Minimally invasive plate osteosynthesis in midshaft clavicular fracture in adults

Tarek M.A. Ghaffar, Emad M. Zayed, Mohamed M. Salem, Abdel H.A. Massaod

Department of Orthopaedic Surgery, Faculty of Medicine, Al Azhar University, Cairo, Egypt

Correspondence to Emad M. Zayed, MD, Al Hussein Hospital, Al Azhar University, Cairo, Egypt Tel: +20 225 128 927; e-mails: emadabdou36@yahoo.com, mohamed_salem9188@yahoo.com

Received: 14 September 2018
Revised: 3 October 2018
Accepted: 22 October 2018
Published: 12 August 2021

The Egyptian Orthopaedic Journal 2020, 55:225–235

Background

Clavicle fractures are common injuries in adults, accounting for 5–12% of all fractures and 44% of all shoulder fractures. Fracture of the middle third is the most common fracture in both children and adults. It is ~80% of clavicle fractures; proximal and distal segments are secured by ligamentous and muscular attachments. Poor outcomes from conservative treatment, including nonunion, malunion, or shortening of the clavicle in displaced or comminuted fractures, have prompted a shift in treatment to surgery. There has been a trend toward operative treatment of clavicle midshaft fractures. There are various methods for treating clavicle midshaft fractures, such as intramedullary K-wires or elastic stable intramedullary nailing and plate fixation. Minimally invasive percutaneous plate osteosynthesis technique may be a good alternative as it has been proven in other long bones.

Objective

This study is performed to address the technique of percutaneous plating and to evaluate the radiographic and clinical outcomes in midshaft fractures of the clavicle in adults treated with minimally invasive plate osteosynthesis (MIPO).

Patients and methods

From December 2015 to November 2017, this prospective case series study was done at Al Azhar University Hospitals. In our study, we present the outcomes of 17 patients (12 men and five women) with acute midshaft clavicular fractures who were treated with the MIPO technique with 3.5-mm superior reconstruction plates. The patients had a mean age of 27.76 years (range, 16–45 years). The left arm was affected in nine patients the right arm in eight patients. The fractures were classified using the Robinson classification system: 10 were type 2B1 and seven were type 2B2.

Results

Fracture union was obtained in all patients at a mean of 11.35±1.90 weeks (range, 8–15 weeks). No delayed unions or nonunions were observed. There were no major complications such as infections, plate breakages, or neurovascular injuries. All of the patients obtained satisfactory shoulder functions. The mean Constant score was 97.47±2.45 (range, 93–100), and the mean Disability of the Arm, Shoulder, and Hand score was 1.29±1.93 (range, 0–5) at the last control visit.

Conclusion

This study demonstrated that the MIPO procedure that uses superior 3.5-mm reconstruction plates for midshaft clavicular fractures can be a reproducible procedure and an alternative to conventional operative methods. In addition, satisfactory clinical and radiologic outcomes were obtained without serious complications. This technique can provide excellent biological healing and optimal stabilization strength.

Level of evidence

Level IV, case series, treatment study.

Keywords:
midshaft clavicular fracture, minimally invasive, plate osteosynthesis

Egypt Orthop J 55:225–235

1110-1148

Introduction

The clavicle provides the junction between the chest and the upper limb, receives the insertions of large muscles, and also has an integrated role in the mechanics of the shoulder girdle, upper extremity, and chest [1].

Clavicle fractures are common injuries in adults, accounting for 5–12% of all fractures and 44% of all shoulder fractures [2].

Clavicle fractures may be classified according to anatomic description, including location, displacement, angulation, pattern (e.g. greenstick, oblique, transverse), and comminution [3].

Fracture of the middle third is the most common fracture in both children and adults. It is ~80% of clavicle fractures; proximal and distal segments are secured by ligamentous and muscular attachments [4].

Most of the clavicular fractures occur in the midshaft. Clavicle midshaft fractures have classically been treated nonoperatively. However, factors including severity of displacement, degree of comminution, and greater than 2 cm of shortening have been reported in the literature to predispose patients to unsatisfactory outcomes with nonoperative treatment [5].

Poor outcomes from conservative treatment, including nonunion, malunion, or shortening of the clavicle in displaced or comminuted fractures have prompted a shift in treatment to surgery [6].

There has been a trend toward operative treatment of clavicle midshaft fractures. There are various methods for treating clavicle midshaft fractures, such as intramedullary K-wires or elastic stable intramedullary nailing and plate fixation. In particular, plate fixation can provide stable anatomical fixation and which can be bent to the S-shaped curvature of the clavicle, being the most preferred [7].

Minimally invasive percutaneous plate osteosynthesis technique may be a good alternative as it has been proven in other long bones. This technique can provide excellent biological healing and optimal stabilization strength. It has been associated with technical difficulties of reduction of the fracture and intraoperative maintenance [8].

