

## ORIGINAL RESEARCH

Medicine Science 2017;6(4):737-42

# Minimally invasive plate osteosynthesis with the application of a superior anatomic locking plate; is it a suitable treatment approach for AO-OTA Type B clavicular midshaft fractures?

Suleyman Semih Dedeoglu

*Okmeydanı Training & Research Hospital, Istanbul, Turkey*

Received 23 May 2017; Accepted 13 June 2017

Available online 20.06.2017 with doi: 10.5455/medscience.2017.06.8652

### Abstract

The minimally invasive osteosynthesis technique has gained attention in fracture treatment in recent years. The aim of this study was to evaluate the effects of the minimally invasive plate osteosynthesis (MIPO) technique, on clinical and radiological outcomes in the surgical treatment of AO-OTA Type B (wedge) clavicular midshaft fractures. This prospective study included twenty-three patients who were diagnosed with acute clavicular midshaft fracture where surgical intervention was indicated and MIPO was performed between February 2014 and April 2016. Exclusion criteria were patients with non-displaced fractures, pathological fractures, open fractures, cases where the index trauma was three weeks ago, or those with concomitant neurovascular injuries. The patients comprised of 16 males and 7 females with a mean age of 36.5 years (range, 18-65 years). The mean time from trauma to surgery was 6.1 days (range, 3-12 days). The mean follow-up period was 15.3 months (range: 12-18 months). The mean duration of surgery was 65.5 mins (range: 50-80 mins). Anatomic reduction was obtained in 11 (47%) patients, of whom 7 were Type B1, 4 were Type B2, and 1 was Type B3. The mean time to union was found to be 15.9 weeks (range: 10-24 weeks). After union was confirmed, the mean Constant Murley score was 83 (range: 68-92) and the mean UCLA score was 29.95 (range: 23-34). The mean proportional length difference in the clavicle was 0.32% (range: -0.55 to +1.63). There was no statistically significant difference for the Constant Murley score and UCLA score between patients with anatomic reduction achieved and not achieved ( $p=0.36$ ,  $p=0.43$  respectively). Osteosynthesis with a minimally invasive percutaneously applied plate (MIPO) could be a successful therapeutic option for the management of acute, displaced AO OTA Type B clavicular midshaft fractures.

**Keywords:** Minimal invasive surgery, clavicle fracture, plate fixation

### Introduction

The clavicle has been reported as the most frequently fractured bone [1]. Midshaft fractures constitute 80% of all fractures [2]. This is due to the fact that the bone structure in this area is thin and also more vulnerable to trauma [3]. In general, these fractures can be successfully managed with conservative modalities such as a shoulder arm sling or figure-of-8 bandage [4].

Among current therapeutic approaches, surgical intervention is at the forefront for patients with a high degree of displacement between fracture lines or who have expectations of an early return to daily activities or sport [5]. Recent studies have shown that the union rates of patients treated surgically were as high as those treated conservatively [6]. Kirschner wires, intramedullary wires, cannulated screws and Knowles pins were used for surgical fixation in the past. The gold standard today is regarded as the open reduction and plate osteosynthesis. Although open reduction and plate osteosynthesis has advantages such as higher union rates, early return to daily activities, and better pain scores, complications

may be seen such as excessive stripping of the periosteum in the fracture area after application, vascular or neural injuries, infection, non-union, implant failure, poor cosmetic appearance, and re-fracture occurring after implant removal [7].

The minimally invasive osteosynthesis technique has gained attention in fracture treatment in recent years. It is based on the principle of causing less injury to soft tissue, protecting periosteal circulation, and providing fracture recovery with secondary callus formation through indirect reduction [8]. The technique is used very often in clavicular fractures in certain circumstances when there is difficulty in obtaining anatomic reduction, or the proximity to the local neurovascular structures, or the high-risk of injury to these structures.

