblique fractures or for wedge fractures. Whenever comminution is present, they proposed plating rather than nailing [6].

Our data show that the patient satisfaction (77.8%) and complication rate (16.7%) at a mean of 29.5 months after limited open reduction and EIN of mid-shaft clavicular fractures are acceptable. However, based on our experience, the key advantage of EIN with limited odd ratio is that it allows for a functional fracture healing (9.3±5.3 weeks) mainly because of restoration of clavicular length (22% improvement). The flexible minimally invasive stabilization of simple or wedge fracture allows for adequate quick healing (simple =5.6±2 weeks, wedge=11±3 weeks) with satisfactory restoration of clavicular length (simple=62.4% improvement, wedge=22.8% improvement) that correlates with shoulder function. However, for the comminuted fractures, we had a longer healing time (13.2±6.5 weeks) and failure to maintain clavicular length (2.8% loss of length). The two cases of nonunion in this series occurred in comminuted fracture type.

The periosteal blood supply might remain intact in simple and wedge fractures. Increasing stability using EIN in a biologically favourable environment might lead to a significant faster osseous union and lower rates of nonunion, which was observed in our study. On the other hand, in comminuted fracture type, postoperative telescoping does not stop until the lateral main fragments gets into contact with the medial main one. These comminuted fractures are typically caused by high-energy trauma and are associated with a higher degree of soft-tissue damage and impairment of the periosteal blood supply. We agree with Jubel *et al.* [6] that surgical stabilization by plating is to be considered for comminuted fractures to provide stability and maintain clavicular length and endosteal blood supply.The rate of nail migration in our series was 5.6%. The rate of hardware migration of EIN in the literature is between 4.5 and 26.6% [6,19,20]. Usually, the nail is cut at the medial insertion site. In our operation, the end of the nail was bent 90°–180° and cut off. Thus, a 1–2 cm bending end was buried subcutaneously at the anteroinferior cortex to avoid being covered with bone (Fig. 2). This bending serves to prevent lateral migration, greatly reduces skin irritation and the nail could be removed with local anaesthesia alone. With full motion of the shoulder girdle, the clavicle moves cranially 30°, dorsally 35° and rotates about 50° [7]. Therefore, as also suggested by Frigg *et al.* [8], we restricted the range of motion to 90° for the first 4 weeks. This helps to decrease the nail migration and to maintain the stability.

There are some limitations of the study that should be considered. The number of patients is relatively small (36 patients), and the mean follow-up time is only 29.5 months. We realize that a larger and a long-term study would appropriately address these issues. With these issues in mind, we believe that the treatment protocol in this study improved the quality of life in the majority of patients (28/36; 77.8%).

Conclusion

The treatment of displaced mid-clavicular fractures in adults with limited open reduction and internal fixation with EIN is a safe and minimally invasive surgical procedure. A high bone union rate and favourable patient satisfaction can be obtained with few complications. In comminuted fractures, however, EIN does not provide the needed stability to restore clavicular length.

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Conflicts of interest

There are no conflicts of interest.

References

1 Robinson CM. Fractures of the clavicle in the adult. Epidemiology and classification. J Bone Joint Surg Br 1998; 80:476–484.

2 McKee MD. Clavicle fractures in 2010: sling/swathe or open reduction and internal fixation? Orthop Clin North Am 2010; 41:225–231.

3 Simon P. Fractures and non-unions of the clavicle. In: Bentley G, editor. European instructional lectures. Vol. 9. Vienna, Austria: EFORT; 2009. pp. 75–80.

4 Hill J, McGuire M, Crosby L. Closed treatment of displaced middle-third fractures of the clavicle gives poor results. J Bone Joint Surg Br 1997; 79:537–539.

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; 88:35–40.

6 Jubel A, Andermahr J, Schiffer G, Tsironis K, Rehm KE. Elastic stable intramedullary nailing of midclavicular fractures with a titanium nail. Clin Orthop Relat Res 2003; 408:279–285.

7 Chen YF, Wei HF, Zhang C, Zeng BF, Zhang CQ, Xue JF, *et al.* Retrospective comparison of titanium elastic nail (TEN) and reconstruction plate repair of displaced midshaft clavicular fractures. J Shoulder Elbow Surg 2012; 21:495–501.

8 Frigg A, Rillmann P, Perren T, Gerber M, Ryf C. Intramedullary nailing of the clavicular midshaft fractures with titanium elastic nail: problems and complications. Am J Sports Med 2009; 37:352–359.

9 Ledger M, Leeks N, Ackland T, Wang A. Short malunions of the clavicle: an anatomic and functional study. J Shoulder Elbow Surg 2005; 14:349–354.

10 Neer CS 2nd. Nonunion of the clavicle. J Am Med Assoc 1960; 172:1006–1011.

11 Rowe CR. An atlas of anatomy and treatment of midclavicular fractures. Clin Orthop Relat Res 1968; 58:29–42.

12 Zolowodzki M, Zelle BA, Cole PA, Jeray K, McKee MD, Orthopaedic Trauma Working Group. Treatment of acute midshaft clavicle fractures: systematic review of 2144 fractures: on behalf of the evidence-based Orthopaedic Trauma Working Group. J Orthop Trauma 2005; 19:504–507.

13 Brinker MR, Edwards TB, O'Connor DP. Estimating the risk nonunion following nonoperative treatment of a clavicular fracture. J Bone Joint Surg Am 2005; 87:676–677.

14 Terjesen T, Aplalset K. The influence of different degrees of stiffness of fixation plates on experimental bone healing. J Orthop Res 1988; 6:293–299.

15 Shahid R, Mushtaq A, Maqsood M. Plate fixation of clavicle fractures: a comparative study between reconstruction plate and dynamic compression plate. Acta Orthop Belg 2007; 73:170–174.

16 Wu CC, Shih CH, Chen WJ, Tai CL. Treatment of clavicular aseptic nonunion: comparison of plating and intramedullary nailing techniques. J Trauma 1998; 45:512–516.

17 Lee YS, Huang HL, Lo TY, Hsieh YF, Huang CR. Surgical treatment of midclavicular fractures: a prospective comparison of Knowles pinning and plate fixation. Int Orthop 2008; 32:541–545.

18 Chu CM, Wang SJ, Lin LC. Fixation of mid-third clavicular fractures with Knowles pins: 78 patients followed for 2–7 years. Acta Orthop Scand 2002; 73:134–139.

19 Kettler M, Schieker M, Braunstein V, König M, Mutschler W. Flexible intramedullary nailing for stabilization of displaced midshaft clavicle fractures: technique and results in 87 patients. Acta Orthop 2007; 78:424–429.

20 Meier C, Grueninger P, Platz A. Elastic stable intramedullary nailing for midclavicular fractures in athletes: indications, technical pitfalls and early results. Acta Orthop Belg 2006; 72:269–275.