

Clinical outcome of internal fixation of middle third clavicle fractures using locking compression plate: Comparison between open plating and MIPO

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1. Introduction

Middle third clavicle fractures have traditionally been treated nonoperatively.^{1,2} Recent studies have shown that the incidence of symptomatic non-union and malunion in displaced middle third clavicle fracture is as high as 15–20%, with low shoulder outcome scores when managed non-operatively.^{3–5} Hence, there is now a trend towards the internal fixation of these fractures, to achieve early return of function and reduce rates of symptomatic nonunion and malunion.⁶ Internal fixation of these fractures is not without complications. Prominent hardware leading to skin irritation, nonunion, implant breakage, numbness and paresthesia around the surgical scar and infection are the some of the common complications,^{7,8} especially with plate fixations. With the introduction of locking plates, minimally invasive plate osteosynthesis (MIPO) has become more popular in the treatment of long bone fractures. However, MIPO technique is not frequently used in fixation of long bone fractures of the upper limb.

Some authors have reported good clinical and radiologic outcomes with the use of MIPO in treating fractures of the clavicle.^{9–13} There are only a few authors who have compared the outcomes between open plating and MIPO, and shown that both methods of internal fixation of acute displaced middle third clavicle fractures, are equally effective and safe.^{14,15} The purpose of our study is to compare the clinical and radiologic outcomes of acute displaced middle-third clavicle fractures treated by internal fixation with locking plates, between conventional open plating and MIPO, and to analyze if similar results are reproducible and report any complications.

2. Materials and methods

A total of 37 patients underwent internal fixation of acute displaced middle third clavicle fractures from January 2014 to June 2016, by a single orthopaedic surgeon at a University teaching hospital. Indications of surgery were; acute displaced middle third clavicle fractures (AO/OTA Type 2) in skeletally mature individuals, with no cortical contact, comminuted fractures, fractures with more than 2 cm of shortening and fractures causing overlying skin tenting. The fractures were treated by internal fixation with locking compression plates, either by open reduction or MIPO technique. Patients who were operated within three weeks of injury and who had regular follow up for a minimum of two years following surgery were included in the study. The patients with open clavicle fractures, in patients with ipsilateral upper limb fractures and patient age more than 70 years were not included in the study. MIPO technique of internal fixation was performed only in fractures which could be reduced without opening of the fracture site. In fractures which couldn't be reduced satisfactorily, underwent conventional open plating method. Patient consent was obtained before surgery, and institutional ethical committee clearance was obtained before commencement of the study. The demographic data were collected from hospital records. The fractures were subdivided according to the AO/OTA classification.¹⁶

2.1. Operative technique

The internal fixation was done under general anaesthesia. The patient was positioned supine, on a radiolucent table with a rolled-towel

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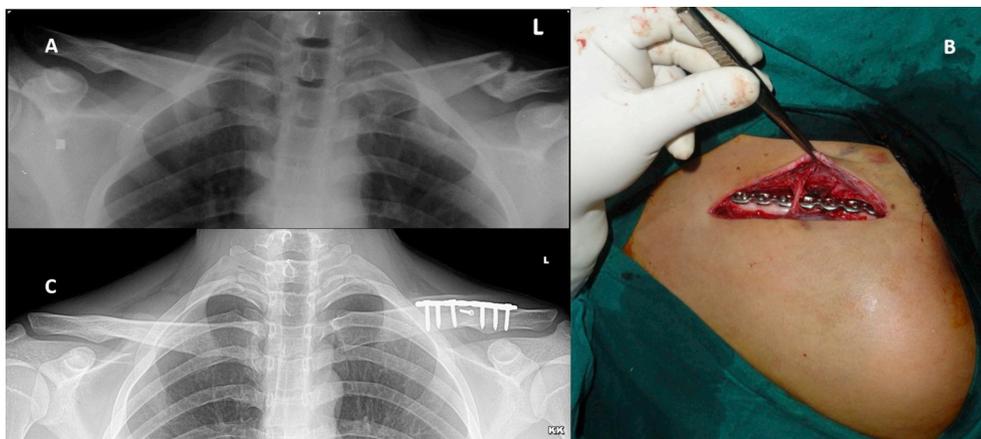


Fig. 1. A: AO/OTA 15.2A fracture in 18 year student causing skin denting over the fracture; **B:** Conventional open plating using locking reconstruction plate and inter-fragmentary screws. Figure also shows supraclavicular nerve in the middle third of the clavicle; **C:** Radiograph at the end of follow up.

in the inter-scapular region. The site of skin incision was infiltrated with about 10 ml 0.25% bupivacaine and adrenalin (1:20000).

