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Fixation of Displaced Midshaft Clavicular Fracture in Adult by Intramedullary Elastic Rod

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ABSTRACT

Background: Intramedullary elastic rod fixation of midshaft clavicular fracture results in rapid free movement of the shoulder and an earlier return to daily activities than the conservative treatment. In comparison with plate fixation, the procedure is less invasive, with no loss of fracture haematoma, rapid union, and less infection. No major surgery for removal with less injury to surrounded neurovascular structures. A smaller incision is required with superior cosmesis. **Objective:** To study the short-term results of treatment of displaced fractures of the middle third of the clavicle using percutaneous elastic intramedullary nails

Patient and Methods: This prospective study was carried out on twenty patients with displaced fractures of the middle third of the clavicle presented to the Hospital and treated by percutaneous elastic intramedullary rod between November 2019 and May 2020.

Results: At the end of the follow-up period, the mean score was 89.70 ± 13.55 ranging from 48 to 100 according to the modified Constant and Murley shoulder score. Fourteen patients (70%) had excellent results, four patients (20%) had good results, one patient (5%) had a fair result, and one patient (5%) had a poor result.

Conclusion: Elastic stable intramedullary nailing (ESIN) is an image dependant procedure indicated best for young medically free patients with acute simple 2 part middle third clavicle fracture. Delay in surgery may necessitate open reduction. Hammering is not recommended to avoid dorsolateral cortex perforation.

Keywords: Midshaft clavicular fracture, Elastic rod, Minimally invasive fixation.

INTRODUCTION

Fracture of the clavicle is considered as one of the most common fractures in adults constituting about 5-10% of all fractures in adults, and 35% to 45% of shoulder girdle injuries. These injuries are most common in younger patients, often associated with direct or indirect trauma to the clavicle [1, 2].

Midshaft clavicular fractures constituting (80%) of all clavicular fractures, followed by lateral third fractures (12% to 15%) and lastly medial third fractures (5% to 6%) [3].

Midshaft clavicular fractures have been treated conservatively, but high-quality randomized studies have recently begun to change the evidence-based management of these fractures toward operative fixation [4].

Although healing and functional outcomes are generally good with conservative treatment for midshaft clavicular fractures, bad cosmetic results due to shortening and angulation are not uncommon [1, 5]. Nonunion rate about 5% with conservative treatment [5, 6]. Moreover, with clavicular shortening of 1-2 cm after conservative treatment, there is a decrease in shoulder function [5, 7]. Although the mild functional decrease is well tolerated by most patients, restoration of clavicular length and full functional recovery of the shoulder is of great importance for athletic patients [5]. Plate osteosynthesis is the standard operative treatment for a midshaft clavicular fracture, but higher complication rates have been described with this technique like hematoma, infection, nonunion, and implant failure [8].

In this study, we analyzed the clinical and radiological results of fixation of displaced midshaft clavicular fractures in 20 patients, by elastic stable intramedullary nailing (ESIN) used by a minimally invasive procedure. This work aimed to study the short term results of treatment of displaced fractures of the middle third of the clavicle using percutaneous elastic intramedullary nails.

PATIENTS AND METHODS

This prospective case series study was done in Al-Azhar University Hospital (Assiut) between November 2019 and May 2020 on 20 patients. The patients had isolated displaced midshaft clavicular fractures. The mean age of patients was 26.4 (18 to 65 years) about 3 females and 17 males who came with a history of trauma of less than 2 weeks duration.

Inclusion criteria: Age above 18 and below 65 years. The duration was less than 2 weeks, and displaced or angulated mid-shaft fracture with shortening and axial malalignment.

Exclusion criteria: Duration of trauma more than 2 weeks, presence of medical comorbidity, pre-existent morbidity of the ipsilateral arm, shoulder or hand, presence of neurovascular injury, and pathological fractures.

Ethical consent:

An approval of the study was obtained from Al-Azhar University academic and ethical committee. Every patient signed an informed written consent for acceptance of the operation. This work has been carried out in accordance with The Code of Ethics

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of the World Medical Association (Declaration of Helsinki) for studies involving humans.

Radiographic studies:

The diagnosis of clavicular fractures usually done through antero-posterior (AP) radiograph. In the emergency room, the surgeon may be given a supine AP chest radiograph as the only diagnostic study. However to visualize the fracture pattern and displacement, an oblique radiograph with a 20° cephalic tilt is helpful, which brings the clavicular image away from the thoracic cage (Fig.1).

Fig. (1): Anteroposterior view with a cephalic tilt showing a midshaft clavicular fracture.

