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Clinical Outcome after Clavicular Hook Plate Fixation for Displaced Medial-End Clavicle Fractures

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Background: Surgery of the medial end of the clavicle remains a challenge for orthopedic surgeons. Moreover, there is no standard surgical procedure for treating displaced fractures or dislocation of the medial clavicle. Thus, the present study aimed to evaluate the safety and efficacy of using a hook plate for treating medial-end clavicular fractures and present functional outcomes.

Methods: We retrospectively investigated 18 patients who underwent surgery with a hook plate from July 2016 to December 2021. There were 14 men and 4 women with a mean age of 57.4 years. Fracture union was assessed at follow-up by computed tomography (CT). Other outcome parameters were complications, including implant failure, infection, nonunion, osteolysis of sternal manubrium, and migration of the hook portion. Range of motion (ROM), visual analog scale (VAS), Quick Disabilities of the Arm, Shoulder and Hand (Quick DASH), and American Shoulder and Elbow Society (ASES) scores were evaluated 6 months postoperatively and at the last follow-up.

Results: The mean operation time was 43.8 minutes (range, 35–50 minutes) and the mean follow-up was 22.8 months (range, 12–42 months). Bone union was confirmed in all cases. The mean union time was 6.2 months (range, 6–7 months). Implant removal was performed routinely according to the clinical course in 17 cases. The mean implant removal time was 10.0 months (range, 6–14 months). Clinical and functional outcomes measured at the last follow-up were significantly improved compared to those at 6 months postoperatively ($p < 0.05$). Regarding complications, there were 6 cases (33.3%) of osteolysis of the sternal manubrium. Although the anteroposterior length of the manubrium and hook depth showed significant differences between the non-osteolysis group and the osteolysis group ($p = 0.024$), ROM, VAS, Quick DASH, and ASES scores were not significantly different between the two groups (all $p > 0.05$).

Conclusions: Clavicle hook plating can be a safe and effective method that can be easily applied with good outcomes if it is used with appropriate surgical planning and technique for medial-end clavicle fracture. CT scans are useful for preoperative planning and postoperative evaluation of bone union or complications.

Keywords: *Clavicle, Fracture, Dislocation, Bone plates*

Fractures of the medial third of the clavicle are rare, accounting for only 2%–3% of all clavicle fractures.[1,2] Because of the intricate anatomy of this region and the risk of damage to neurovascular and airway structures with operative intervention, displaced medial-end fractures present a surgical challenge. They have traditionally been treated nonoperatively.[3] However, nonoperative treatment of these fractures can lead to poor functional outcomes

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and symptomatic, painful nonunion. Some studies have shown a considerable risk of delayed union and nonunion for displaced medial-end clavicle fractures.[3-5] Several recent studies have reported that surgical stabilization of concomitant clavicle fractures in flail chest or multiple rib fractures offers good long-term benefits for return to the premorbid state.[6,7] Therefore, a shift towards operative treatment for displaced medial-end clavicle fractures has been suggested in recent research studies.[8,9]

Various operative techniques including K-wire and tension band, fixation using plates (distal radial plate, small T-plate, standard T-locking plate, and pilon plate crossing the sternoclavicular [SC] joint), resection of the medial clavicle end, and arthrodesis of the SC joint have been described.[5-11] However, they show complications[8-12] including the limited movement of the shoulder girdle, loosening, migration, nonunion, neurovascular injury,[10,11] and displacement and breakage of plates and screws.[12]

Clavicular hook plate fixation is a common technique for treating acromioclavicular joint dislocation. Successful treatment of clavicle distal Neer II fractures has also been confirmed with hook plate fixation techniques, which can effectively improve fixation stability and early mobilization of the shoulder joint.[13,14] However, fixation of displaced medial clavicle fractures using clavicle hook plates has not been reported yet. Therefore, the present study aimed to evaluate the safety and efficacy of using a hook plate for treating medial-end clavicular fractures and present functional outcomes.

METHODS

We conducted this study in compliance with the principles of the Declaration of Helsinki. The design and protocol of this retrospective case-control study were approved by the Institutional Review Board of Jeonbuk National University Hospital (No. 2022-06-010). The patients gave written informed consent for publication of this report and the accompanying images. Medial clavicle fracture was defined as one that occurred in the anatomic medial third of the clavicle according to Allman.[15] The Edinburgh classification describes a different segmentation of the clavicle: type 1 fractures are located within the one-fifth of the clavicle bone lying medial to a vertical line drawn upward from the center of the first rib. In addition, subclassifications A and B describe the aspect of displacement.[4]