Patients and methods

From December 2015 to November 2017, a prospective case series study was performed at Al Azhar University Hospital. The study was approved by the institutional ethics committee in the Orthopedic Department of Orthopaedic Surgery, Al Azhar University, Cairo, Egypt. A total of 17 patients with midshaft clavicular fractures were admitted to our treatment group.

Inclusion criteria were as follows:

(1) Patients who are skeletally mature.
(2) Patients with a displaced clavicular midshaft fracture (no cortical contact between medial and distal fragment and/or more than 2-cm shortening).
(3) Skin tensioning.

Exclusion criteria were as follows:

(1) Age more than 70 years.
(2) Fractures more than 3 weeks between the injury and the operation.
(3) Open fractures.
(4) Pathologic fractures.
(5) Bilateral clavicle fractures at the initial trauma.
(6) Presence of neurovascular compromise from the initial trauma.

Patient criteria

A total of 17 patients (12 men and five women) with acute midshaft clavicular fractures were treated with the minimally invasive plate osteosynthesis (MIPO) technique with 3.5-mm superior reconstruction plates. Patients had a mean age of 27.76 years (range, 16–45 years). The left arm was affected in nine patients and the right arm in eight patients. The fractures were classified using the Robinson classification system: 10 were type 2B1 and seven were type 2B2 (Table 1).

Surgical technique

The operation was done under general anesthesia. The patient was placed on a radiolucent table in the beach-chair position (Fig. 1).

Contouring of the plate

A 3.5-mm reconstruction plate was contoured to match the superior surface of the unaffected clavicle, considering individual differences in clavicular shapes. Plate length was based on the overall size of the fracture area on the preoperative clavicle caudal-tilt view. The plate should be long enough to fix at least three holes at each side of the fracture. So, we usually use a plate with nine or 10 holes (Fig. 2).

The plate bending occurred by special binder for side and front curvature of reconstruction plate, preventing hole distortion (Fig. 3).

If this binder was not available, we used a large ordinary binder, but hole distortion may have occurred (Fig. 4).

The plate bending sequence progresses from the lateral end of the clavicle. The second hole of one side

Table 1 Demographics and preoperative sheet

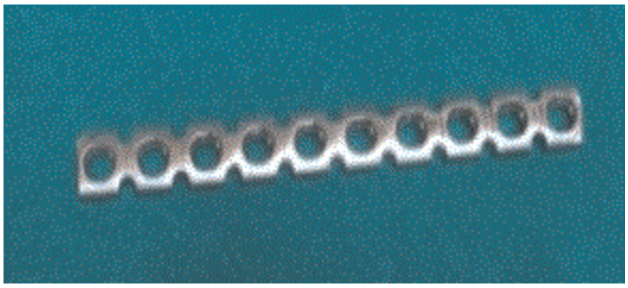
Number	Age	Sex	Side	Smoking	DM	Mode of trauma	Associated injury	Classification	Period before operation (days)
Case No 1	18	M	Rt	No	N o	Falling on ground	Non	2B1	7
Case No 2	17	M	Rt	No	No	RTA	Non	2B2	21
Case No 3	25	F	Lt	No	No	RTA	MTB	2B2	14
Case No 4	16	M	LT	No	No	Falling on ground	Non	2B1	3
Case No 5	19	M	Lt	No	No	RTA	Non	2B1	8
Case No 6	41	F	Lt	No	No	RTA	Non	2B2	4
Case No 7	19	M	Lt	No	No	Falling on ground	Non	2B2	5
Case No 8	38	M	RT	Yes	No	RTA	DR	2B2	5
Case No 9	25	M	Lt	Yes	No	RTA	Non	2B1	5
Case No 10	45	M	Lt	Yes	YES	Falling on ground	ULNA	2B1	4
Case No 11	29	M	Lt	Yes	No	RTA	MTB	2B1	7
Case No 12	20	F	Rt	No	No	RTA	Non	2B1	9
Case No 13	31	F	Rt	No	No	RTA	Non	2B1	4
Case No 14	41	M	RT	Yes	No	RTA	Non	2B1	5
Case No 15	19	M	Lt	No	No	Falling on ground	Non	2B1	4
Case No 16	30	f	RT	No	No	Falling on ground	Non	2B2	4
Case No 17	39	M	Rt	Yes	No	RTA	MANDIBLE	2B2	10

F, female; Lt, left; M, male; MTB, metatarsal bone; Rt, right; RTA, road traphic accident.

