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ORIGINAL ARTICLE

Minimally invasive plate osteosynthesis (MIPO) in AO/OTA type B displaced clavicle fractures

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Abstract

Introduction Open reduction and plate fixation is known to reduce chances of malunion and symptomatic nonunion in displaced middle-third clavicle fractures. However, this treatment modality is also associated with several complications, such as hardware irritation, numbness around the surgical scar, infection, nonunion and implant failure. The minimally invasive plate osteosynthesis (MIPO) technique may reduce these complications.

Objective To study clinical, radiological and functional outcomes of MIPO in AO/OTA type B displaced clavicle fractures and report any complications.

Materials and methods A total of 22 patients underwent internal fixation of acute displaced AO/OTA type B clavicle fractures from Jan 2014 to Dec 2015 by MIPO using locking compression plates. Patients were followed up at a regular interval and assessed clinically and radiologically. The clavicle length difference was measured. Functional assessment was done at the end of 2 year using constant shoulder score (CSS) and disability of the arm, shoulder and hand score (Quick DASH) and complications if any were noted.

Results All fractures united at a mean of 12.5 weeks. One (4.5%) patient had numbness around the surgical scar. None of the patients had wound-related complications. In four patients, hardware irritation was noted. The difference in clavicle length was not significant. All patients had excellent CSS and Quick DASH score at the final follow-up.

Conclusion Internal fixation of displaced AO/OTA type B clavicle fractures by MIPO showed high fracture union rates and good functional outcomes.

Keywords Minimally invasive plate osteosynthesis (MIPO) · Displaced clavicle fractures · Locking compression plate

Introduction

Fractures of the clavicle account for approximately 2–5% of all fractures and 44% of injuries around the shoulder girdle. Approximately 80% of these fractures are seen in the middle third [1–4]. Most of these fractures can be managed non-operatively with a figure of eight bandage and an arm sling [5, 6]. However, recent studies have shown that the incidence of symptomatic malunion and nonunion in displaced middle-third clavicle fracture is as high as 15–20%, with low shoulder outcome scores, when managed non-operatively [7–9].

Therefore, there has been a trend toward the operative management of these fractures. The advantages are the early return of function and lower rates of symptomatic malunion and nonunion [10]. However, open reduction and internal fixation (ORIF) of these fractures is not without complications. Prominent hardware leading to skin irritation, implant breakage, numbness and paresthesia around the surgical scar and infection are some of the common complications [11, 12].

Closed intramedullary nailing can reduce these soft-tissue complications. However, intramedullary nails do not hold length or rotation well in comminuted fractures. Nail migration and breakage my lead to dangerous complications [13].

Recently some authors have reported good clinical and radiologic outcomes with the use of MIPO in treating

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fractures of the clavicle [14–17]. The purpose of this study is to analyze the clinical and radiographic outcomes of MIPO in treatment of displaced middle-third clavicle fractures (AO/OTA type B) [18].

Materials and methods

In our institution, we treated 22 patients with displaced middle-third clavicluar fractures (AO/OTA type B) by MIPO using locking compression plates between January 2014 and December 2015. The primary indications of surgery were displaced middle-third clavicle fractures (AO/OTA type B) with no cortical contact, comminuted displaced fractures and fractures with more than 2 cm of shortening. Patients with ipsilateral upper limb injuries, open fractures and those who refused surgery were excluded from the study. This procedure was not done in patients where satisfactory reduction could not be achieved preoperatively. Average delay of surgery after injury was 3 days. All surgeries were performed by the same surgeon in a similar manner. Patient consent was obtained prior to surgery, and institutional ethical committee clearance was obtained before commencement of the study.

Operative technique

The anaesthetized patient was positioned supine, on a radiolucent table with a roll-towel in the interscapular region. The head of the patient was turned away from the operating side. Fluoroscopic images were taken in neutral, 30 degree cranial and caudal directions to determine the fracture displacement. The surgical site was prepared and draped. A precontoured locking compression plate was placed over the skin, the appropriate length of the plate was selected under fluoroscopy guidance, and the incision site was marked. The length of the plate was selected in order to get at least two bi-cortical screws on either side of the fracture.