Surgical technique:

Surgery was performed with the patient under general anesthesia. The patient was placed on a radiolucent operating table in the semi setting (beach-chair) position with a small towel roll placed between the scapulae to provide an extension of the shoulder girdle. Prophylactic antibiotic prophylaxis (1st generation cephalosporin) was given half an hour before starting the operation. It is important to scrub the whole ipsilateral upper extremity to allow free manipulation of the shoulder and arm during surgery and to scrub the chest till the midline for the entry point. An image intensifier was used during the operation (Fig.2)

Fig. (2): The patient is placed on a radiolucent operating table in the beach-chair position with an image intensifier from behind.

Skin incision:

A short skin incision of about 1 cm was made just lateral to the sternoclavicular joint centered above the medial end of the clavicle localised by image intensifier (Fig. 3, 4, 5).

Fig. (3): The skin incision was localized about 1cm lateral to the sternoclavicular joint.

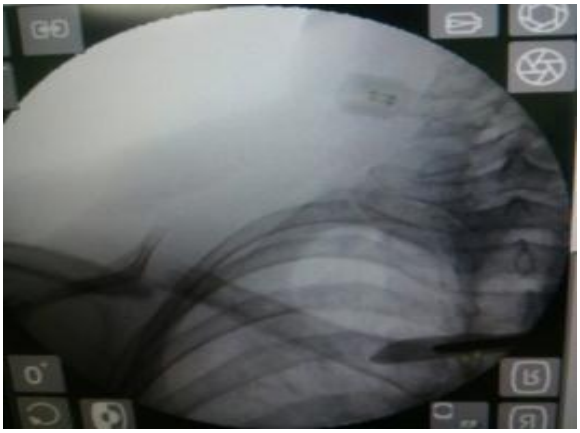

Fig. (4): Skin incision localized by the image intensifier.

Fig. (5): Short skin incision.

Procedure:

The medullary cavity of the clavicle was opened using an awl about 1 cm lateral to the sternoclavicular joint. The awl was pointed laterally in-line with the clavicle and angled at about 30° to the coronal plane. Care was taken not to perforate the dorsal cortex to avoid major complications (fig.6).

Fig. (6): The medullary cavity of the clavicle was opened using an awl.

Once the medullary cavity was opened, an elastic intramedullary nail (ESIN) was carefully inserted. The implanted nails had diameters between 2.0 and 3.0 mm according to the patient's dimensions. The nail was fixed in a universal chuck with a T handle and advanced with oscillating movements till it reached the fracture site (fig.7).

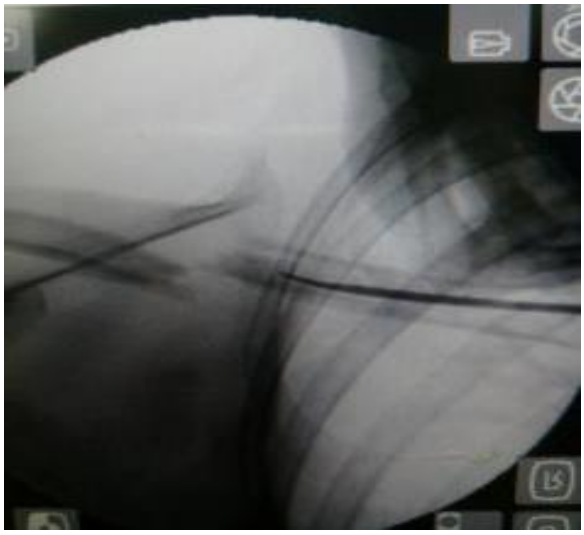

Fig. (7): ESIN reached the fracture site

Once the nail reached the fracture site closed reduction by direct pressure on the fragments combined with manipulation of the arm was performed. Usually, the reduction was facilitated when a small pointed reduction forceps were applied percutaneously to the lateral fragment (fig.8).

Fig. (8): A small pointed reduction forceps was applied percutaneously to the lateral fragment.

In 6 patients closed reduction could not be achieved. In these patients, a short incision directly over the fracture site (2 cm) with minimal dissection (to avoid injury of the supraclavicular nerve) was performed to reduce the fracture (fig.9).

Fig. (9): A small incision over fracture site showing supraclavicular nerve.

Then the nail was pushed into the lateral part of the clavicle close to its extremity. Care was taken to avoid perforation of the dorsolateral cortex of the lateral clavicle (fig.10). The protruding medial end of the nail was left out of the cortex and shortened close to its entry point into the bone followed by wound closure (fig.11).

Fig. (10): The nail was then pushed into the lateral part of the clavicle close to its extremity.

Fig. (11): Medial end of a nail cut close to its entry point into the bone.