2.1.1. Conventional open technique

A longitudinal skin incision of required length was made over the clavicle. The supraclavicular nerves were isolated and preserved. The skin was pulled up superiorly before putting incision, so that post-operative closed surgical wound was inferior to the plate. The fracture site was exposed and reduced under vision. AO/OTA type 2A transverse fractures were fixed by compression plating. AO/OTA type 2A oblique, 2B and C fractures were fixed using inter-fragmentary screws and neutralization plate (Fig. 1 A, B and C). In most cases, precontoured plates were used depending on the curvature of the clavicle. In some cases where clavicle was relatively straighter, 3.5 mm reconstruction plates were used. The fixation was checked under fluoroscopy. The surgical wound was closed over a drain.

2.1.2. Minimally invasive plate osteosynthesis (MIPO)

Two skin incisions, each measuring 2–3 cm were made over the medial and lateral thirds of the clavicle. The skin over the fracture site was left intact. The supraclavicular nerve when identified was preserved. The superior surface of the clavicle was exposed. A submuscular plane was created between the two incisions using a Bristow periosteal elevator. The fracture was reduced by manipulating either side of the fracture using the bone lever, and the implant was passed in the submuscular plane. Temporary fixation was achieved using K wires through the locking drill sleeves. Fluoroscopy images were taken in neutral, 30 degrees caudal and 30 degrees cranial, to confirm the reduction and placement of the implant. Definitive fixation was achieved using 3.5 mm cortical screws on either side of the fracture. Locking screws were used to complete the internal fixation (Fig. 2A, B and C), and the surgical wound was closed in layers. Suction drains were not used in MIPO group.

Postoperatively, the injured upper limb was immobilized in an arm sling, and the patients were encouraged to perform gentle pendulum exercises. There was no difference in postoperative rehabilitation protocol in both the groups. At six weeks, active shoulder mobilization was started, and the arm sling was discontinued. Follow up clinical and radiological assessment was performed at 6 weeks, 12 weeks, 18 weeks, 6 months, 1 year and 2 years following surgery. The clinical outcome was assessed at the final follow-up using Constant Shoulder Score (CSS) and Quick Disabilities of Arm, Shoulder, and Hand (Quick DASH) score.^{17–19} The radiological outcome was assessed using standardized anteroposterior including both the shoulders. The fracture was considered united when bridging callus was seen at the fracture site. At 2 years follow up, the percentage length difference of the clavicle, was

assessed. Complications like hardware irritation, numbness, and paresthesia around the surgical scar, nonunion, failure of fixation and infection were noted.

3. Results

Thirty-seven patients underwent internal fixation of the clavicle fractures with locking compression plates. Among these, 21 were done by MIPO and 16 were done by open plating method. The demographic data is as shown in Table .1.

There were no statistically significant differences in the age, sex, mechanism of injury, type of fracture and its associated injuries in both groups. All patients underwent internal fixation at an average interval of 3 days after injury. Seventeen of 21 cases in the MIPO group underwent fixation by bridge plating and 4 by neutralization plating. Of 16 cases in open plating group, 10 underwent inter-fragmentary compression and neutralization plate, 4 cases by compression plating and 2 cases by bridge plating technique.

The mean duration of surgery was lesser in the MIPO group (55.71 ± 11.43 min) when compared to open plating method (65.31 ± 8.65 min). The difference was statistically significant ($p = 0.008$).

There were no intra-operative complications in both the groups. The median duration of fracture union and average time taken to return to work was 12 weeks in both the groups with no statistically significant difference.

Three patients in the open plating group had the stiffness of shoulder at six weeks patients, which resolved spontaneously which physiotherapy. One patient among MIPO group had shoulder stiffness, which resolved after shoulder manipulation. There was no statistical significance. All 4 of them had ipsilateral multiple rib fractures.

At the end of follow up, all the fractures united without any wound complication or infection. In one case among MIPO group, there was an early loss of fixation, but the fracture united despite loss of fixation (Fig. 3 A and B). There was no loss of fixation in open plating group.