Figure 1

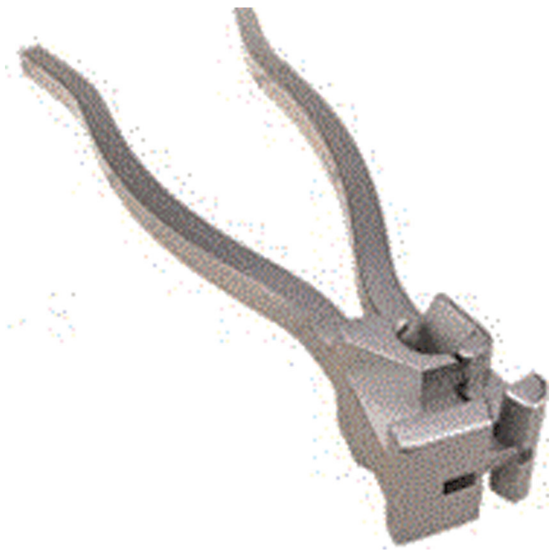
Beach-chair position of the patient.

Figure 2



3.5-mm reconstruction plate with 10 holes.

Figure 3



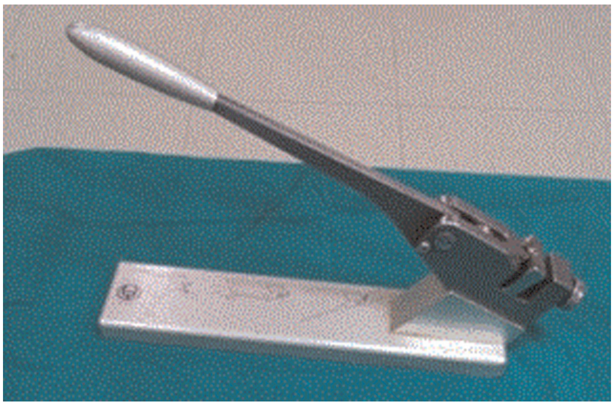
Pelvis arc 3.5 reconstruction plate bender.

of the plate, which would be located laterally, was bent concavely to the third and fourth hole, and that point was slightly bent to match the contour of the superior surface of the lateral clavicle (Fig. 5).

The lateral bent portion of the plate was aligned with the lateral curvature of clavicle so that the medial bending point of the plate could be determined based on the alignment between the plate and the medial convexity of the clavicle (Fig. 6).

The next step was to confirm whether the plate curvature fits the clavicle properly (Fig. 7).

Figure 4



Large bender (bone plate bender).

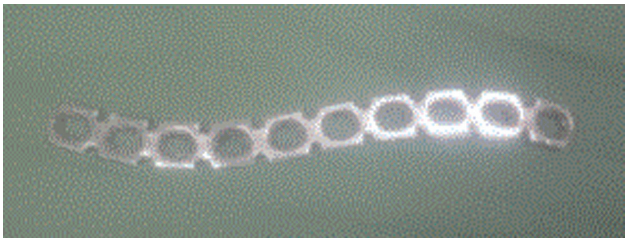
Figure 5

Bending of the plate from lateral end.

A fluoroscope was positioned at the contralateral side of the injured arm, perpendicular to the longitudinal axis of the table. The C-arm of the fluoroscope was placed to obtain anteroposterior view (Fig. 1). This will provide images for the reduction and proper plate positioning before fixation. The predraping images were acquired for all three views before skin preparation for an adequate intraoperative assessment. Then sterile draping was administered to the whole upper limb capable of being moved freely during operation.

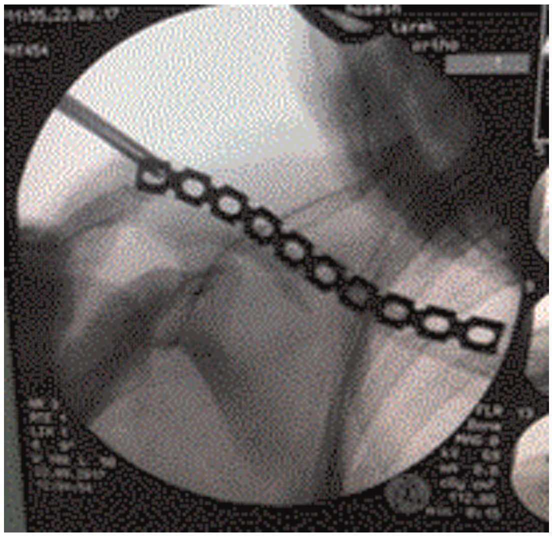
Anatomical landmarks, clavicle, fracture site, coracoid process, acromion, and A-C joint were identified and marked (Fig. 8).