The aim of this study was to evaluate the effects of the minimally invasive plate osteosynthesis (MIPO) technique, on clinical and radiological outcomes in the surgical treatment of AO-OTA Type B (wedge) clavicular midshaft fractures.

### Material and Methods

This single-center prospective study was approved by the Ethics Committee of Okmeydanı Research and Training Hospital. Written informed consent was obtained from all the study participants

\*Corresponding Author: Suleyman Semih Dedeoglu, Okmeydanı Training & Research Hospital, Istanbul, Turkey  
E-mail: [s.semihdedeoglu@gmail.com](mailto:s.semihdedeoglu@gmail.com)

before surgery. The study included twenty-three patients who were diagnosed with acute clavicular midshaft fracture where surgical intervention was indicated and MIPO was performed between February 2014 and April 2016. Inclusion criteria for the study were defined as patients aged between 18-65 years, with an acute, displaced (no cortical contact between medial and lateral fragments) midshaft region fracture classified as AO-OTA Type B1, B2, B3 (spiral wedge, bending wedge, fragmented wedge), with a gap of >2cm. Exclusion criteria were patients with non-displaced fractures, pathological fractures, open fractures, cases where the index trauma was three weeks ago, or those with concomitant neurovascular injuries. According to the AO/OTA fracture classification, the fractures were Type B1 (spiral wedge) in 9 patients, Type B2 (bending wedge) in 7 patients and Type B3 (fragmented wedge) in 7 patients. The patients comprised of 16 males and 7 females with a mean age of 36.5 years (range, 18-65 years). In 15 patients, the right shoulder was affected and in remaining 8 patients, the left shoulder was affected. The mean time from trauma to surgery was 6.1 days (range, 3-12 days).

The mean follow-up period was 15.3 months (range: 12-18 months). Concomitant injuries were determined as multiple rib fractures in four patients (two of whom also had a fracture of the scapular neck), head trauma not causing neurological injury in two patients, distal radius fracture in two, scaphoid fracture in one, and femoral diaphyseal fracture in one patient. Pre-existing hypertension was determined in 2 patients and type 2 diabetes in 1, and 6 patients were smokers. The mechanism of trauma was a motor vehicle accident in 12 patients, a fall from height in six, sports trauma in three, and physical assault in two patients.

### Surgical technique

Under general anesthesia, all the patients were placed on a radiolucent operating table in the beach-chair position in a manner to allow movements of the affected extremity. The scapula was supported from the posterior with a silicon pillow which could be pushed towards the anterior. The head of the patient was turned towards the non-affected side to allow for drilling of the medial fragment and the screw procedures. The fluoroscope was positioned on the other side of the table so that it would not intrude on the surgical field. Before starting the procedure, images were taken and the fracture line, the sternoclavicular joint, and the acromioclavicular joint were marked with a marker pen (Figure 1). The surgical site and the extremity were sterile stained and draped. The appropriate plate size was selected by evaluating the fracture under fluoroscopy (3.5mm superior midshaft clavicle plate; Acumed Oregon, USA).

Skin and subcutaneous tissue was passed through by an approximately 2cm longitudinal skin incision from the medial of the acromioclavicular joint. The periosteum was reached by blunt dissection over the clavicle and with the aid of cauterization between the trapezius and deltoid muscles. Then, elevating the periosteum with the plate crossing the fracture line from lateral to medial, a tunnel that reached at the medial fragment was formed. The anatomic locking clavicular plate was advanced percutaneously from the lateral side (Figure 2). The plate was palpated over the medial fragment and a mini longitudinal incision of approximately 2 cm was made over the fragment. Without opening the fracture line and by supporting the extremity from below under fluoroscopy

