Minimally Invasive Plating for Fresh Displaced Midshaft Fractures of the Clavicle

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The clavicle is one of the most commonly fractured bones, accounting for 2.6% of adult fractures and 35% of shoulder injuries.1 Approximately 80% of all fractures of the clavicle are midshaft fractures.2 Traditionally, conservative treatment has been employed for clavicle fractures.3 Recently, however, open reduction and internal fixation has been recommended for significantly displaced fractures in adults.4

In the past several years, various methods, involving Kirschner wires, intramedullary wires, cannulated screws, plates, and Knowles pins, have been used and satisfactory results have been achieved with internal fixation for displaced midshaft fractures of the clavicle.5 The minimally invasive plate osteosynthesis (MIPO) technique, having the advantage of minimal soft tissue compromise, has been widely used to treat limb fractures. To the best of the authors’ knowledge, only Sohn et al6,7 have published about this technique applied for midshaft fracture of the clavicle. The current authors describe the technique and the clinical results of MIPO with a universal reconstruction ribbon plate (URRP) for fresh displaced midshaft fractures of the clavicle.

Materials and Methods

A total of 269 patients who underwent the MIPO technique with URRP for fresh displaced and comminuted midshaft fracture of the clavicle from September 2006 to August 2011 were retrospectively reviewed. Indications for surgery included persistent separation of the fracture with a gap more than half the diameter of the clavicle. Of these patients, 167 were men and 102 were women. Mean age was 40.2±5.6 years (range, 18-69 years). Fifteen patients had insulin-dependent diabetes mellitus, 10 had hypertension, and 40 were heavy smokers (>20 cigarettes per day) or heavy drinkers (>500 g of alcohol per week). In addition, 190 patients were Type 2B1 and 79 were Type 2B2 according to the Robinson classification.2
Surgical Technique

While under general or regional (interscalene brachial plexus block) anesthesia, the patient was placed in the supine position, with a small pad below the scapula and the involved upper extremity tucked into the bed sheet. The patient’s head was slightly tilted to the opposite side to allow easy access to the clavicle with surgical instruments. The fracture site, sternoclavicular joint, and acromioclavicular joint were marked under C-arm fluoroscopy (Figure 1A). The surgical site was prepared using a sterile procedure and then draped. According to the fluoroscopic image, a proper 3.5-mm URRP (DePuy International Ltd, Shanghai, China) was bent to an “S” shape to match the clavicle (Figures 1B and 2A).

A 1.5-cm longitudinal skin incision was made laterally and then medially over the superior surface of the clavicle. The dissection was carefully extended sharply down to the periosteum after identifying the supracleavicular cutaneous nerves. An extraperiosteal tunnel was created by passing a tunneling instrument (Figure 2B). The bent plate was inserted into the extraperiosteal tunnel (Figure 1C).

The authors usually first fixed screw 1 (Figure 2C) and then reduced the fracture by closed manipulation. Typically, the medial fragment was displaced superiorly, while the lateral fragment was displaced inferiorly, translated medially, and rotated anteriorly. Usually, the shortened displacement was partly reduced by inserting the small pad below the scapula, which caused the shoulder to be in abduction. The complete reduction of shortened displacement through pushing the plate outward using the retractor (Figure 2D) was followed by the fixation of screw 5 (Figure 2E). Next, the authors fixed screws 3, 6, 4, and 2 in turn with the individual lateral and medial incisions (Figures 2F-H). The superior-inferior displacement was reduced by the force of the screw pulling the bone to the plate (Figures 2F-G). A blunt retractor was usually used to reduce the fragment (Figure 2D). In 4 patients, an additional incision within 1 cm of the fracture was used because the fragment could not be indirectly restored to good alignment. At least 3 screws were fixed in each of the lateral and medial fragments (Figure 2H). To preserve important adjacent structures, the clavicle must be precisely drilled. The incisions were routinely closed and sutured without closed drainage. No bone graft was applied, even at the site of comminuted fracture.

Results

Mean follow-up was 40.6 months (range, 14-60 months). All patients had bony union, with the average healing time being 14.6 weeks (range, 8-46 weeks), and 2 patients had delayed union. On functional evaluation of the shoulder at 2-month postoperative follow-up, the mean Constant-Murley score was 92 points (range, 66-100 points; scoring system range, 0-100 points; ideal, 100 points) and the mean Disabilities of the Arm, Shoulder and Hand score was 4.6 points (range, 0-23 points; scoring system range, 0-100 points; ideal, 0 points).

In all patients, pain in the area of the fracture decreased significantly within approximately 1 week. Neither pulmonary injury nor neurovascular...
impairment was noted postoperatively. One patient reported an approximately 3-cm² area of peri-incisional numbness. One plate breakage was noted (Figures 3A-B); this patient eventually healed without functional impairment and underwent hardware removal 14 months postoperatively. Two patients had medial screws removed at 9 and 11 weeks postoperatively, respectively. Both healed with conservative care without secondary displacement and underwent hardware removal at 11 and 13 months postoperatively, respectively (Figures 3C-D). A total of 166 patients underwent hardware removal at an average of 15 months (range, 10-26 months). None had re-fracture after hardware removal. Overall, 258 (96%) patients were satisfied with the results of this surgery.