Inclusion criteria were as follows: (1) patients who were surgically treated with a 3.5-mm locking compression plate clavicle hook plate (DePuy Synthes) for a medial-end clavicle fracture of Edinburgh type 1 between July 2016 and December 2021, (2) open fracture, (3) fracture displacement greater than 5 mm, (4) symptomatic nonunion among cases in which conservative treatment was first performed, (5) patients with computed tomography (CT) obtained preoperatively and postoperatively, and (6) follow-up period at least 12 months. Patients under 18 years of age and those with a physeal fracture were excluded from this study. A total of 18 patients who were available for follow-up were included in this study. There were 14 males and 4 females with a mean age of 57.4 years (range, 42–70 years). Descriptive and demographic data including age, sex, injury site, and follow-up period were collected (Table 1). Preoperative assessment included physical examination, radiographs, and CT scans with three-dimensional reconstructions for preoperative planning and for assessing the proximity of the fracture to neurovascular structures.

Surgical Technique

All patients were positioned supine with a towel roll placed under the medial border of the scapula on the operating table under general anesthesia (Fig. 1A). By adjusting

Table 1. Demographic Characteristics of Patients Undergoing Operative Fixation of a Displaced Medial Clavicle Fracture and Results of Follow-up

Variable	Value
Sex (male : female)	14 : 4
Age (yr)	57.4 ± 8.9
Injury site (right : left)	11 : 7
Time interval between injury and operation (day)	15.6 ± 28.1
Follow-up period (mo)*	22.8 ± 8.3
Injury mechanism (high energy : lower energy)	18 : 0
Operation time (min)	43.8 ± 3.8
Union time confirmed on CT scan (mo)	6.2 ± 0.5
Metal removal (yes : no)	17 : 1
Time interval between operation and metal removal (mo)	10.0 ± 3.7
Acute fracture : chronic fracture	17 : 1
Fracture type (Edinburgh classification) 1B1 : 1B2	10 : 8
Displacement direction (anterior/ posterior)	18 : 0

Values are presented as number or mean ± standard deviation.
CT: computed tomography.
*High energy: motorcycle crash, direct hit, fall from height, and pedestrian traffic accident, Lower energy: slip down.

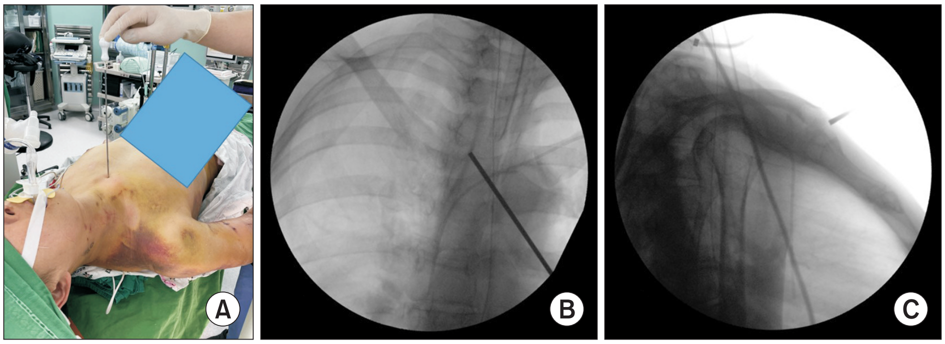

Fig. 1. Preoperative position for clavicle hook plating in a displaced medial-end clavicle fracture. (A) Patients is positioned supine with a towel roll placed under the medial border of scapula on the operating table. (B, C) By adjusting the direction of the C-arm fluoroscopy, the sternoclavicular joint and fracture site are confirmed on anteroposterior and lateral views.