Skin incision site was infiltrated with lignocaine with adrenaline 1:20000 IU. Two skin incisions, each measuring 2–3 cm, were made over the medial and lateral thirds of the clavicle (Fig. 1) leaving skin over the fracture intact. The platysma over the clavicle was divided. The visible supraclavicular nerves at the incision sites were preserved. The superior surface of the clavicle was exposed. A submuscular plane was created between the two incisions using a Bristow periosteal elevator (Fig. 2). The fracture was reduced (Fig. 3), and the implant was passed in the submuscular plane (Fig. 4). Temporary fixation was achieved using K wires. Fluoroscopy images were taken in neutral, 30 degrees caudal and 30 degrees cranial, to confirm reduction and placement of the implant (Fig. 5a, b, c). Definitive fixation was achieved using 3.5 mm cortical screws on either side of the fracture. Locking screws were used to complete the

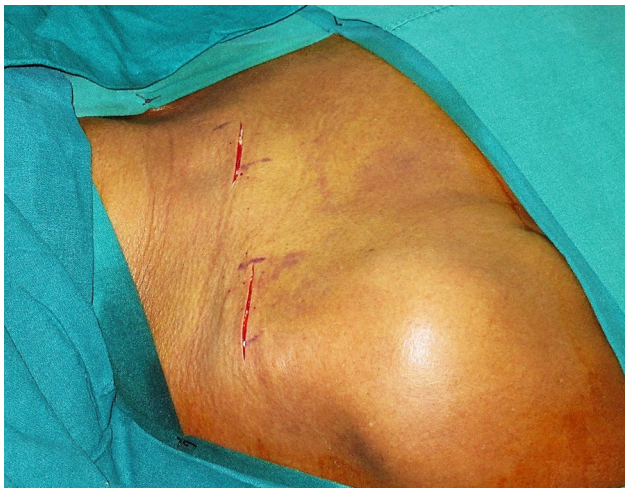

Fig. 1 Skin incisions

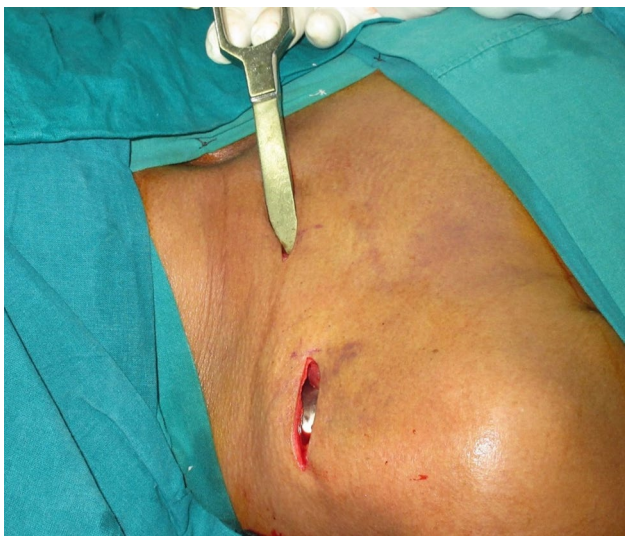

Fig. 2 Creating submuscular plane

internal fixation and the surgical wound was closed in layers (Fig. 6a, b). In 18 patients, precontoured locking compression plates specific for clavicle were used, and in four patients, non-contoured locking reconstruction plates were used.