The mean Quick DASH scores were also slightly better in Open plating group (4.1) when compared to MIPO (4.7), with no statistical significance ($p = 0.566$). Though the mean constant shoulder score at the final follow up was marginally higher in Open plating group (96) when compared to the MIPO (94), both were excellent, with no statistical significance ($p = 0.248$).

The average length difference was significantly less in the open plating group (0.6%) than in the MIPO group (3%) with $p < 0.001$. There was a weak correlation ($r = -0.203$) between Constant shoulder score and length difference. However, it was statistically insignificant ($p = 0.228$). Seven (43%) patients in open plating group had numbness

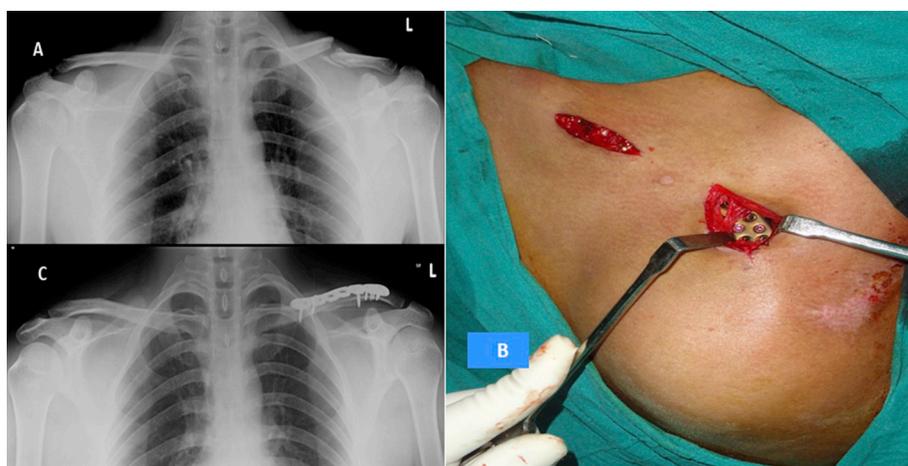


Fig. 2. A: AO/OTA 15.2C fracture in 32 year man with motor vehicle accident; 2B: Internal fixation by MIPO using precontoured locking plate; 2C: Radiograph at the end of follow up.

Table 1
The demographic data.

Variables	MIPO (n = 21)	Open (n = 16)
Gender		
Male	18	16
Female	3	0
AO/OTA type		
15.2A	4	6
15.2B	5	8
15.2C	12	2
Mechanism of injury		
RTA	20	14
Sports	1	2
Associated injuries		
Yes	6	8
No	15	8
Additional procedures		
Yes	1	0
No	20	16

below the surgical scar. However, this was noted in only 1 (4.7%) patient in the MIPO group. The finding was statistically significant ($p = 0.012$). Hardware irritation was seen in 10 (27%) cases. 7 of them were in non-contoured plates, and 3 were in pre-contoured plates. The difference was statistically significant ($p = 0.017$). There was no correlation between hardware irritation and the technique (MIPO/Open) with which fixation was done ($p = 0.274$). The comparison between the results of the outcome is shown in [Table 2](#).

Table 2
Comparison of outcome and complications between the two techniques.

Variables	MIPO (n = 21)	Open (n = 16)	p value
Duration of surgery (min)	55.71 (± 11.43)	65.31 (± 8.65)	0.008
Fracture union (weeks)	12 (10–12)	12 (6–12)	0.280
Constant score	94 (92–96)	96 (92.25–98)	0.248
Quick DASH score	4.7 (± 3.2)	4.1 (± 3.2)	0.566
Length difference (%)	3.1 (1.28–4.45)	0.65 (0.00–1.27)	< 0.001
Additional procedures	1(manipulation)	0	
Hardware irritation	4	6	0.274
Loss fixation	1	0	
Nonunion	0	0	
Infection	0	0	
Shoulder stiffness	0	0	
Numbness below surgical scar	1	7	0.012

4. Discussion

Fractures of the clavicle account for approximately 2–5% of all fractures and 44% of injuries around the shoulder girdle. Eighty to eighty-five percent of these fractures are seen in the middle third.^{20–23} The internal fixation of displaced middle third clavicle fractures is becoming more popular, as it not only provides early pain relief and return to activities but also prevents complications like symptomatic nonunion and malunion.³ Plate osteosynthesis is the standard method of internal fixation of clavicle fractures. Clavicle, being a subcutaneous bone with less soft tissue cover, is more prone for surgical wound related complication and hardware irritation following open reduction and plate osteosynthesis. Intramedullary devices, though can be used