A single simple interrupted suture using 3-0 prolene was used to close the skin. In case of open reduction, a standard closure of the other wound was then performed in layers using 2-0 absorbable sutures for the myofascia and subcutaneous tissue then subcuticular stitch for the skin. After the surgery, the patient was placed in a sling for 2 weeks. Sutures were removed after 2 weeks. The postoperative exercise started 2 weeks postoperatively in the form of passive and active shoulder motion. Immediate postoperative X-ray was done, then after one and half months then every month till union.

Follow up:

Clinical outcomes were assessed after 3 months using A modified Constant and Murley Score (CMS) [9], then done every 6 months up to 2 years. Removal of the nails was done after 1 year of surgery. There were 6 patients with complications in this study; one patient developed an incisional infection, 2 patients developed medial end skin irritation, one of them had to remove the nail, while the other improved within 2 weeks of medical treatment, 2 patients presented with dorsolateral migration of the nail, which was followed up until removal of the nail. Lastly, one patient presented with hypertrophic non-union and had to be revised by platting.

Statistical analysis

The collected data were coded, processed and analyzed using the SPSS (Statistical Package for Social Sciences) version 22 for Windows® (IBM SPSS Inc., Chicago, IL, USA). Data were tested for normal distribution using the Shapiro Walk test. Qualitative data were represented as frequencies and relative percentages. Chi square test ($\chi 2$) to calculate difference between two or more groups of qualitative variables. Quantitative data were expressed as mean ± SD (Standard deviation). Independent samples t-test was used to compare between two independent groups of normally distributed variables (parametric data). P value ≤ 0.05 was considered significant.

RESULTS

At the end of the follow-up period, the mean score was 89.70 ± 13.55 ranging from 48 to 100 according to the modified Constant and Murley shoulder score. Fourteen patients (70%) had excellent results, four patients (20%) had good results, one patient (5%) had a fair result, and one patient (5%) had poor results (Table 1).

Table (1): Distribution of the studied patients regarding the final score according to a modified Constant and Murley score

Final score	No.	%
Excellent (91 - 100)	14	70.0
Good (75 - 90)	4	20.0
Fair (60 - 74)	1	5.0
Poor (< 60)	1	5.0
Min. – Max.	48.0 – 100.0	
Mean ± SD.	89.70 ± 13.55	

Pain: At the end of the follow-up period, the mean final constant score for pain was 14.50 ± 2.24 ranging from 5 to 15 (Table 2).

Table (2): Distribution of the studied patients regarding pain

Pain	No.	%
None	19	95.0
Moderate	1	5.0
Min. – Max.	5.0 – 15.0	
Mean ± SD.	14.50 ± 2.24	

The activity of daily living: At the end of the follow-up period, the mean final Constant score for the activity of daily living was 18.80 ± 3.69 ranging from 8 to 20 (Table 3).

Table (3): Distribution of the studied patients regarding the activity of daily living

Activity of Daily Living	No.	%
Activity level		
Full work	18	90.0
Full recreation/sport	18	90.0
Unaffected sleep	20	100.0
Positioning		
Up to neck	2	10.0
Above head	18	90.0
Min. – Max.	8.0 – 20.0	
Mean ± SD.	18.80 ± 3.69	

Range of motion:

1- **Active forward flexion:** At the end of the follow-up period, the mean final Constant score for active forward flexion was 9.60 ± 1.39 (145-174°) ranging from 4 to 10 (Table 4).

Table (4): Distribution of the studied patients regarding active forward flexion.

Active forward flexion	No.	%
61-90°	1	5.0
121-150°	1	5.0
151-180°	18	90.0
Min. – Max.	4.0 – 10.0	
Mean ± SD.	9.60 ± 1.39	

2- Active Abduction: At the end of the follow-up period, the mean final Constant score for active abduction was 9.60 ± 1.39 (145-174°) ranging from 4 to 10 (Table 5).

Table (5): Distribution of the studied patients regarding active abduction.

Active abduction	No.	%
61-90°	1	5.0
121-150°	1	5.0
151-180°	18	90.0
Min. – Max.	4.0 – 10.0	
Mean ± SD.	9.60 ± 1.39	

3- Active external rotation: At the end of the follow-up period, the mean final Constant score for active external rotation was 9.60 ± 1.23 ranging from 6 to 10 (Table 6).

Table (6): Distribution of the studied patients regarding active external rotation.