Postoperatively, the radiographs were taken in 30 degree cranial and caudal views. The upper limb was supported in an arm sling for 6 weeks, and the patient was encouraged to perform gentle pendulum exercises within the arm sling form first postoperative day. At 6 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. Clinical outcome was

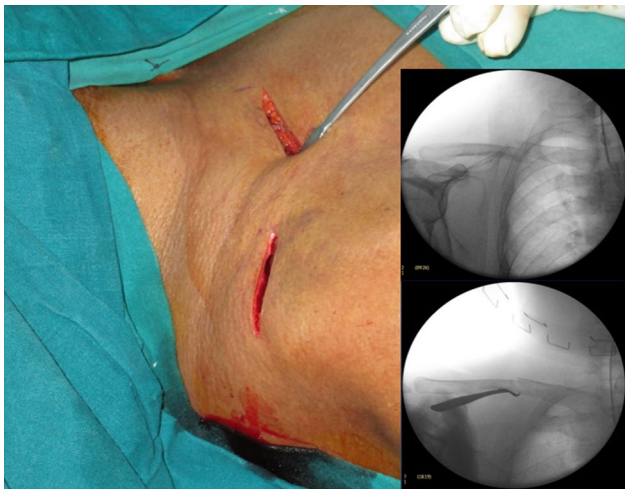

Fig. 3 Fracture reduction using bone levers. Inset: fluoroscopy image before (top) and after (bottom) reduction

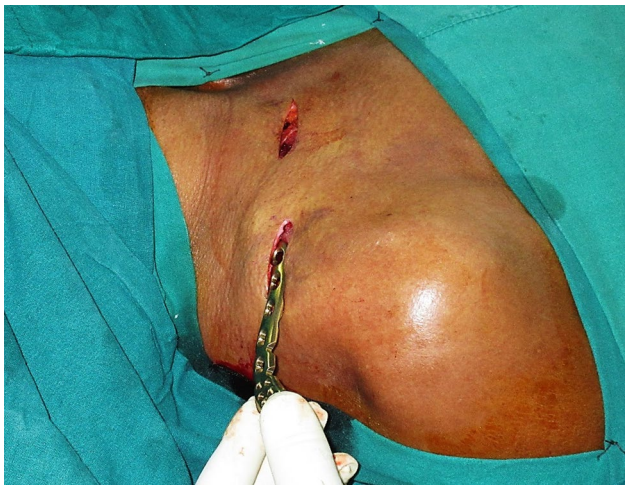

Fig. 4 Placement of plate in the submuscular plane

assessed using constant shoulder score (CSS) and disabilities of arm, shoulder and hand (DASH) score [19–21]. The radiological outcome was assessed using the same projections previously adopted. The fracture healing was considered in the presence of bridging callus the fracture site. Clavicle length difference was assessed. Complications related to hardware, numbness and paresthesia around the surgical scar and infection were noted.

Statistical analysis

Statistical analysis was done using Statistical Package for Social Sciences version 13. Quantitative data such as age, clavicle length difference, CSS and Quick DASH score were expressed as mean ± SD, while qualitative data such as gender and radiological union were expressed as a percentage. The clavicle length difference was correlated with the CSS using binary correlation and regression.

Results

The demographic data of studied sample and fracture patterns are shown in Table 1. The average duration of surgery was 56 min (range 30–70 min). Sixteen patients (73%) returned to light work by 6 weeks and preinjury activities by 12 weeks. The remaining six patients returned to their preinjury activities by 18–24 weeks. The mean CSS and DASH scores at follow-up and complications are shown in Table 2.

In 19 patients (86.3%), radiologic fracture union was seen at 12 weeks, and in three patients (13.6%), the union was at 18 weeks. All fractures were consolidated at the final follow-up. In 12 cases, there was a lengthening of 5.6 ± 3.8 mm, and in 10 cases there was a shortening of 4.0 ± 2.3 mm. However, the mean difference in the length was not significant. There was no correlation between the clavicle length difference and CSS ($p = 0.346$).

All patients achieved full range of shoulder movement at 3 months except one with ipsilateral rib fractures, where additional procedure in the form of mobilization of the shoulder under anesthesia was performed. None of the patients developed an infection or any wound-related complications. All wounds were healed with minimal surgical scar (Fig. 7). In one patient, there was a loss of fixation due to screw back-out, which did not influence consolidation (Fig. 8). Only one patient had numbness below the surgical scar.