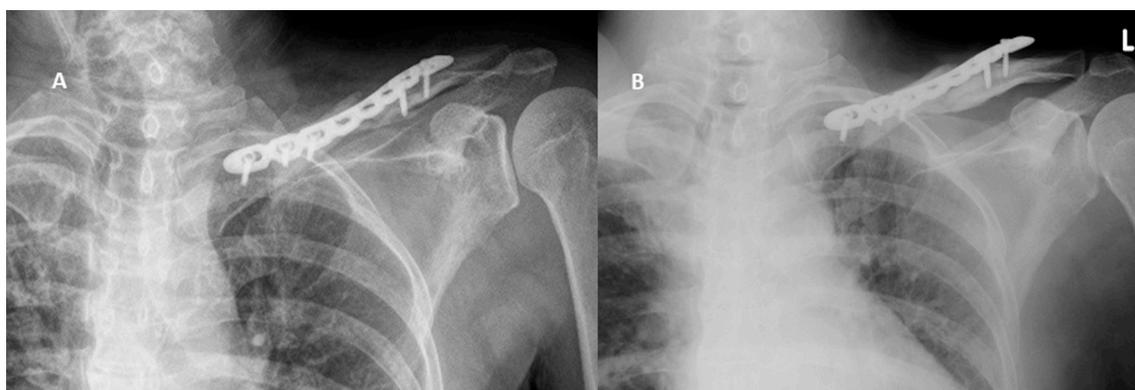


Fig. 3. A: AO/OTA 15.2C fracture in a 57 year man, internally fixed with pre-contoured plate by MIPO; 3B: At 2 years, fracture united despite early loss of fixation.

with minimal soft tissue dissection, they do not hold length or rotation well in comminuted fractures. Implant migration and breakage may lead to dangerous complications.²⁴

With the availability of locking compression plates, there is a trend towards fixation of long bone fractures by MIPO. Although MIPO, using locking compression plates is a well-accepted technique of internal fixation of long bone fractures of the lower limb, it is still not a commonly used technique in the upper limb. The main advantages of MIPO are the preservation of soft-tissue attachments to the bone at the fracture site while providing relative stability, allowing biologic healing and less wound-related complications.²⁵ There are only a few studies where results of internal fixation of middle third clavicle fractures by MIPO technique is compared with conventional open plating method.^{14,15}

We started doing MIPO in certain comminuted middle third clavicle fractures, where comminuted fractured fragments were too small to be fixed with lag screws and where the fractured ends could be reduced without opening the fracture site. Later on, the MIPO technique was used even for lesser comminution fractures like Type 2A and 2B. The fractures were reduced by either by just positioning on the table using a rolled sheet in the interscapular region and/or by manipulating the main fractured fragments using bone levers. In some cases, vertical displacement was reduced by adjusting the level of the shoulder. In fractures, where acceptable alignment could not be achieved, open plating method was performed. All the fractures were fixed with locking plates.

We noted that the mean duration of surgery was approximately 10 min shorter in the MIPO group when compared to open plating method and this was statistically significant ($p = 0.008$). A similar observation was done by Sohn et al., where the average operating time was less in the MIPO group,¹⁴ though not statistically significant. In MIPO technique, the tissue dissection is limited, there is no need of isolation of the supraclavicular nerve which is located in the middle third region of the clavicle, and inter-fragmentary screw fixation step can be avoided. This was probably the reason for a shorter duration of surgery and may not have much clinical significance in the outcome, however reducing the operating time could be useful in polytrauma patients requiring multiple fracture fixations. The early postoperative period (first two days) was less painful (using Visual Analogue Scale VAS) in MIPO group than in open plating method. After two days, the VAS score was similar in both the groups. None of the patients had any wound healing complications.

Most of the cases operated in MIPO group were AO/OTA type 2C and in comparison with open plating group, where predominant types were 2A and 2B. The median duration of fracture union and average time taken to return to work was similar (12 weeks) in both the groups, suggesting that both techniques are equally effective in achieving fracture union despite more patients of comminuted fractures (AO/OTA Type 2C) in MIPO group. There is always a risk of de-vascularisation of the comminuted fragments if they were fixed by open reduction.