Figure 6



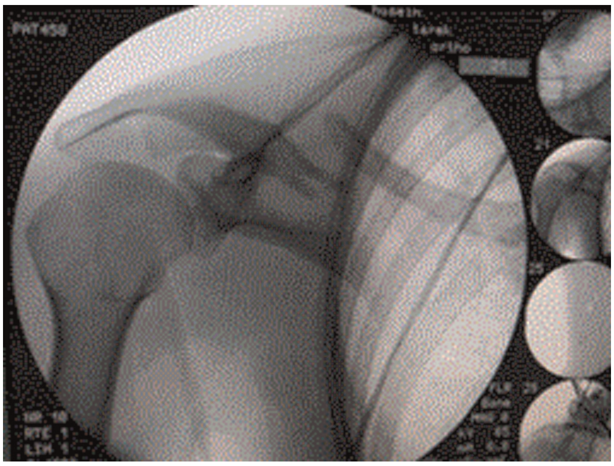
Contoured plate.

Figure 7



Confirmation whether the plate curvature fit the clavicle.

Figure 8



Identification of anatomical landmarks.

A 3-cm skin incision was made along the skin crease at the level of the second hole of the plate on the lateral fragment. A subcutaneous-supraperiosteal plane was created using a periosteal surfer along the superior surface of the clavicle from the lateral to medial fragment. A 2-cm lateral incision was first made along the superior border of the clavicle, and the dissection was extended between the trapezius and deltoid muscles to expose the superior surface of the clavicle. A blunt dissection was performed from the lateral to the medial side of the fracture with a periosteal elevator. The plate was inserted from the lateral access across the fracture area to the medial clavicle. Another 2-cm incision was made along the superior border of the medial clavicle (Fig. 9).

Cortical screws were inserted into two holes of the three lateral holes to closely attach the plate to the lateral region of the fracture on the superior border of the clavicle. The length of the cortical screws ranged from 16 to 18 mm and was confirmed by the measure.

After this procedure, the upper arm was retracted laterally and downward to reduce the fracture with the help of the trapezius and deltoid muscles' envelope. Meanwhile, the medial clavicular region was pushed by hand to close to lateral clavicular region for reduction.

Other cortical screws were inserted into three medial holes (Fig. 10).

The direction of drills is very important to avoid injury of neurovascular structures, especially subclavian vessels. The subclavian vein is very close to the medial third of the clavicle, and in some scans was even apposed to the posterior cortex. Therefore, in this zone, extreme caution should be exercised in drilling or tapping the clavicle. A craniocaudal direction for drills, taps, and screws is less likely to damage the vein (Fig. 11).

We do not drill the midshaft clavicle when we use the MIPO technique; therefore, we avoid injury of the subclavian vessels (Fig. 12).

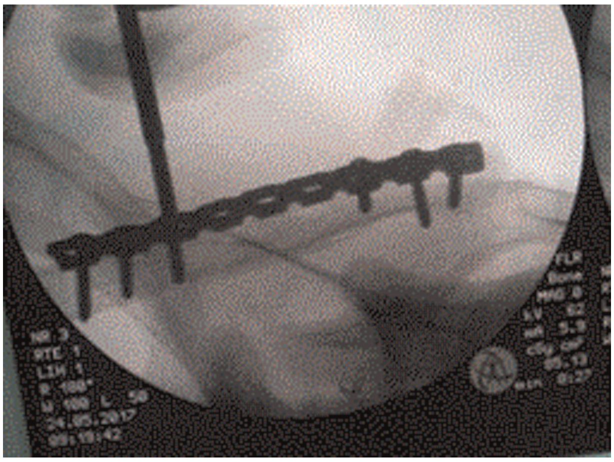
At the lateral end of the clavicle, subclavian vessels descend more acutely within the axilla, so drilling at lateral end of the clavicle is more or less safe.

We can use mini-incision over the fracture site open to ensure reduction by elevating the fragment by the Hohmann retractor (Fig. 13).

Figure 9

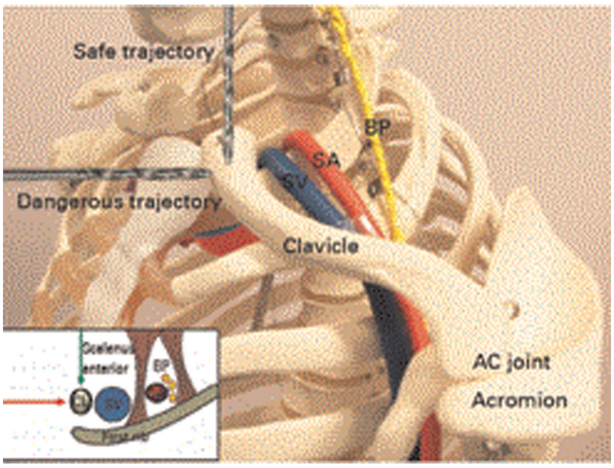
Medial and lateral incision.