Discussion

Internal fixation of clavicle fractures is gaining popularity. It not only provides early pain relief and return to activities but also prevents complications like symptomatic nonunion and malunion [7–9]. With the availability of locking compression plates, there is a trend toward treating these fractures by ORIF. MIPO, using locking compression plates, has been a well-accepted treatment modality of lower limbs fractures. The advantage of MIPO is the preservation of soft-tissue attachments at the fracture site while providing relative stability, thereby allowing early rehabilitation. Reduced invasiveness is linked to a lower rate of wound-related complications. There are only a few studies where MIPO has been used in treatment of clavicle fractures.

Achieving fracture reduction without exposing the fractured fragments is the prerequisite for MIPO in any long bone. A rolled sheet was kept in the interscapular region to retract the shoulder. In four patients, there was only vertical displacement of fracture and adjusting the level of shoulder

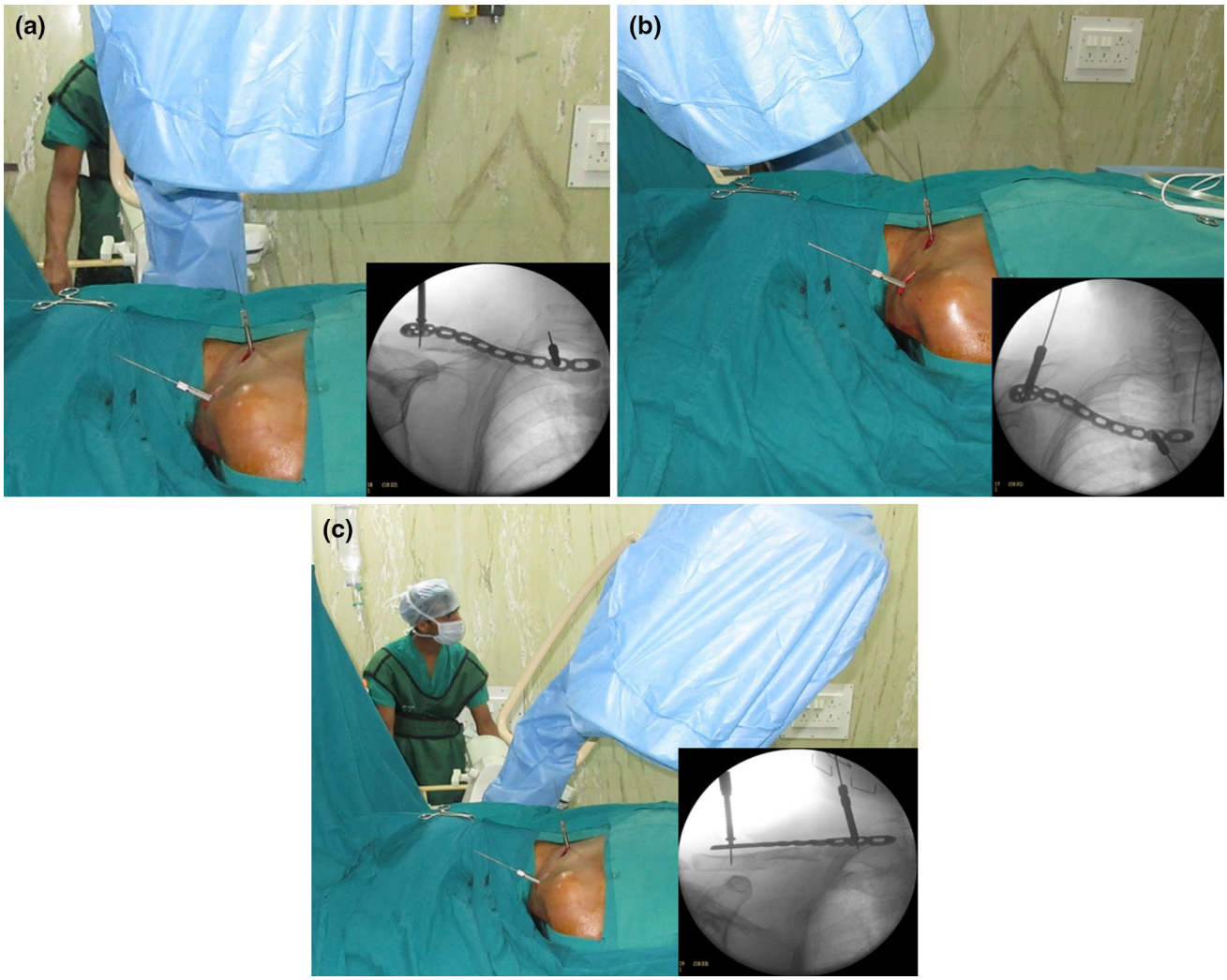

Fig. 5 Temporary fixation and fluoroscopy images taken in **a** neutral, **b** 30° caudal and **c** 30° cranial

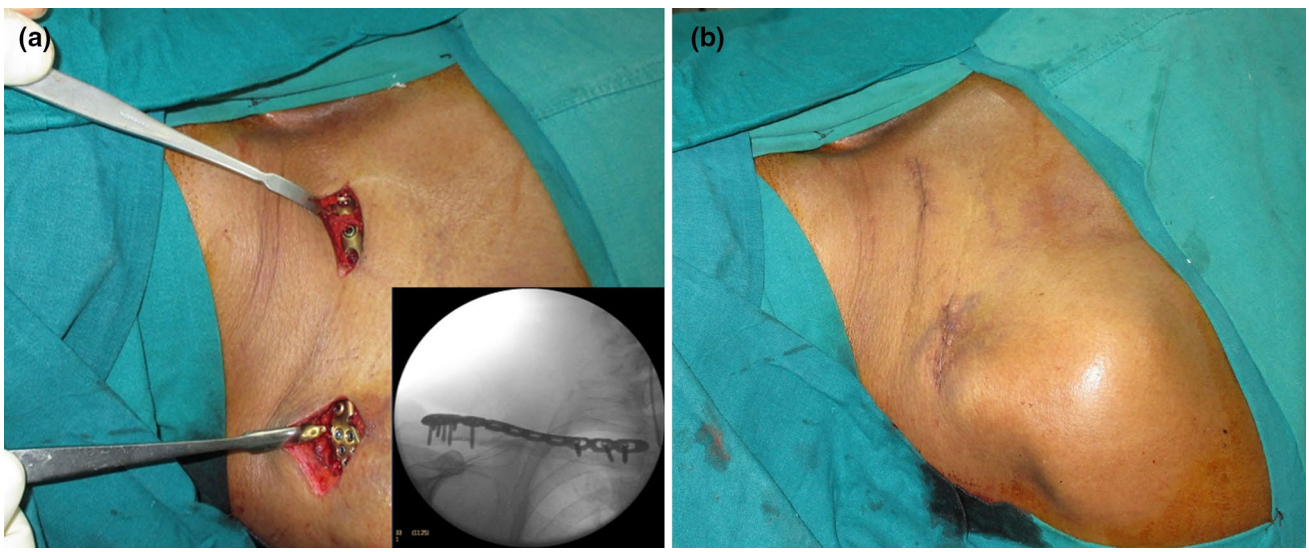

Fig. 6 **a** Completing fixation and **b** wound closure

Table 1 Demographic and fracture-related characteristics. ($n=22$)

Age (years)	36.1 (18–60)
Gender (male: female)	19:3
Mechanism of injury	
Motor vehicle accident	21 (95.5%)
Sports injury	1 (4.5%)
AO/OTA type	
15-B1	4 (18.2%)
15-B2	5 (22.7%)
15-B3	13 (59.1%)
Associated injuries (n = 8)	
Rib fractures	3
Blunt injury abdomen	2
Opposite upper limb fractures	2
Lower limb fractures	1