**Discussion**

For decades, open reduction and internal fixation has been used for midshaft clavicle fractures. One major disadvantage of plate osteosynthesis is the large incision, which leads to soft tissue trauma and denuding of bone fragments. Because of this limitation, the authors attempted a modified technique of closed reduction and plate fixation for mid-shaft clavicle fractures. It is based on the principle of the MIPO technique, involving a percutaneously inserted plate that bridges both the medial and the lateral fragments. The rationale for using this technique is as follows. First, the clavicle is located subcutaneously, making it easier to identify the incisions, create the subcutaneous tunnel, and reduce fractures with closed reduction. Second, plate fixation with the MIPO technique can minimize soft tissue dissection, thus promoting bony union, reducing soft tissue complications, and leading to a smaller surgical scar compared with conventional open reduction and internal fixation. Third, plate fixation has better biomechanical performance and anti-rotation ability and lower risk of secondary shortening compared with intramedullary fixation.

A recent systematic review showed that the rate of non-union of dislocated midshaft clavicle fractures was less than 10% after plate fixation. In the current series, none failed to unite but there were 2 delayed unions. The MIPO technique and anatomical reduction of fracture fragments are essential for fracture union. In comminuted fractures, the
length of the contralateral clavicle was assessed clinically and radiographically to restore the shortened fragments. In the authors’ practice, achieving cortical contact or avoiding a fracture gap was kept in principle. In cases with significantly displaced fragments, an additional incision is useful for achieving good reduction.

The URRP, a special type of reconstruction plate with a combination of screw holes and connecting rods, can be easily bent to the shape of the clavicle. Due to the multi-axial displacement of the clavicle, the plate was bent to an “S” shape in this series. Thus, the laterally superior-inferior screws were fixed to the flat acromial end of the clavicle and the medially superior-inferior screws with an anterior tilt of 20° to 30° were fixed to the triangular sternal end of the clavicle, which disperses stress during movement of the clavicle. Recently, in a series of acute displaced clavicular midshaft fractures treated with MIPO, a union rate of 100% with good shoulder function and a low complication rate were achieved.6,7 That study used a 3.5-mm locking reconstruction plate fixed at the anterior-inferior aspect of the clavicle. The anterior-inferior plate had a lower failure load in cantilever bending in addition to the advantages of the safe use of screws, the implant being less prominent outside the skin, and more stiffness in axial compression or torsion than the superior plate.12,13 The current authors prefer the superior plate because, in most circumstances, the major forces are an inferior pull on the lateral clavicle generated by the trapezius, the latissimus dorsi, the clavicular section of the pectoralis muscle, and the concentric action of the anterior deltoid.14 Lateral plate liftoff is a concern with superior plating. The long plate required by the MIPO technique can decrease the incidence of this. In addition, to increase the resistance to pullout, the authors commonly used a cancellous screw in screw 1 (Figure 2C) and discouraged heavy lifting until radiological evidence of bony union appeared. The authors found that medial screw pullout was most likely due to insufficient anterior rotation of the medial part of the plate. One case of plate breakage was found at the connection between screw holes; this may have been partly due to excessive twisting preoperatively.

Postoperatively, all of the patients were placed in a sling for 2 weeks. Heavy lifting was discouraged until radiological evidence of bony union appeared. Range of motion exercises for the shoulder joint in the scapular plane were begun once patients could tolerate postoperative pain. Patients were followed and evaluated at least until union was achieved on physical and radiographic examination. Radiographic union was defined as complete cortical bridging between proximal and distal fragments on radiographs.

The lowest Constant-Murley score occurred in a patient who had an associated scapular fracture and brachial plexus nerve injury. The other low scores occurred in patients with proximal humeral fractures. These 2 patients had shoulder pain and moderate restriction of abduction and external rotation.

After open reduction and internal fixation of midshaft clavicle fractures, the incidence of numbness of the peri-incisional skin and proximal chest wall due to supraclavicular nerve injury has been reported to range from 12% to 29%.15 The supraclavicular nerve comprises medial, lateral, and/or intermediate branches. There are small safe zones medially and laterally, with no medial branches found within 2.7 cm of the sternoclavicular joint and no lateral branches found within 1.9 cm of the acromioclavicular joint.16 In the current study, only 1 patient, a 45-year-old man with an additional incision at the middle-third of the clavicle to achieve good reduction of comminuted fractures, reported an approximately 3-cm² area of peri-incisional numbness, appearing to indicate that the intermediate branch of the supraclavicular nerve was damaged. The low rate of cutaneous nerve damage in this study was likely due to 2 factors. First, with this technique, most of the incisions lie in the lateral and medial safe zones. Second, the branches may provide reciprocal innervation in case of injury to 1 branch.

An unattractive scar has been a common deterrent to surgery for clavicle fractures. The current method resulted in less visible scars compared with conventional plate fixation, and most patients, especially those who were female, were satisfied with their appearance postoperatively. However, hardware prominence, an inherent shortcoming of plating, was inevitable in this series. A total of 166 patients (62%) underwent hardware removal, mainly due to Chinese culture not accepting implants in the human body and a high percentage of accidents in this study requiring hardware removal to complete the procedure and receive final reimbursement. This was a significantly higher number than in previous reports.5,10

CONCLUSION
This retrospective study had the limitation of no alternative treatment or control group with which to compare the results. However, the preliminary results demonstrate that this minimally invasive technique is safe, simple, effective, and practical and leads to rapid recovery, a high rate of union, a favorable cosmetic outcome, and excellent function restoration. Therefore, it can be considered an alternative to conventional plate osteosynthesis, intramedullary fixation, or non-operative treatment for fresh displaced midshaft clavicle fractures.

REFERENCES