Figure 10



Insertion of lateral and medial screws.

Figure 11



Photograph of a model showing the medial end of the clavicle and the subclavian vessels, with two drills showing anteroposterior and craniocaudal trajectories (SV, subclavian vein, SA, subclavian artery; BP, brachial plexus).

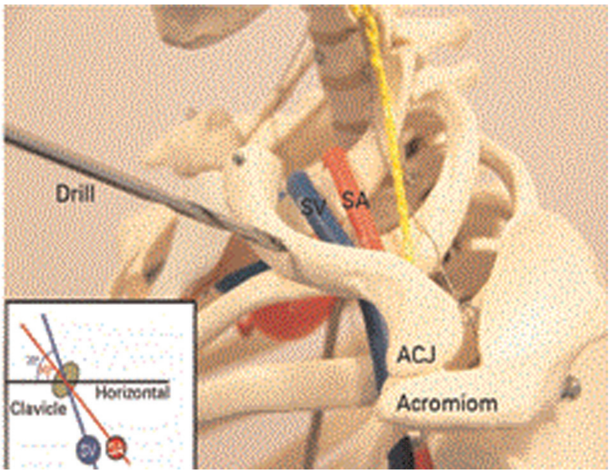
The Hohmann retractor is put subperiosteally to avoid injury of the neurovascular structures.

We can use towel forceps over fracture site through the skin for reduction (Fig. 14).

After the reduction procedure was finished, the reduction was confirmed with anteroposterior and 45 cephalic oblique radiographs (Fig. 15a, b).

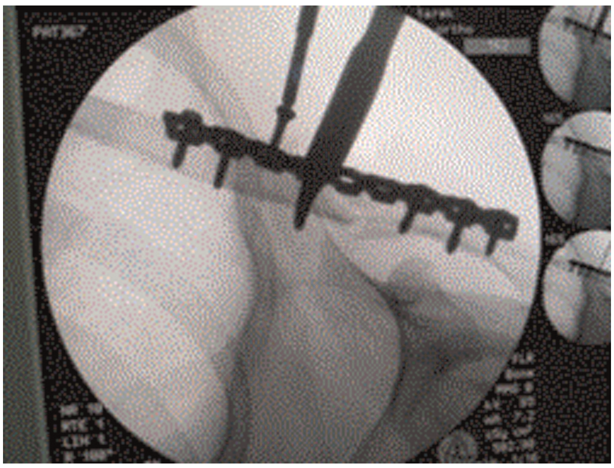
If an obvious free fragment remained, as observed in the 45° cephalic oblique radiograph, a towel forceps was used to reduce the fracture. If the length of the clavicle was not equal to other side, then the mentioned procedure was done again. After radiographic confirmation, the incision was closed (Fig. 16).

Figure 12



Photograph of a model showing a dangerous trajectory represented by a drill at middle one-third. Inset image shows the mean angles of the subclavian artery (SA) and vein (SV) with the horizontal in relation to the clavicle.

Figure 13



Use of Hohmann for reduction.

Rehabilitation

After surgery, patients were instructed to protect their shoulder with a sling for ~2 weeks, and within this period, pendulum mobilization of the shoulder joint was encouraged. Daily activities were allowed 4 weeks postoperatively. Weight lifting with the injured arm was forbidden until a bony union was observed.

Regular follow-up occurred at 4, 8, and 12 weeks postoperatively. Anteroposterior plain radiograph images of the clavicle were taken at follow-up. Union was defined as bony bridging between fracture fragments and confirmed by clinical manifestation, which consists of tenderness and shoulder joint function. Delayed union was defined as radiologically visible callus formation after 24 weeks, and no callus formation and pathologic movement after 24 weeks were accepted as nonunion [9]. The last clinical follow-up assessments were performed at a mean of 11.06±7.80 months (range, 3–24 months).

For clinical evaluations, the Constant score and the Disability of the Arm, Shoulder, and Hand score were assessed.