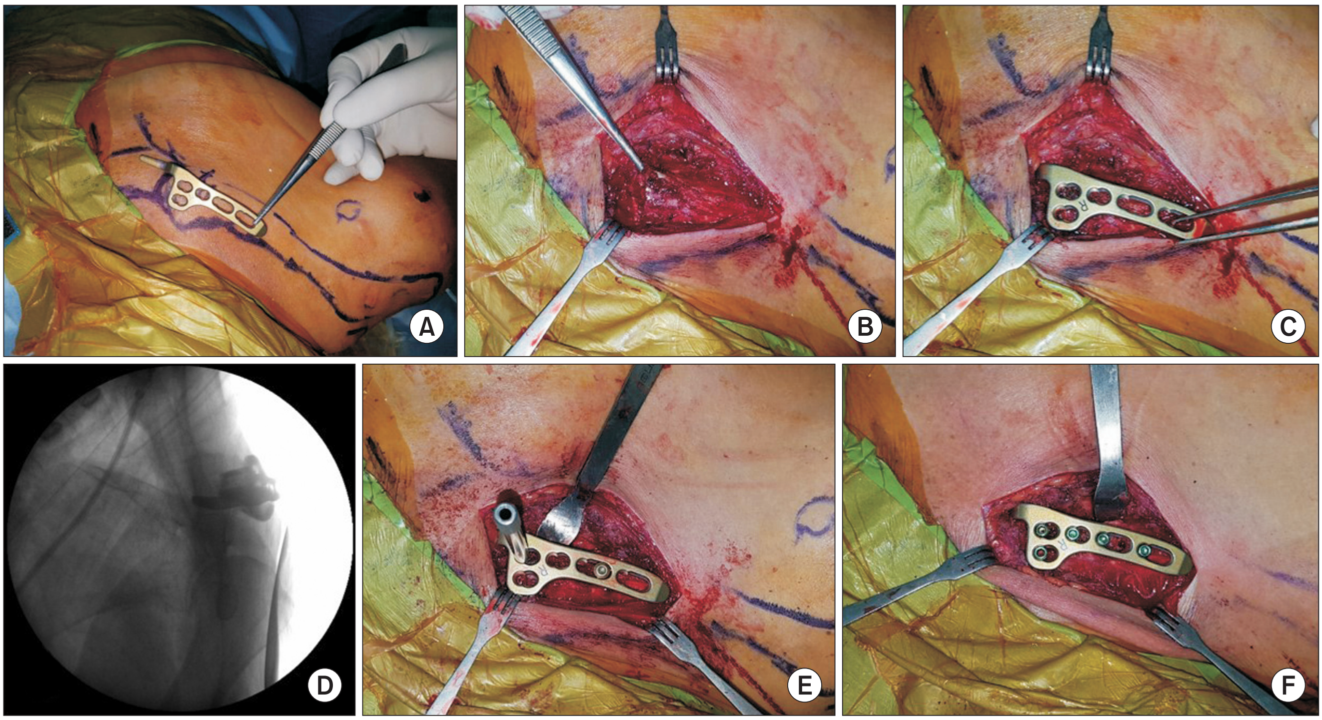

Fig. 2. Surgical techniques of the clavicle hook plating. (A) An anteroinferior straight incision is extended from the medial clavicle to the mid aspect of the sternal manubrium. (B) After dissecting the subcutis, the fracture is exposed. (C, D) While checking the C-arm fluoroscopy, the pointed end of the hook plate is inserted between the clavicle and the first costal cartilage at the sternoclavicular joint, gently entering along the dorsal bone surface of the sternal manubrium. (E, F) Five or six screws are then fixed in the clavicle through the plate. When bicortical screw fixation of the medial bone fragment is attempted, posterior structures can be protected by carefully using a Darrach retractor.

the direction of the C-arm fluoroscopy, the SC joint and fracture site were confirmed in the anteroposterior (AP) view and the sternum was confirmed in the lateral view (Fig. 1B and C). An anteroinferior straight incision was extended from the medial clavicle to the mid aspect of the sternal manubrium (Fig. 2A). The SC joint, the sternal manubrium, and the medial clavicle were exposed. After dissecting the subcutis, the fracture was exposed (Fig. 2B). Careful surgical preparation was applied to avoid denudation of fracture fragments. Direct reduction and temporary fixation were done using reduction forceps. For the hook plate, the implant with 5 or 6 holes was selected (Fig. 2C). The hook depth was selected based on the AP length of the sternal manubrium measured on a preoperative CT scan (Fig. 3). In preoperative CT, if the posterolateral corner of the manubrium was bony protrusion compared to the center or if the AP length of the sternal manubrium was greater than 21 mm, the hook portion was used after bending to prevent internal fixation of the hook portion into the manubrium.

While checking the C-arm fluoroscopy, the pointed end of the hook plate was inserted in a 10 mm × 15 mm space bounded by the medial clavicle superiorly, the anterior SC ligament medially with the upper portion of the first costal cartilage inserted inferiorly,[16] and the costoclavicular ligament inserted laterally, gently entering along the dorsal bone surface of the sternal manubrium (Fig. 4A and B).

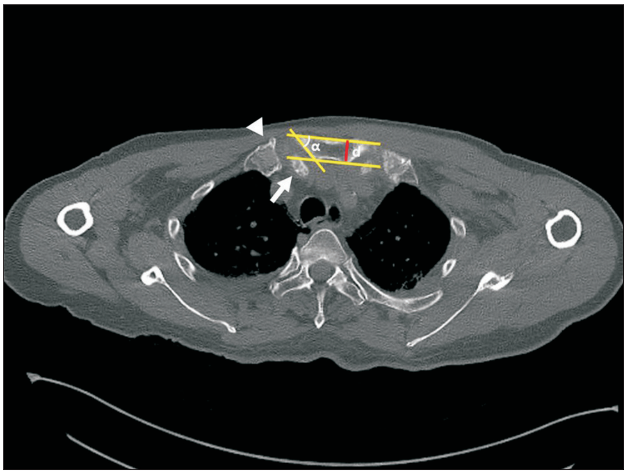

Fig. 3. The hook depth is selected based on the anteroposterior length (d) of the sternal manubrium measured in the last image where the medial clavicle is observed among the axial images of the preoperative computer tomography scan (white arrow: medial clavicle, white arrowhead: first-rib costal cartilage). Peripheral oblique angle (α) of the manubrium was defined as the angle formed by the line connecting the anterior and medial lines of the manubrium.