Table 2 Summary of radiological and functional outcomes

Average time to fracture union (weeks)	12.5 (12–18)
Average time to return to normal work (weeks)	14.2 (6–12)
Constant shoulder score (mean ± SD)	92.95 ± 5.83
DASH score (mean ± SD)	4.63 ± 3.23
Hardware irritation	4 (18%)
Nonunion	Nil
Loss of fixation	1 (4.5%)
Wound complications	Nil
Numbness below surgical scar	1 (4.5%)
Length difference (% of opposite clavicle)	3.3%

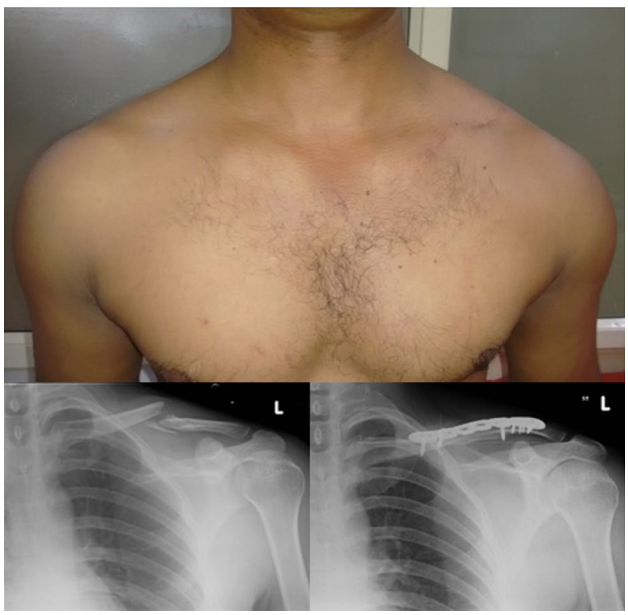

Fig. 7 Surgical scar at the final follow-up of a patient with AO/OTA type B3 fracture

vertically reduced the fracture. In all other cases, where there was angulation and anteroposterior displacement which was not correcting with the position, bone levers and hooks were used as lever to reduce the fractures (Fig. 3) in addition to adjusting the shoulder level. Only in two cases where reduction could not be achieved because of soft-tissue interposition, they underwent ORIF. These cases were not included in the study.

The skin over the middle third of the clavicle was kept intact, avoiding exposure of the fracture site. As the skin incisions were made in the direction of Langer's lines, the postoperative scarring was minimal (Fig. 7). There were no infections and nonunion. These results were similar to the other studies where internal fixation was done by MIPO [22]. Limited dissection and preservation of soft-tissue coverage around the fracture fragments has probably prevented these complications.

A comparative study of MIPO technique and conventional ORIF which mainly included AO/OTA type B1 and B2 groups showed that fractures united 1 week earlier in MIPO group [23]. However, randomized comparative analysis done by Sohn et al., where the majority of the fractures were AO/OTA type B2 and B3, showed that fractures treated by ORIF united earlier compared to MIPO [22]. In contrast to these studies, AO/OTA type B3 fractures were predominant (59.1%) in our study, with a mean duration of fracture union at 12.5 weeks. Higher incidence of AO/OTA type B3 fractures (59.1%) was seen probably because most of the injuries were due to high-energy motor vehicular accidents.

At the final follow-up, the mean CSS was excellent (92.95 ± 5.83), which was slightly lower than the study done by Sohn et al. (CSS = 95.75 ± 4.25) [22]. The mean DASH score at the final follow-up was also excellent (4.63 ± 3.23). This was slightly higher than the study done by Zhang et al. [24].

