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Locked anatomic plate fixation in displaced clavicular fractures

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Objective: We aimed to evaluate the results and complications of open reduction and internal fixation by locked anatomic plates in adult midshaft clavicular fractures.

Methods: Sixteen patients (11 males, 5 females; mean age: 39.6 years) who underwent open reduction and internal fixation with locked anatomic plate for displaced-comminuted midshaft clavicular fractures and were followed-up for at least one year were reviewed retrospectively. Complications in the early and late postoperative periods and functional scores according to the Constant and DASH scoring systems from the latest follow-up were evaluated.

Results: Mean follow-up period was 24.6 (range: 12 to 52) months and mean union time was 13.3 (range: 10 to 23) weeks. None of the patients had superficial and/or deep infections in the early postoperative period or neurovascular complications. Two (12.5%) patients had implant irritation. In two (12.5%) patients, implant failure was detected in the late postoperative period. Delayed union was suspected in these patients and they were operated with longer plate and grafting in the 4th month. At the final follow-up, none of the patients had nonunion or malunion and the mean Constant and DASH scores were 85.5 and 12.8, respectively. Constant scores in patients with complications (p=0.007) and DASH scores in patients with no complications (p=0.001) were significantly lower.

Conclusion: Fixation with locked anatomic plates in displaced midshaft clavicular fractures has lower complication rates. Possible postoperative complications are generally associated with implant irritation and failure. These problems can be avoided with the development in implant technology and new implant designs.

Key words: Clavicle; displaced; fracture; locked anatomic plate; open reduction; plate fixation.

The traditional treatment choice for clavicle fractures is conservative. Surgical treatment indications are open fractures, fracture ends irritating the skin, accompanying neurovascular injury, floating shoulder injury, patients with polytrauma and cases with nonunion after conservative treatment. Good and excellent functional results can be achieved with conservative treatment for clavicle fractures in children and adolescents in which cortical contact is maintained.[1] However, high nonunion and symptomatic malunion rates following the conservative treatment of displaced and comminuted fractures, high functional expectations of patients and the development in implant technology have led to a higher number of surgeries.[2-7] Therefore, complication rates have increased correspondingly.

There is no clear consensus on the ideal implant to be used in the surgical treatment of clavicle fractures.

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Nowadays, intramedullary fixation and plate fixation methods are preferred. Intramedullary fixation has some advantages, such as a small incision, protection of soft tissue coverage and bone nutrition, prevention of supraclavicular nerve injury and easy extraction of the implant even with local anesthesia; however, disadvantages include implant migration and corresponding failure, refracture after implant extraction and nonunion.[8,9]

Currently, plate fixation is the preferred method. However, problems related to this method, such as infection, skin problems, nonunion, implant failure, poor cosmetic results and localized numbness have been reported.[9,10] In addition, approximately 30% of patients request implant extraction after fracture healing due to skin irritation.[5] Generally, outcomes following fixation with reconstruction plates and straight plates are reported in the literature.[5-7,9,10] Relatively fewer clinical studies related to locked anatomic clavicle plates exist and the current literature focuses mainly on biomechanical studies.[11-13]

In our study, the clinical and radiographic outcomes of open reduction and internal fixation of clavicle fractures with locked anatomic plates and the related complications were evaluated retrospectively.

Patients and methods

Patients treated for clavicle fractures between October 2006 and November 2010 were retrospectively evaluated. Patients between the ages of 18 and 65 who underwent surgery for isolated midshaft clavicle fractures without any cortical contact between the main fragments were included in the study. The exclusion criteria were fractures at the proximal or distal end of the clavicle, fractures with cortical continuity, accompanying fractures of the shoulder girdle, accompanying acromioclavicular joint pathologies and/or rotator cuff tears, open and pathological fractures, accompanying neurovascular injury, untreated fractures for more than three weeks, medical pathologies that prevent surgery and patients younger than 18 or older than 65 years. According to these criteria, 25 patients were evaluated. Five patients dropped out of the follow-up and an additional four patients were not evaluated at the final follow-up. The study group consisted of 16 (11 males, 5 females) patients who had at least one year of follow-up. The mean age of patients was 39.6 (range: 18 and 65) years at the time of surgery. All patients were informed about further investigations within this study at their latest follow-up.

Eight patients had left- and eight patients had right-sided fracture. Twelve patients had fracture at the dominant upper extremity. Trauma mechanism was car accident for eight patients, sports trauma in four patients and direct trauma in four patients. Two patients had accompanying rib fractures and one patient had a rotationally and vertically stable pelvis fracture on the same side. All accompanying injuries were treated conservatively.