Active external rotation	No.	%
Hand on top of the head with the elbow held forward	2	10.0
Full elevation from on top of the head	18	90.0
Min. – Max.	6.0 – 10.0	
Mean ± SD.	9.60 ± 1.23	

4- Active internal rotation: At the end of the follow-up period, the mean final Constant score for active internal rotation was 9.60 ± 1.23 ranging from 6 to 10 (Table 7).

Table (7): Distribution of the studied patients regarding active internal rotation.

Active internal rotation	No.	%
Dorsum of hand to waist (3rd lumbar vertebra)	2	10.0
Dorsum of hand to interscapular region (DV 7)	18	90.0
Min. – Max.	6.0 – 10.0	
Mean ± SD.	9.60 ± 1.23	

Strength: At the end of the follow-up period, the mean final constant score for strength was 24.0 ± 3.08 ranging from 15 to 25.

Union: Time of union in the studied patients ranged from 8 weeks to 12 weeks with a mean of 10.0 ± 1.33 weeks with an exception of one patient, which presented with hypertrophic non-union (Table 8).

Table (8): Distribution of the studied patients regarding union.

Union (weeks)	No.	%
Non union	1	5.0
Union	19	95.0
Min. – Max.(n=19)	8.0 – 12.0	
Mean ± SD.	10.0 ± 1.33	

DISCUSSION

A clavicle fracture is a common traumatic injury that comprises about 45% of shoulder girdle injuries and 5% of all skeletal injuries [(1)]. A direct blow on the point of the shoulder is the most commonly reported mechanism of injury [(2)].

Fractures of the clavicle are classified according to its localization as middle, lateral and medial third fractures. The Middle third being first in the frequency of occurrence approximately 80% of clavicle fractures. Middle third clavicle fractures are further classified into two types with two subtypes: A) Cortical alignment, which is subdivided into A1: Non-displaced and A2: Angulated, B) Displaced, which is subdivided into B1: Simple or single butterfly fragment and B2: Comminuted or segmental minimally displaced [(10)].

Weight of the arm, pectoralis major, pectoralis minor, latissimus dorsi, trapezius, and scapular motions act on the fracture site to impair union in displaced fractures. Non-operative treatment may result in delayed or non-union [(11)]. Many authors advocated the primary surgical treatment of displaced injuries. Imminent perforation of the skin, impending or existing neurovascular compromise, and the floating shoulder represent absolute indications for operative treatment. Gross displacement of fracture fragments, as well as non-unions, are seen as relative indications for surgical fixation [(2)]. Plate osteosynthesis is the standard operative treatment. Currently, the implants most commonly used are either dynamic compression or locking plates. Reconstruction plates have fallen into disfavor, since they are susceptible to deformity at the fracture site, leading to mal-union. Site-specific pre-contoured locking plates have recently been introduced, and they are less prominent after healing, leading to lower rates of hardware removal after union [(12)]. The complications related to the use of plate fixation are infection, plate failure, hypertrophic scars, implant loosening, non-union, refracture after plate

removal, and very rarely intraoperative vascular injury [13].

A variety of intramedullary devices including Knowles pins, Kirschener wires, Hagie pins, and Rockwood pins have been used [14]. Implant migration with fatal complications, implant failure, and mal- and non-unions have been mentioned as complications [15].

In some comparative studies between EISN and plate fixation for midshaft clavicular fractures, although they showed better functional results in plate group in the first 2 months, after 2 years there were no significant differences between the two groups regarding functional results. They concluded that EISN is a safe, minimally invasive surgical technique with a lower complication rate, excellent cosmetic and comparable functional results, and can be used as an equally effective alternative to plate fixation in displaced non-comminuted midshaft clavicle fractures [16, 17].

Assobhi [9] treated 38 patients randomly by either plating (plate group) or titanium elastic nailing (TEN group). Results were similar between the two groups after the 12th week. However, earlier union and functional recovery were obtained in the 6th week for the TEN group. The rate of complications was significantly higher (15.8%) in the plate group compared with the TEN group (0%). The conclusion is that the TEN technique has more advantages and lower complications than plating making its use to be more favorable. It is recommended for athletes and young active individuals [9].

Hartmann *et al.* [18] studied 15 cases with fractures of the clavicle treated by elastic intramedullary nailing. The mean follow-up time was one year. All fractures healed clinically and radiologically. Non-union or infections were not observed. Functional results according to the Constant score were excellent. As a conclusion, the operative treatment of displaced midclavicular fractures with ESIN results in an excellent functional outcome. This technique provides more rapid free movement of the shoulder and an earlier return to daily activities than conservative treatment.