guidance, the distal fragment was taken above and laterally by applying abduction, and thus the clavicular length and reduction were obtained. A blunt-tipped retractor was used during reduction. When adaptation of the plate over the fracture was achieved, after ensuring that the screw holes remained over the bone, first one unlocked spongy screw was placed in the most distal hole, thus retracting the plate to the bone. Then, with a second unlocked cortical screw placed from the medial, the plate was adapted to the bone (Figure 3). When the reduction was decided to be satisfactory (cortical contact provided on the superior surface of the fracture line) as verified by fluoroscopy (Figure 4), the fracture was fixed by placing two locking cortical spongy screws to the medial and two to the lateral. The deltoid and trapezius muscles which had been separated were repaired end-to-end. Skin-subcutaneous sutures were applied. After applying a dressing, a shoulder arm sling was applied to the patient, and the procedure was completed (Figure 5,6).



**Figure 1.** The sternoclavicular joint, the fracture line, and the acromioclavicular joint were marked before surgery.



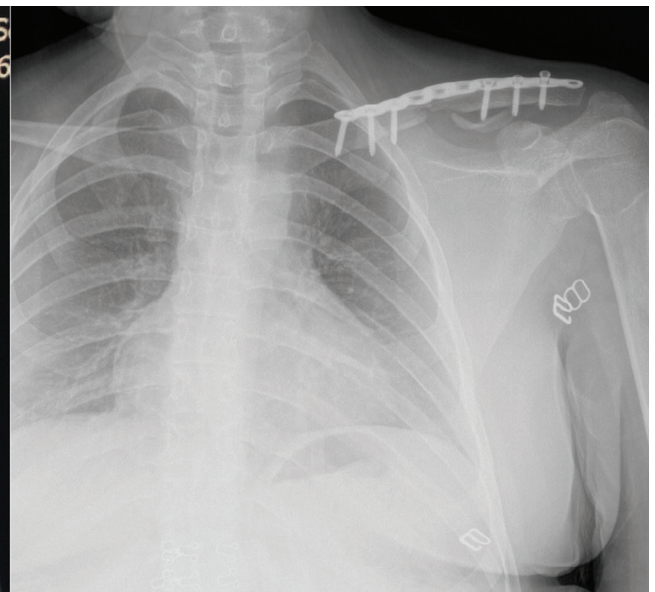
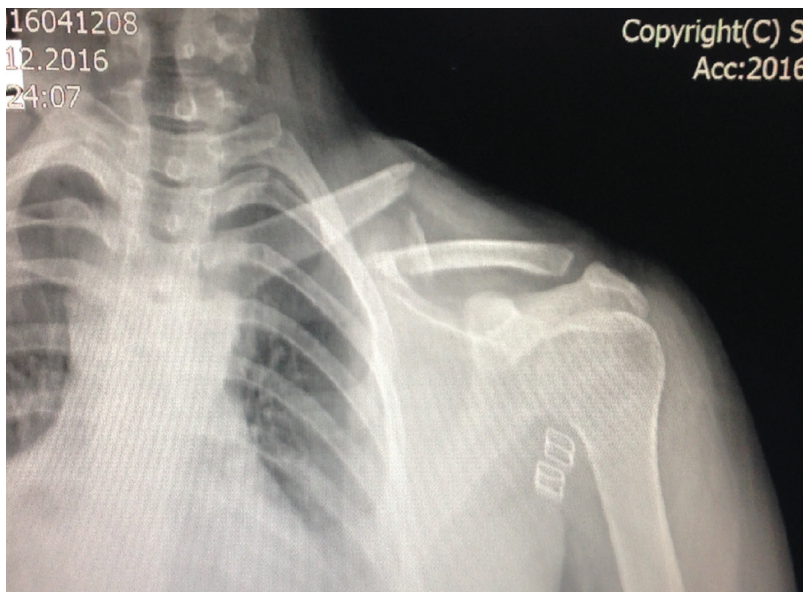
**Figure 2.** The anatomic locking clavicular plate was advanced percutaneously from the lateral side.