Lazarides and Zafiropoulos 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 [25]. We also noticed the length difference. In 12 cases, there was lengthening, and in 10 cases there was a shortening. Only two patients in our study had length difference of more than 10 mm. The average length difference was not significant (3.3%). This was higher than a study done by Lee et al. [15]. However, it was not significant. There was no correlation between the clavicle length difference and CSS ($p=0.346$). The length difference was higher, because majority (82%) of the fractures were comminuted (AO/OTA type B2 and B3) and fixation was done by bridge plate technique, rather than anatomic reduction where length is also restored.

One of the complications of ORIF of these fractures is injury to the supraclavicular nerves, resulting in numbness

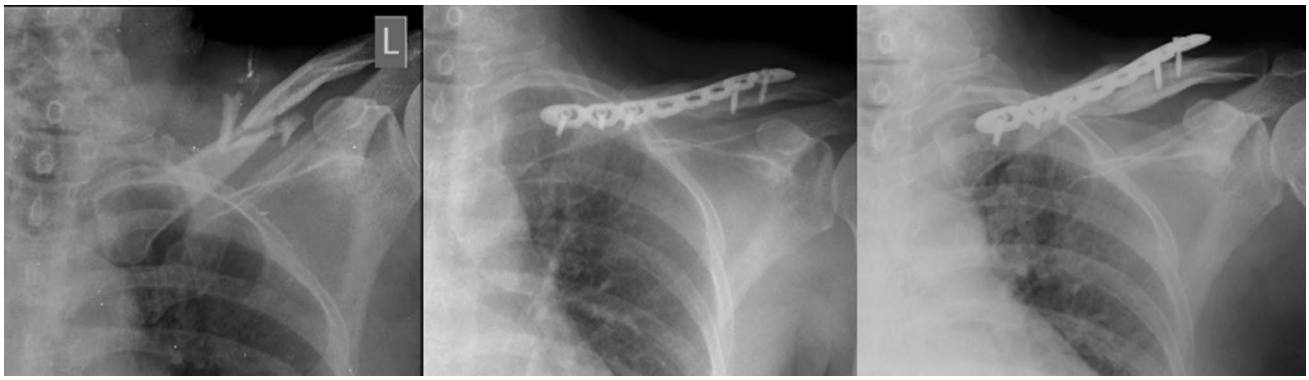

Fig. 8 57-year patient with AO/OTA type B3 fracture (left), postoperative fixation (middle) and fracture union in spite of loss of fixation (right) at the final follow-up

and paresthesia below the incision. Its incidence ranges from 10 to 29% [7]. The intermediate of the three supraclavicular nerves is constantly located over the middle-third clavicle [26] and the most commonly encountered in ORIF. Supraclavicular nerves were encountered only in three patients in the medial incision. They were isolated and protected. We made dissection in submuscular plain close to the bone at the fracture site. Keeping the skin and the platysma intact and passing the plate submuscularly has possibly avoided inadvertent injury to this branch. This was probably the reason for the lower incidence (4.5%) of numbness and paresthesia in our series, when compared to overall incidence (10–29%) and the results are quite encouraging.

Hardware irritation is another common complaint following plate osteosynthesis of clavicle fractures with an incidence as high as 21% (11). In our series, four patients (18%) complained of hardware irritation. Out of four patients where locking reconstruction plates were used, three patients had hardware irritation. Hardware irritation was seen only in one (of 18) patient, where precontoured plates were used and was due to early loss of fixation (Fig. 8). None of the other patients, where precontoured plates were used, had this complication. More incidence of hardware irritation in locking reconstruction plates is possibly due to the mismatch in the contour of the implant with the bone. This complication of hardware irritation can be minimized by use of precontoured plates.

Limitations

The drawback of this study is its relatively small sample size.

Conclusions

Internal fixation of displaced middle-third clavicle fractures (AO/OTA type B) by MIPO using locking compression plates showed high fracture union rates and good functional outcomes. Non-contoured locking reconstruction plates have higher hardware irritation compared to precontoured plates. The clavicle length difference following MIPO was not significant and did not correlate with the shoulder function. Numbness and paresthesia below the surgical scar can be minimized by MIPO.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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