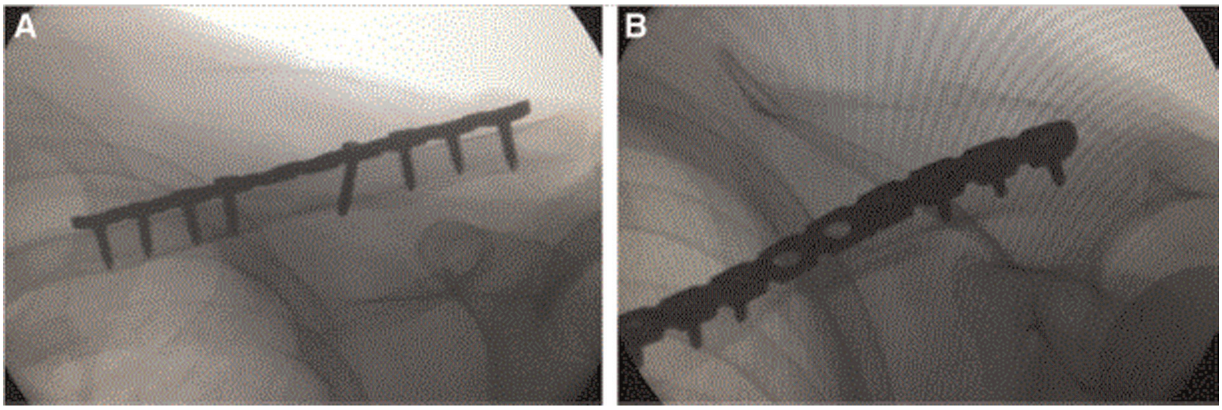
Results

The average operative time was 54.12±22.45 min (range, 25–90 min), with blood loss of 25±5 ml (range, 20–30 ml) during the operation. Fracture union was obtained in all patients at a mean of 11.35±1.90 weeks (range, 8–15 weeks). No delayed unions or nonunions were observed. There were no major complications, including infections, plate breakages, or neurovascular injuries. No skin

Figure 14

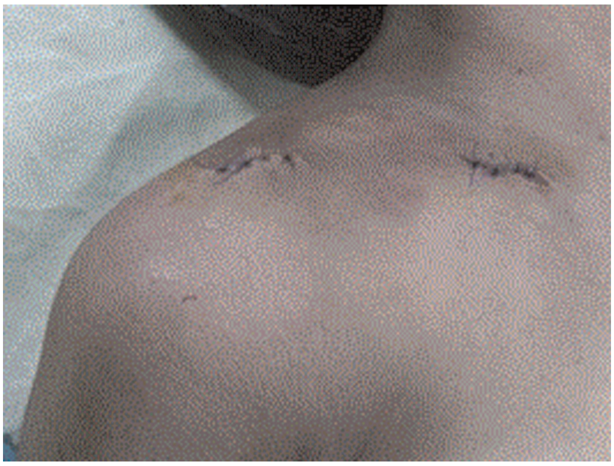
Use of towel clamps for reduction.

Figure 15



(a) Anteroposterior and (b) 45 cephalic oblique radiographs of the injured clavicle after the operation.

Figure 16



Closure of incision.

irritation was observed, and only three patients had prominent implant and one patient had bad scar. All of the patients obtained satisfactory shoulder functions. The mean Constant score was 97.47±2.45 (range, 93–100) and the mean Disability of the Arm, Shoulder and Hand score was 1.29±1.93 (range, 0–5) at the last control visit (Tables 2 and 3).

Discussion

Midshaft clavicular fractures have traditionally been treated nonoperatively, but recent studies have showed high nonunion, malunion, and poor shoulder function with nonoperatively managed displaced midshaft clavicular fractures.

Altamimi [10] compared plate fixation and nonoperative treatment for displaced midshaft clavicular fractures and found improved functional outcome and a lower rate of malunion and nonunion with plate fixation compared with nonoperative treatment at 1 year of follow-up in their clinical trial. Many other authors have also recommended open reduction internal fixation (ORIF) for displaced midshaft clavicular fractures, especially for those with shortening greater than 20 mm, total fracture displacement, and any displacement with comminution [11,12].

Canadian Orthopaedic Society reported a multicenter, prospective, randomized trial analyzing patients treated by ORIF versus nonoperative treatment, and level the evidence was Level I. The study done on 111 patients with 1-year follow-up. Results showed Constant and Disability of the Arm, Shoulder and Hand scores significantly improved in ORIF group. Faster union (16 vs. 28 weeks) and lower nonunion were seen in the ORIF group, with few symptomatic malunions [6].

Open reduction and internal plate fixation and intramedullary fixation are two of the most commonly used surgical techniques for treating midshaft fracture clavicle [13].

For plate fixation, different types of plates are available: (precontoured) dynamic compression plates [14], tubular plates, or reconstruction plates [15].

For intramedullary fixation, the Knowles pin [16], Rockwood pin [17], or elastic stable intramedullary nailing [18] using a titanium elastic nail have been described.

In recently published prospective randomized studies, functional results after both plate fixation and intramedullary fixation proved to be superior compared with nonoperative treatment of midshaft fracture clavicle [6].