**Figure 3.** With a second unlocked cortical screw placed from the medial, the plate was adapted to the bone



**Figure 4.** Intra-operatively fluoroscopic confirmation of the reduction,



**Figure 5, 6.** Preoperative and postoperative X-Rays of the patient.

### Postoperative rehabilitation

The shoulder arm sling was continued for 6 weeks postoperatively. On postoperative day 2, pendular shoulder exercises allowing joint range of movement, wrist, and elbow movements were permitted to the level of pain tolerance. Daily activities were not permitted for 6 weeks. Lifting of any weights was not permitted unless full union was ensured.

### Follow-up and evaluation

The duration of surgery and length of hospital stay were recorded. The first postoperative follow-up examination was at 2 weeks. Sutures were removed, radiographs were taken (shoulder AP-30° cephalic and caudal tilt radiographs), and early VAS scores were evaluated. Subsequent follow-up examinations were at monthly intervals from 6 weeks onwards until full union was determined. At 3 months after confirmation of full union, functional evaluation was made by measuring the Constant Murley and UCLA scores. The time to union and the amount of shortening in the clavicular length by comparison with the unaffected side was measured.

Union was accepted as the presence of bone bridging in the fracture line along with no pain in the physical examination. Lack of union until 24 weeks was considered as non-union. Presence of non-union, infection, joint stiffness, neurovascular injuries, implant failure, skin irritation, sensitivity, or sensory loss was considered as complication events.

### Results

The mean duration of surgery was 65.5 mins (range: 50-80 mins). At the 2nd-week postoperative follow-up visit, pain over the operated area was found to be below the satisfactory level with a mean VAS score of 2.1 (range: 1-5). The mean length of hospital stay was determined as 1.5 days (range: 1-3 days).

Anatomic reduction was obtained in 11 (47%) patients, of whom 7 were Type B1, 4 were Type B2, and 1 was Type B3. The mean Constant Murley score of these patients was 82.8 (range: 70-90) and the mean UCLA score was 29.6 (range: 23-34). There was no

statistically significant difference for the Constant Murley score and UCLA score between patients with anatomic reduction achieved and not achieved. ( $p=0.36$ ,  $p=0.43$  respectively) (Table 1).

**Table 1.** Comparison of Constant Murley and UCLA scores of patients with anatomic and non-anatomic reduction.

|                 | Anatomic reduction |      | Non anatomic reduction |      | p    |
|-----------------|--------------------|------|------------------------|------|------|
|                 | Mean               | ± SD | Mean                   | ± SD |      |
| N of patients   | 11                 |      | 12                     |      |      |
| Constant Murley | 84.8               | 4.5  | 81.5                   | 5.5  | 0.36 |
| UCLA            | 30.6               | 3.4  | 29.28                  | 4.2  | 0.43 |

Independent sample t test was used.

Union was observed in 21 patients with no requirement for a second surgical intervention. Non-union was seen in two (8.6%) patients. One of these patients had an AO-OTA Type B2 fracture and the other one with a history of 30 pack-years smoking had a Type B3 fracture. In both of these patients, the implant was removed, grafting was applied by harvesting autogenous bone graft from the iliac wing, plating was applied again, and union was obtained. The mean time to union was found to be 15.9 weeks (range: 10-24 weeks). After union was confirmed, the mean Constant Murley score was 83 (range: 68-92) and the mean UCLA score was 29.95 (range: 23-34). The mean proportional length difference in the clavicle was 0.32% (range: -0.55 to +1.63).

Superficial soft tissue infection was observed in the early period in two patients who were successfully managed with oral antibiotics. No patient had late stage or deep tissue infection. Two patients developed postoperative brachial plexus injury. Both of these patients were AO-OTA Type B3. The injury was evaluated as neuropraxia that was thought to be associated with traction or compression in both cases, where physical therapy was applied and monitored. Nerve functions were restored at week 8 and 12, respectively, and these patients recovered with no sequelae. No complications such as plate breakage or screw pull-out were seen in any patient. In three patients, the implants were removed after full union on the request of the patients as they felt discomfort associated with plate prominence.