Standard and 20° caudal anterior-posterior shoulder radiographs were evaluated in all patients after neurovascular examination (Fig. 1a). Shortness of more than 2 cm was detected in seven (43.7%) patients and nine (56.3%) patients had comminuted-segmented clavicle fractures. Patients underwent surgery for a mean of 5.5 (range: 1 to 12) hours after trauma. One gram of first generation cephalosporin (Cefazolin) prophylaxis was applied to all patients 30 minutes before surgery. Patients were operated under general anesthesia in the beach chair position. A straight incision was made over the fracture line. Butterfly or free fragments in comminuted fractures were fixed to the main fragment with a lag screw in four (25%) patients before fracture reduction and were fixed to the plate in four (25%) patients after fracture reduction. A small fragment which could not be fixed was sutured with non-absorbable suture material (Ethibond 2.0; Ethicon Inc., Somerville, NJ, USA) in one (12.5%) patient. Periosteal damage was avoided during the surgery as much as possible. After reduction of the main fragments, titanium alloy, locked anatomic compression plates (Acumed; Hillsboro, OR, USA) were applied on the superior surface of the clavicle. A minimum of six cortexes were fixed with 3.5 mm locked cortical screws on the medial and lateral sides of the fracture (Fig. 1b). Auto- or allografts were not used in any patient during the surgery.

A shoulder-arm splint was applied to the upper extremity in all patients for three weeks following the surgery. Passive shoulder exercises were started at the second postoperative day and active range of motion exercises were started at the third week. Patients were discharged in a mean of 2 (range: 1 to 4) days after surgery and were evaluated with radiographs and clinical examination at the 3rd, 6th and 12th weeks and the 6th and 12th months postoperatively (Fig. 1c). Shoulder strengthening exercises were started at the 6th week depending on the presence of radiological and clinical healing. At the end of the 3rd month, all pre-trauma movements and activities were permitted, excluding contact sports. At the end of the 6th month, all activities were permitted without any limitation.

Patients were evaluated for wound problems, superficial and deep infections, neurovascular complications, and skin irritation at the early follow-ups. After the 3rd month, nonunion, malunion, implant failure and keloid

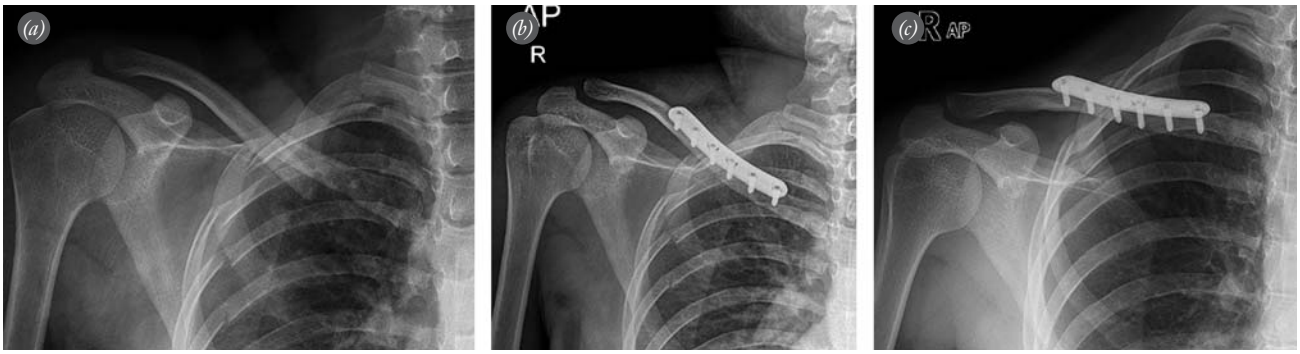

Fig. 1. **(a)** Preoperative anteroposterior shoulder radiograph of a 25-year-old female patient showing right midshaft clavicle fracture with 2 cm shortening **(b)** Postoperative radiograph of the shoulder. **(c)** Control radiograph at 12 months.

formation were evaluated. Radiologically visible callus formation after 24 weeks was accepted as delayed union and no callus formation, pathological movement and pain after 24 weeks were accepted as nonunion.[6,8] Malunion was described as the malalignment of the clavicle anatomical alignment and asymmetry when compared with the uninjured clavicle.[8] Implant failure was described as a loss of anatomical reduction with bending of the plate or a broken plate and loosening of the screws.[8] Functional evaluation was made by using the Constant shoulder[10,14] and disability of the arm, shoulder and hand (DASH)[1,15] scores at the final follow-up.

NCSS 2007 software package (NCSS Statistical Software, Kaysville, UT, USA) was used for statistical evaluation. Apart from descriptive statistical methods, such as mean and standard deviation (SD), functional scores of complicated and non-complicated cases were compared using the chi-square test. A p value of <0.05 was considered statistically significant.

Results

The mean follow-up period was 24.6 (range: 12 to 52; SD: 13) months and mean union time was 13.3 (range: 10 to 23; SD: 3.7) weeks. None of the patients had nonunion at the final follow-up.