Table 2 Intraoperative evaluation

	Operative time	Blood loss (ml)	Method of fixation	Miniopen reduction
Case No 1	90	30	3.5 mm reconstruction plate	No
Case No 2	90	25		No
Case No 3	80	30		No
Case No 4	75	30		Yes
Case No 5	70	25		No
Case No 6	70	25		No
Case No 7	40	20		No
Case No 8	50	25		Yes
Case No 9	50	25		No
Case No 10	70	30		Yes
Case No 11	50	20		No
Case No 12	30	20		Yes
Case No 13	30	20		No
Case No 14	30	20		No
Case No 15	30	20		No
Case No 16	25	20		No
Case No 17	40	25		No

Table 3 Clinical and radiographic outcomes

	Fracture union (weeks)	Period of follow up (months)	Complications	Removal	Constant score	DASH score
Case No 1	10	24	Prominent implant	Yes	99	0.2
Case No 2	12	23	No	No	100	0
Case No 3	12	21	No	No	95	2
Case No 4	10	20	Bad scare	No	100	0.3
Case No 5	15	19	Prominent implant	Yes	100	0.1
Case No 6	13	17	No	No	95	3
Case No 7	8	12	No	No	100	0
Case No 8	13	9	Prominent implant	No	93	5
Case No 9	12	8	No	No	96	0.4
case No 10	13	7	No	No	95	5
Case No 11	12	5	No	No	98	0.3
Case No 12	8	5	No	No	100	0.2
Case No 13	9	5	No	No	97	0.4
Case No 14	12	4	No	No	95	3
Case No 15	12	3	No	No	99	0
Case No 16	10	3	No	No	100	0
Case No 17	12	3	No	No	95	4

DASH, Disability of the Arm, Shoulder and Hand.

This was also underlined by the systematic review by Zlowodzki *et al.* [19], which reported a relative risk reduction of 86% (plate fixation) and 87% (intramedullary fixation) for nonunion compared with conservative treatment [19]. Theoretically, both plate fixation and intramedullary fixation have their own advantages.

A biomechanical study shows that plate fixation provides a more rigid stabilization compared with intramedullary fixation and may provide a stronger construction for early rehabilitation protocols [20].

On the contrary, intramedullary fixation has the advantage of preserving the soft tissue envelope, periosteum, and vascular integrity of the fracture site. Therefore, infection rates may be decreased and fracture callus formation enhanced [21].

Both surgical procedures have their own (dis) advantages. Plate fixation is technically easy to perform, and long-term experience is available. With improved implants, prophylactic antibiotics, and better soft-tissue handling, plate fixation has been a reliable and reproducible technique [6].

Despite experience and improvement, plate fixation is not free from complications. Typical complications of plate fixation include infection, hypertrophic scars, implant loosening, nonunion, and refracture after implant removal [22]. Compared with plate fixation, intramedullary fixation is technically more demanding [23]. Nevertheless, several studies have describe excellent results after intramedullary fixation of midshaft fracture clavicle, with significant improvement of shoulder function, reduction of pain postoperatively, good cosmetic results, and minimal nonunion rates [24].

In recent years, however, more and more surgeons have realized that conventional fixation methods might be the key reason for increasing complications observed in patients with fracture [25,26].

Therefore, the biological osteosynthesis concept has been developed to draw more attention to soft tissue circumstances [27,28].

Shukla *et al*. [29] compared treatment of fracture midshaft clavicle in adults by external fixator with conservative treatment. Close reduction of acute fracture midshaft clavicle and fixation with external fixator is a simple procedure. It provides the benefits of conservative treatment as the fracture environment is undisturbed and also provides the benefits of implant fixation in terms of maintenance of reduction. Pain relief is faster, union time is shorter, and there are no hardware-related complications. It has the potential to become a mainline treatment option for displaced midshaft fracture of clavicle.

In addition, numerous MIPO techniques have been designed aiming to preserve soft tissue and the periosteum blood supply at the fracture site, including femoral, tibial, and humeral shaft fractures [9].

However, owing to the difficulty in adapting a plate to the curved anatomy of the clavicle and its complex peripheral structures, using the MIPO technique for displaced midshaft clavicular fracture is extremely challenging.

In this study, we performed the MIPO procedure with a 3.5-mm reconstruction plate that was contoured by a binder according to the anatomic shape of the superior clavicular surface.

In our study, we designed an effective indirect reduction procedure. One cortical screw was used to pull the plate against the bone, which brought the lateral clavicular fragment under control in one hand; meanwhile, the medial clavicular fragment that bulged on the body surface could be controlled with the other hand. Thus, the main fracture fragments could be easily controlled, and fracture reduction could be achieved by hand, according to the fracture displacement, with the aid of a well-contoured plate. For comminuted fractures, if the free fragment was grossly displaced, we used a towel clip clamp to bring it close to the clavicular shaft; if not, we just left the fragment as it was. For overriding fracture, we used miniopen reduction using the Hohmann retractor. With this indirect reduction procedure, bony unions were obtained in all patients at a mean of 11.35±1.90 weeks (range, 8–15 weeks) in our study compared with Yuelei *et al*. [30], who used superior anatomical locked plate. Fracture union was obtained in all patients at a mean of 10.1±1.4 weeks (range, 8–12 weeks). Yang *et al*. [31] reviewed patients treated with the MIPO technique with a reconstruction ribbon plate. All patients had bony union, with the average healing time being 14.6 weeks (range, 8–46 weeks), and two patients had delayed union. However, locking compression plates and reconstruction ribbon plates have to be bent during the operation. This is time consuming and probably decreases the intensity of the device.