## Discussion

In recent studies, open reduction and internal fixation in the treatment of acute displaced clavicular midshaft fractures has been shown to have come to the fore with better clinical and functional outcomes together with lower complication rates compared to conservative treatment [9]. The minimally invasive technique has become a popular surgical modality as it offers biological bone healing with the protection of fracture hematoma since the fracture line is not opened and less soft tissue and periosteal damage occurs with protection of periosteal circulation [10]. In the comparisons with open reduction and plate fixation in several recent studies, the minimally invasive technique has been shown to be successful at a satisfactory level [8-10].

Intramedullary pinning, which can be applied in a minimal invasive fashion, is a widely used technique. However, despite the successful outcomes in literature, high complication rates were reported to be associated with the pins used [11-12]. In particular,

because of insufficient rotational stability, it is not considered as an appropriate treatment option for Type B fractures. High rotational stability is particularly evident with plate osteosynthesis. In the current study, no rotational instability developed in any patient.

Studies in literature reported an incidence of 6-15% for non-union following osteosynthesis with open reduction of displaced clavicular fractures [13-14]. However, these studies were not conducted on a specific fracture type, and non-union rates were reported as overall. In the current study, although all the fractures were AO-OTA Types B1, B2 and B3, the non-union rate was 8.6%. One of the two patients with non-union was a long-term smoker and the other had a Type B3 fracture.

For successful fracture healing of clavicular fractures, anatomic reduction is recommended [2]. Anatomic reduction of Type B3 fractures in particular could be difficult if performed without making an additional incision and opening the fracture line. As the principle of the MIPO technique is not compatible with opening the fracture line, the fracture line was not opened in any patient in the present study. The aim of reduction in this study was to provide cortical contact between the medial and lateral fragments and thereby obtain indirect reduction by providing appropriate length, accepting the length of the contralateral clavicle as reference. The mean length of shortening in the clavicle was found to be consistent with reports from the literature.

In the placement of the plate, techniques have been described of anterior application from the inferior and superior [11]. Although anterior inferior plates have advantages like absence of protrusion below the skin, a high risk of vascular and nerve injury was reported because of the close proximity to the subclavian artery [15]. On the other hand, superior plating was recommended to increase plate stability in the indirect reduction of multi-fragmented fractures [16]. In the current study, superior plating was applied due to the plate type used (3.5mm anatomic locking clavicular plate) and fracture types included in the study. Because of the S-shaped curve structure previously applied to the plate to conform to the curves of the clavicle, no bending or curving of the plate was made intraoperatively. In fact, previous studies reported that intraoperative bending and curving procedures applied to the plate for compatibility with the bone increased the fragility of the plate [11-17]. In the current study, no screw pull-out, screw breakage, plate breakage, or complications related to plate instability were observed in any patient. The implant was removed in three cases because of discomfort from feeling the plate prominence.

The prevalence of sensory loss associated with supraclavicular nerve damage following open reduction was reported as 29% [18]. In a study which evaluated 269 patients undergoing MIPO, sensory loss associated with nerve damage was reported in only one patient. This was thought to be related to an additional incision made for the reduction [2]. In the present study, no sensory loss associated with suprascapular nerve damage was observed.

Although full anatomic reduction was not obtained in all the patients of the current study, mean Constant Murley and UCLA scores, and the time to union were found to be consistent with literature [19]. An excellent-good ( $>27$ ) Constant Murley score was determined in 20 (86%) patients. In three patients with a low functional score, the mean age was seen to be 58.6 years. In 2 of

these patients, the fracture was AO OTA Type B2 and in the other, the fracture was Type B3. Although union was obtained, the low functional scores of these patients was thought to be associated with non-compliance with the rehabilitation program. In addition, in comparison of the groups where anatomic and non-anatomic reduction was obtained, no significant difference was determined in respect of time to union, functional scores or complication rates.