When the shoulder function was evaluated at the final follow up, the patients in both the groups had excellent Constant shoulder score (CSS). However patients had marginally better scores in open plating group (CSS = 96) when compared to MIPO group (CSS = 94). Similar excellent Quick DASH scores were noted in both the groups, but patients did slightly better in Open plating group (4.1) when compared to MIPO (4.7). Both these functional outcomes showed no statistical significance between MIPO and open plating group.

Lazarides and Zafiroopoulos studied the relevance of shortening and functional outcome of the shoulder. They concluded that the final clavicular shortening of more than 18 mm in male patients and 14 mm in female patients, was significantly associated with an unsatisfactory result.²⁶ Rasmussen JV et al. also noted that final shortening was associated with a mild reduction of shoulder function.²⁷

In our study, we noted that the percentage length difference is significantly less in the open plating group (0.6%) than in MIPO group

(3.0%) with $p < 0.001$, and there is a weak ($r = -0.203$) correlation between Constant shoulder score and percentage length difference. However, this was statistically insignificant ($p = 0.228$). Lengthening was seen in 10 (of 21) cases of MIPO. Only two patients among MIPO group had lengthening more than 10 mm. Both these cases were type 2C. Lengthening at the fractured comminuted bone distracts the fractured ends, predisposing for fracture nonunion. Despite lengthening, none of the fractures developed nonunion in the MIPO group, suggesting that preserving the soft tissue benefits healing of comminuted fractures.

One of the complications of open reduction and internal fixation of these fractures is an injury to the supraclavicular nerves, which results in significant numbness below the surgical scar. Most of the times, this is the only complaint which, despite excellent shoulder function, results in a higher rate of patient dissatisfaction with the surgery.²⁸ The incidence ranges from 10% to 29%.³ In our study, numbness below the surgical scar was seen in 8 cases (21%). This complaint was seen only in one patient in MIPO group (4.7%) when compared to 7 patients in open plating method (43.7%) with significant statistical difference ($p = 0.012$). In all case of open plating method, the supraclavicular nerves encountered, were isolated (Fig. 1B). Despite the isolation of supraclavicular nerves, there was a higher incidence of numbness below the surgical scar. The numbness was probably because of unintentional, traction injury during manipulation during internal fixation or partly due to nerve entrapment in the surgical scar. One of the supraclavicular nerves is constantly located over the middle third of the clavicle.²⁹ This was avoided by keeping the skin intact in the MIPO group.

Hardware irritation is also one of the common complaints following plate osteosynthesis of clavicle fractures with an incidence as high as 21%.⁷ The incidence was quite high in our series, where 10 patients (27%) complained of hardware irritation. It was observed mainly where non-contoured plates were used (7 cases) with $p = 0.017$. Among 3 cases of hardware irritation in pre-contoured plates, one was due to early loss of fixation (in MIPO group) (Fig. 3B) and one due to loosening of one cortical screw (in Open plating group). Fracture union was complete in both these cases. There was no correlation between hardware irritation and the technique used. More incidence of hardware irritation in non-contoured plates is probably due to the mismatch in the contour of the implant and the bone. This complication of hardware irritation can be minimized by use of precontoured plates.

Shoulder stiffness is rarely seen in middle third clavicle fractures. It was seen in 3 patients in open plating group and one patient in the MIPO group, with no statistical significance. All these cases were seen in clavicle fractures who had the same side multiple rib fractures. Three of them improved by 12 weeks by physical therapy. One patient in the MIPO group needed manipulation at 6th month as the patient did not improve in the range of motion as expected. This patient also achieved a full range of movement at the end of the follow-up. Rib fractures on the same side affect early rehabilitation of the clavicle fractures.

5. Limitations

- Nonoperative treatment is still the predominant method of treatment of middle third clavicle fractures at our institute. This is the reason for having a small number of patients in this study group.
- There was no randomization between the two groups before planning of type of technique.

6. Conclusions

- Internal fixation of middle third clavicle fractures with locking compression plate, done by MIPO technique is equally effective as conventional open plating in terms of fracture union rates, duration of fracture union and functional shoulder outcomes.
- The clavicle length difference was less in open plating technique than in MIPO. There is a weak and statistically insignificant

correlation between Constant shoulder score and clavicle length difference.

- c) Sensory abnormality around the surgical scar and operating time were significantly less in MIPO technique.
- d) Non-contoured locking compression plates have higher incidence hardware irritation when compared to pre-contoured plates, regardless of the technique used.

Conflicts of interest

The Authors declares that there is no conflict of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jor.2019.04.009>.

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