Meier *et al.* [5] case series was done to evaluate indications, technical pitfalls, and functional outcome of elastic stable intramedullary nailing of displaced midclavicular fractures in 14 athletes. When the operation was delayed for more than 7 days closed reduction was never achieved suggesting that patients benefit from early intervention. In one case the dorsolateral cortex was perforated when the EISN was advanced to the lateral end of the clavicle using a hammer with force. As this problem was realized during the procedure the Titanium nail was withdrawn a few centimeters and repositioned. They do not recommend using a hammer anymore. A smaller implant should be chosen if it is not possible to advance the nail by oscillating movements only.

In this study, 20 patients were included with a mean age of 26.40 ± 8.91 years, 17 patients (85%) were males and 3 patients (15%) were females. The time-lapse before surgery in the studied patients ranged from 1 day to 10 days with a mean 4.60 ± 2.93 day. Open reduction was done in 6 cases (30%) out of 20 cases after a failed closed reduction of the fracture. Time of union in the studied patients ranged from 8 weeks to 12 weeks with a mean 10.0 ± 1.33 weeks with an exception of one case presented with hypertrophic non-union.

The final Constant score after 6 months was 95.70 ± 13.55. 14 patients had excellent results, 4 patients had good results, 1 patient had a fair result and 1 patient had poor results. In comparison, **Narsaria *et al.*** [16] study showed a higher score for the plating group, while **Assobhi** [9] showed a higher score with the nailing group. However, both documented no significant difference between the two groups regarding functional and radiological outcomes at the 2-year follow-up. **Meier *et al.*** [5] case series showed constant shoulder score averaged 81 after 7 days. After 6 months and after hardware removal, all patients (n = 13) presented with basically normal shoulder function (mean: 98, range: 93 to 100).

Regarding pain, it was moderate in one patient (5%) and no pain in 19 patients (95%). Similar results were reported in **Assobhi** [9] study for TEN group in the first 6 weeks of follow up, while the pain was equal in both groups (plate and TEN) after 12 weeks.

Time of union in the studied patients ranged from 8 weeks to 12 weeks with a mean of 10.0 ± 1.33 weeks with an exception of one case, which started hard work after 2 weeks. He presented with hypertrophic non-union and went through revision by nail removal and fixation by plate and screws. In **Hartmann *et al.*** [18] study, fracture healing was assessed with a mean follow-up time of one year. All fractures healed clinically and radiologically between 8-11 weeks. Non-union was not observed. While, **Kettler *et al.*** [8] in their case series showed nonunion in 2 patients. In **Keihan *et al.*** [19] case study, clinical union was achieved in 3-5 weeks and radiographic union appeared in 6-12 weeks.

There were 6 patients with complications in this study; one patient (5%) developed an incisional infection and 2 patients (10%) developed medial end skin irritation, one of them had to remove the nail, while the other improved within 2 weeks of medical treatment. Furthermore, 2 patients (10%) presented with dorsolateral migration of the nail, which was followed up until removal of the nail. This can be explained as during insertion of the nail in these two patients the dorsolateral cortex was perforated, so even if it was noticed during surgery and the nail was retracted and repositioned mostly it will migrate in the old track. Lastly, one patient (5%) presented with hypertrophic non-union and had to be revised by

platting. In **Kettler *et al.* [8]** case study only 6 patients out of 87 complained of irritation or scar formation at the medial entry point. In 2 cases, the protruding end of the nail at the medial side irritated. In 2 patients, the nail missed the medullary canal of the lateral fragment. One patient underwent a second operation to reintroduce the nail and the other refused a further operation and the fracture healed with a slight malunion.

Lastly, **Hartmann *et al.* [18]** showed that there were 5 patients with complications and four patients suffered from skin irritation and pain at the sternal end of the clavicle 1 to 4 months after the operation. In three cases, the prominent medial end of the TEN was shortened, in one case the TEN was removed early (5 months after the operative treatment) [18].

The limitation of this study was the limited number and lack of comparative study with other methods of treatment.

CONCLUSION

Elastic stable intramedullary nailing (ESIN) is an image dependant procedure indicated best for young medically free patients with acute simple 2 part middle third clavicle fracture. Delay in surgery may necessitate open reduction. Hammering is not recommended to avoid dorsolateral cortex perforation. The most common complication is medial skin irritation which may end in skin perforation and this is because of the subcutaneous position of the clavicle and the sharp end of the cut nail. Removal of the nail is required after a complete radiological union. The main advantage of this technique is providing a more rapid free movement of the shoulder and an earlier return to daily activities than in the conservative treatment. In comparison with plate fixation, the procedure is less invasive, with no loss of fracture haematoma, rapid union, and less infection. No major surgery for removal with less injury to surrounded neurovascular structures. A smaller incision is required with superior cosmesis.

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