In a study by Asadollahi et al., postoperative superficial wound infections were reported as 3.6%-10% [20]. Rates of deep tissue infections in intramedullary nailing and plate fixation were noted to be 7% and 1%, respectively [20]. In the current study, no deep tissue infection was observed, but superficial soft tissue infection was seen in two (8.6%) patients. This was thought to be associated with difficulties experienced during reduction in these patients since the duration of surgical procedure of these patients was relatively longer than that of other patients. Despite the mean operating time of 65.5 mins, the mean operating time of these 2 patients was 75 mins.

Brachial plexus injury was reported as 0%-1.5% after surgery of clavicular fractures [21-22]. In a cadaver study by Lo et al, it was shown that the brachial plexus passed approximately 12mm below the clavicular midshaft [15]. The injury may develop secondary to trauma, compression, or entrapment. Literature search showed no report of brachial plexus injury following surgery applied with the MIPO technique. Brachial plexus paralysis developed in two (8%) of the current study patients. In both patients, neuropraxia was considered associated with traction or compression, and they recovered with no sequelae in mean of 10 weeks with physical therapy and conservative monitoring. It was reported that traction-related injuries could take up to 6 months to recover [23]. These patients in the current study were AO OTA Type B3 and the mean operating time (80 mins) was longer than the mean of the whole group. These injuries were thought to be associated with the forced abduction applied to obtain clavicular length and excessive elevation to raise the lateral fragment, which were performed during reduction.

Present study has some limitations. There was no control group of different treatment procedures which could be compared with MIPO. In addition, study population was small in size with limited number of subjects for fracture subtypes. The follow-up period was not long enough to determine long-term complications, and both the patient and surgical staff were exposed to long periods of radiation with the use of fluoroscopy for the application of the closed technique.

## Conclusion

The results of this study show that osteosynthesis with a minimally invasive percutaneously applied plate (MIPO) could be a successful therapeutic option for the management of acute, displaced AO OTA Type B clavicular midshaft fractures. In addition to very good radiological and functional outcomes, it is a method which may be preferred by patients with high cosmetic expectations. However, this technique may be associated with several complications such as infection and neurovascular injuries, potentially due to prolonged duration of the surgery and excessive force maneuver to ensure fracture reduction. If necessary, the procedure can be completed by converting to an open fixation method without forcing reduction.