Jiang and Qu [32] compared the MIPO technique and conventional ORIF with a locking compression plate. The time to union was observed at an average of 15.69 weeks (range, 12–22 weeks) in the open plating group and 16.78 weeks (range, 12–24 weeks) in the MIPO group.

The average operative time was 54.12±22.45 min (range, 25–90 min) in this study. This is in contrast to Yuelei *et al*. [30] who used precontoured plate. The average operative time was 60.2±20.1 min (range, 40–80 min). The difference could be owing to upgrading of our learning curve in contouring the plate.

Jiang and Qu [32] noticed the operation time was longer in the open plating group (mean, 87.50 min; range, 60–110 min) than in the MIPO group (mean, 77.19 min; range, 55–110 min).

The optimal plate position for midshaft clavicular fracture treatment is still controversial. Some authors have preferred anteroinferior plates with less hardware prominence for clavicular fractures. For comminuted fractures, they have suggested that the superior plate fixation point moves laterally, which may cause pullout of lateral screws [33].

Sohn *et al*. [34] introduced a midshaft clavicular fracture MIPO technique using anteroinferior plating and received good clinical results.

However, an anatomical study showed that the subclavian artery is closest to the posterior cortex in the medial half of the clavicle; thus, anteroinferior plating may pose a great risk to the neurovascular structures in the medial clavicular region [35].

Although the neurovascular encroachment incidence was the same for the superior plate as for the anteroinferior plate taking into account such great potential risks from neurovascular injury, more surgeons prefer superior plating for the treatment of clavicular midshaft fractures [36].

We preferred using superior anatomic plates, as safety comes first, and no neurovascular injury or other severe complications were observed in this study, except three (17.6%) cases with prominent hardware and one (5.9%) patient with bad scar (keloid). Two patients with prominent hardware needed removal. One of the patients with prominent hardware was owing to bad contouring of the plate. The other two case with prominent hardware were owing to being very thin patients. The patient with bad scar underwent corticosteroid injection with satisfactory result.

Yuelei *et al*. [30] documented that only two patients felt local incision numbness.

Jiang and Qu [32] documented five (15.2%) patients of all consecutive patients complained of skin irritation or discomfort owing to plate prominence (three in the open plating and versus two in the MIPO). There were four cases of postoperative skin numbness below the operation scar in the open plating group during the follow-up period. Implant failure or screw loosening was demonstrated in two patients of all consecutive patients in this study. One patient (a 56-year-old male with a 15-B1.3 transverse fracture) developed plate breakage in the MIPO group at 4 weeks postoperatively. He underwent MIPO with the anteroinferior plating method and achieved bony union 15 weeks after the second operation. Another patient (a 58-year-old male with a 15-B2.3 wedge comminuted fracture) in the open group had been identified as having loosening of an interfragmentary screw related to the bone resorption of anterior free fragment fixed by screw at 5-months postoperatively.

Jiang and Qu [32] compared the MIPO technique and conventional ORIF with a locking compression plate, and Yang *et al.* [31] reviewed patients treated with the MIPO technique with a reconstruction ribbon plate, and both observed satisfactory results with MIPO. However, locking compression plates and reconstruction ribbon plates have to be bent during the operation. This is time consuming and probably decreases the intensity of the device. Moreover, contoured plates that fit the clavicle poorly will cause skin irritation.

Anatomic locking clavicle plates fit the superior surface in most patients. When the lateral side was fixed to the distal clavicular fragment, reduction could be achieved with the S shape of the plate, especially for comminuted fractures. In addition, for comminuted fractures in which the bridging fixation technique was recommended, locking plates could provide angular stability by threaded fixation of the screws on the plate and have little effect on the comminution fracture configuration [37].

Conclusion

This study demonstrated that the MIPO procedure that uses superior 3.5-mm reconstruction plates for midshaft clavicular fractures can be a reproducible procedure and an alternative to conventional operative methods. In addition, satisfactory clinical and radiologic outcomes were obtained without serious complications.

The limitations of this study were the small number of the patients and the absence of a control group treated with open plating. A randomized controlled trial with a larger sample size is required in the future to confirm the outcomes achieved in our study.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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