There were no superficial or deep surgical site infections in the early postoperative period. Implant irritation was detected in two (12.5%) patients (Fig. 2). After clinical and radiological healing, implants of these two patients were removed at the 4th and 5th months. No refracture was detected after implant removal. Implants of the other patients without irritation were not removed. Implant failure was detected in two (12.5%) patients after the 3rd month. Loss of reduction of the fracture and loosening of the screws located on the lateral side of the fracture line were detected in both of these. These findings were accepted as delayed union and patients underwent second surgeries at the 4th month. Autogenous grafting and fixation with longer plates (8 holes) were applied. Healing was detected at their last follow-up. There was no keloid formation on the surgical incision in any patient at the final follow-up.

At the final follow-up, the mean Constant shoulder and DASH scores were 85.5 (range: 70 to 96; SD: 7.2) and 12.8 (range: 6.1 to 23.25; SD: 5.3), respectively. Of the 4 patients with complications (25%), the mean Constant shoulder and DASH scores were 78 (range: 70 to 89; SD: 7.5) and 20.7 (range: 18.4 to 23.25; SD:

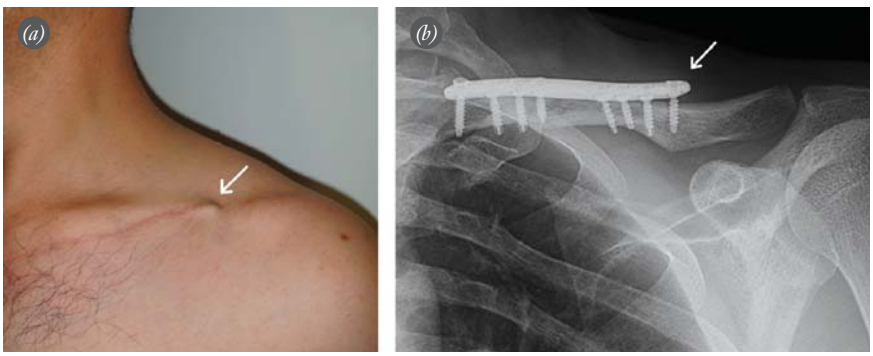

Fig. 2. **(a)** Clinical and **(b)** radiological postoperative views of a patient who was treated by open reduction and internal fixation with locked anatomic clavicle plate due to midshaft fracture. The marked lateral edge (white arrow) of the plate under the skin is seen at the 5th month. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

2.1), respectively. However, for patients without complications the mean Constant shoulder and DASH scores were 88 (range: 82 to 96; SD: 4.7) and 10.2 (range: 6.1 to 12.3; SD: 2.6), respectively. Constant scores of patients with complications (p=0.007) and DASH scores of patients without complications (p=0.001) were significantly lower.

Discussion

Nonunion and symptomatic malunion rates of clavicle fractures occurring after high-energy trauma with a shortening greater than 20 mm, displacement, angulation greater than 30º or fragmentation are high.[16] It is reported that malunion impairs the static anatomical relations of the shoulder girdle and leads to restriction of extension and abduction movements of the glenohumeral joint.[17] In addition, shoulder asymmetry and related cosmetic displeasure has been reported due to shortening greater than 20 mm.[3] In this study, primary indications of surgery in midshaft fractures were a shortening greater than 20 mm and a segmented-comminuted fracture type.

In a systematic review of 22 studies reporting conservative and surgical outcomes of midshaft clavicle fractures (2,144 fractures),[5] the nonunion rate after conservative treatment was reported as 5.9% for all fractures and 15.1% for displaced fractures. A 20 to 25% decrease of shoulder and arm strength at the five year follow-up due to conservative treatment was also reported. Related factors of nonunion and progression of long-term sequels after conservative treatment were listed as; displacement at the fracture line, fragmentation, female sex, and patient age. It was reported in the same study that nonunion rates after plate fixation of all fractures and displaced fractures were 2.5% and 2.2%, respectively.

A randomized, controlled, prospective and multicentric study of 111 patients (62 surgical, 49 conservative treatments)[6] reported better Constant and DASH scores after surgery and higher nonunion and symptomatic malunion rates after conservative treatment. It was also reported that the total number of operated patients with complications was nine and most had minor complications (lokal skin irritation and feeling of the plate and screws under the skin).

In our study, four (25%) patients developed complications. Complications were divided into two groups; major (affecting shoulder girdle functions) and minor (not affecting shoulder girdle functions) complications. Major complications (implant failure) were present in 12.5% and minor complications (plate and screw irritation) in 12.5% of the patients. Implant failure was caused by delayed union of the fracture. Irritation was related to superior plate placement. There were no cases with nonunion at the final follow-up. Revision surgery was applied in two patients who had delayed union, preventing nonunion.