## References

1. Khan LA, Bradnock TJ, Scott C, Robinson CM. Fractures of the clavicle. *J Bone Joint Surg Am.* 2009;91(2):447-60.
2. Tieyi Y, Shuyi L, Yan Z, Guohua H, Jin S, Rui J. Minimally invasive plating for fresh displaced midshaft fractures of the clavicle. *Orthopedics.* 2014;37(10):679-83.
3. Leroux T, Wasserstein D, Henry P, Khoshbin A, Dwyer T, Ogilvie-Harris D, Mahomed N, Veillette C. Rate of and Risk Factors for Reoperations After Open Reduction and Internal Fixation of Midshaft Clavicle Fractures: A Population-Based Study in Ontario, Canada. *J Bone Joint Surg Am.* 2014;96(13):1119-25.
4. Collinge C, Devinney S, Herscovici D, DiPasquale T, Sanders R. Anterior-inferior plate fixation of middle-third fractures and nonunions of the clavicle. *J Orthop Trauma.* 2006;20(10):680-6.
5. Kulshrestha V, Roy T, Audige L. Operative versus nonoperative management of displaced midshaft clavicle fractures: a prospective cohort study. *J Orthop Trauma.* 2011;25(1):31-8.
6. McKee RC, Whelan DB, Schemitsch EH, McKee MD. Operative versus nonoperative care of displaced midshaft clavicular fractures: a meta-analysis of randomized clinical trials. *J Bone Joint Surg Am.* 2012;94(8):675-84.
7. Der Tavitian J, Davison JN, Dias JJ. Clavicular fracture non-union surgical outcome and complications. *Injury.* 2002;33(2):135-43.
8. Sohn HS, Kim WJ, Shon MS. Comparison between open plating versus minimally invasive plate osteosynthesis for acute displaced clavicular shaft fractures. *Injury.* 2015;46(8):1577-84.
9. Zlowodzki M, Zelle BA, Cole PA, Jeray K, McKee MD; Evidence-Based Orthopaedic Trauma Working Group. Treatment of acute midshaft clavicle fractures: systematic review of 2144 fractures: on behalf of the Evidence-Based Orthopaedic Trauma Working Group. *J Orthop Trauma.* 2005;19(7):504-7.
10. Sohn HS, Shin SJ, Kim BY. Minimally invasive plate osteosynthesis using anterior-inferior plating of clavicular midshaft fractures. *Arch Orthop Trauma Surg.* 2012;132(2):239-44.
11. Zhang Y, Xu J, Zhang C, Sun Y. Minimally invasive plate osteosynthesis for midshaft clavicular fractures using superior anatomic plating. *J Shoulder Elbow Surg.* 2016;25(1):e7-12.
12. Zehir S, Zehir R, Şahin E, Çalbıyık M. Comparison of novel intramedullary nailing with mini-invasive plating in surgical fixation of displaced midshaft clavicle fractures. *Arch Orthop Trauma Surg.* 2015;135(3):339-44.
13. Wijdicks FJ, Van der Meijden OA, Millett PJ, Verleisdonk EJ, Houwert RM. Systematic review of the complications of plate fixation of clavicle fractures. *Arch Orthop Trauma Surg.* 2012;132(5):617-25.
14. Canadian Orthopaedic Trauma Society. Nonoperative treatment compared with plate fixation of displaced midshaft clavicular fractures. A multicenter, randomized clinical trial. *J Bone Joint Surg Am.* 2007;89(1):1-10.
15. Lo EY, Eastman J, Tseng S, Lee MA, Yoo BJ. Neurovascular risks of anterior-inferior clavicular plating. *Orthopedics.* 2010;33(1):21.
16. Favre P, Kloen P, Helfet DL, Werner CM. Superior versus anteroinferior plating of the clavicle: a finite element study. *J Orthop Trauma.* 2011;25(11):661-5.
17. VanBeek C, Boselli KJ, Cadet ER, Ahmad CS, Levine WN. Precontoured plating of clavicle fractures: decreased hardware-related complications? *Clin Orthop Relat Res.* 2011;469(12):3337-43.

18. Wang K, Dowrick A, Choi J, Rahim R, Edwards E. Post-operative numbness and patient satisfaction following plate fixation of clavicular fractures. *Injury*. 2010;41(10):1002-5.
19. Sohn HS, Shon MS, Lee KH, Song SJ. Clinical comparison of two different plating methods in minimally invasive plate osteosynthesis for clavicular midshaft fractures: A randomized controlled trial. *Injury*. 2015;46(11):2230-8.
20. Asadollahi S, Hau RC, Page RS, Richardson M, Edwards ER. Complications associated with operative fixation of acute midshaft clavicle fractures. *Injury*. 2016;47(6):1248-52.
21. Wijdicks FJ, Van der Meijden OA, Millett PJ, Verleisdonk EJ, Houwert RM. Systematic review of the complications of plate fixation of clavicle fractures. *Arch Orthop Trauma Surg*. 2012;132(5):617-25.
22. S Thyagarajan D, Day M, Dent C, Williams R, Evans R. Treatment of mid-shaft clavicle fractures: A comparative study. *Int J Shoulder Surg*. 2009;3(2):23-7.
23. Jeyaseelan L, Singh VK, Ghosh S, Sinisi M, Fox M. Iatrogenic brachial plexus injury: a complication of delayed fixation of clavicle fractures. *Bone Joint J*. 2013;95-B(1):106-10.