Plate placement, fixation technique and plate type differs in terms of superior or anterior-inferior placement, locked or unlocked screw fixation, 1/3 semi-tubular plate, reconstruction plate, dynamic compression plate (DCP), limited contact dynamic compression plate (LC-DCP), locked compression plate (LCP) or locked anatomic clavicle plate for plating applications in clavicular fractures.[11,18,19]

In a study comparing the results of superior and anterior-inferior plate placement, lower visual analog pain scores after anterior-inferior placement was reported.[5] Another study reported that plate irritation and neurovascular complications can be avoided with anterior-inferior plate placement.[19] However, there are no anatomical plates for anterior-inferior placement; therefore surgeon should bend straight plates in the surgery room.

In a prospective clinical study with 73 clavicle fractures (age: 20 to 50 years),[20] forty-five patients were operated by superiorly placed, pre-bended reconstruction plates and twenty-eight patients were treated conservatively with simple shoulder-arm sling. Better results were reported after surgery in terms of malunion, nonunion and functional scores. It was also reported that 9% of patients required plate removal due to plate irritation. In this series, the first 15 surgeries were performed through a superior incision and the later 30 through an anterior-inferior incision. All cases of plate irritation were seen in the first group. An anterior- inferior incision was suggested for fixation with straight plates to avoid implant irritation and scar development.

Although some studies in the literature report good results after fixation with reconstruction plates and unlocked screws, implant related problems can occur.[20,21] Therefore, low-profile, anatomic locked plate fixation is popular.

In a retrospective study[11] comparing fixation of 52 acute, displaced midshaft clavicle fractures with straight plates (DCP, LC-DCP, LCP and reconstruction plate) and pre-bended plates (locked anatomical clavicle plate) through a superior incision, plate irritation was reported in 64.3% of patients with straight plates and in 32.1% of patients with pre-bended plates. It was also reported that the rate of secondary surgery for plate irritation and the rate of plate removal were lower for pre-bended anatomic clavicle plates.

Various biomechanical studies have evaluated the durability of clavicle plates. In a study on fresh frozen cadaver clavicles,[12] 3.5-mm reconstruction plate, 3.5-mm LC-DCP, 3.5-mm LCP and 4.5-mm intramedullary pin were compared. Bones were divided into two groups; with or without inferior cortical defect. Bending and torsional forces were applied. Plate fixation through a superior incision was more durable against bending and torsional forces than the intramedullary pin. Reconstruction plate fixation for clavicles with inferior cortical defects was found to be less durable against bending forces than other plates. LC-DCP and LCP plates were suggested for comminuted, midshaft fractures with cortical defects.

There are various studies in the literature reporting better durability against torsional and bending forces with locked plate fixation of humerus and radius fractures than unlocked plates.[22,23] In a biomechanical study with 48 human cadaver clavicles,[13] locked anatomic plates, DCP's and external fixators were compared for durability against torsional and three point bending forces. Locked plates were reported as more durable against torsional and bending forces when compared with DCPs and external fixators at displaced clavicle fractures.

Clavicle fracture can occur with falling on the shoulder and direct trauma or with high-energy trauma with accompanying injuries. In our study, two patients had rib fractures and one had a rotational and vertically stable pelvis fracture. For patients with life-threatening concomitant injuries, surgery can be delayed. While stable pelvis fractures generally do not cause so many problems, bleeding after unstable pelvis fractures of polytraumatized patients can cause hemodynamic instability.[24] For these patients, the primary goal of the surgeon is to stabilize the pelvic ring and selective embolization or open ligation for the bleeding to prevent hemodynamic instability.[24,25] For patients with accompanying life-threatening complications such as hemopneumothorax or rib fractures causing intrathoracic organ injuries, the primary goal is stabilization of the general status of the patient.[26] In our study, two patients with rib fractures were operated after excluding a possible hemopneumothorax. The patient with pelvic fracture was operated following 12 hours of evaluation of hemodynamic balance. Chest tube insertion was planned due to a possible pulmonary problem after positive ventilation during surgery, but no intraoperative complications occurred that required tube insertion.

In conclusion, straight plates and reconstruction plates that were widely used for the treatment of displaced, comminuted clavicle fractures have now been replaced with low-profile, locked anatomic clavicle plates. Common complications of conservative treatment such as nonunion or malunion could be prevented with a proper technique and locked anatomic clavicle plates. Anatomic plates are strong and prevent plate irritation but can still cause irritation. Problems after operation are generally related to subcutaneous perceiving of the plate or implant failure in cases with delayed union caused by early motion. New plate designs and new plates can prevent complications after fixation of clavicle fractures with locked anatomic plates.

Conflicts of Interest: No conflicts declared.

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