After the hook portion was fully inserted, the lever effect was obtained by pressing down the lateral part of the clavicle. At this time, by positioning the lower edge of the hook plate to match the lower edge of the clavicle as much as possible in the proximal part of the clavicle, the hook portion should be inserted in an appropriate position below the sternal manubrium (Fig. 2D). Five or six screws were then fixed in the clavicle through the plate (Fig. 2E and F). For stable fixation of the lateral bone fragment, screws were fixed in at least 3 holes (3 bicortical locking screws) on the lateral fracture fragment. When bicortical screw fixation of the medial bone fragment was attempted, posterior structures could be protected by carefully using a Darrach retractor (Fig. 2E and F). If the anterior SC ligament was injured, it was repaired with absorbable sutures.

Postoperative Management

In the first 6 weeks, the shoulder was immobilized with a sling, and easy exercises such as pendulum exercises in the glenohumeral joint, but not over 90° of abduction, were

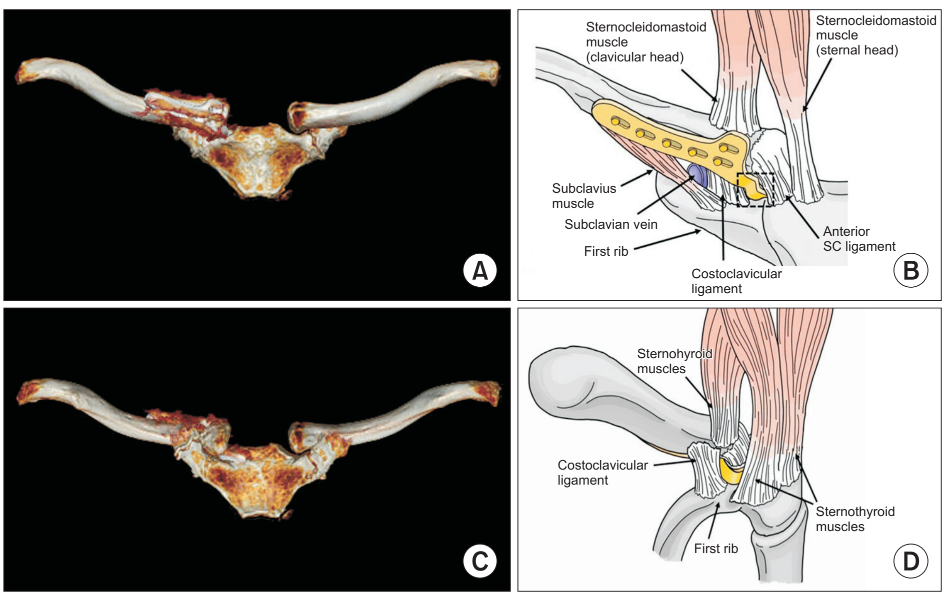

Fig. 4. (A) Anterior image of three-dimensional computed tomography (3D-CT) reconstruction taken after fixation with a clavicular hook plate for a medial-end clavicle fracture. (B) Anatomical illustration of a right sternoclavicular (SC) joint (anterior view). The pointed end of the hook plate (black dotted square) is inserted into a 10 mm × 15 mm space bounded by the medial clavicle superiorly, the anterior SC ligament medially, the upper portion of the first costal cartilage inserted inferiorly, and the costoclavicular ligament inserted laterally.[15] The subclavian vein is found posterior and lateral to the lateral edge of the costoclavicular ligament. (C) Posterior image of 3D-CT reconstruction taken after fixation with a clavicular hook plate for a medial-end clavicle fracture. (D) Anatomical illustration of the SC joint (posterior view). The sternohyoid muscle is inserted on the posterior aspect of the SC joint capsule and the clavicle with the sternothyroid muscle inserted on the posterior aspect of the sternum and costal cartilage. Thus, anterior to sternothyroid muscle bellies is a potential safe zone without vascular structures.

allowed. After 6 weeks, the range of motion (ROM) could be increased according to the clinical course. Standard postoperative follow-up studies including chest AP and sternum lateral view radiographs were done at 2, 6, 12, 24 weeks, and 12 months in the outpatient department. CT scans were performed for all patients immediately after surgery and at 6 months postoperatively (Fig. 4). Implant removal was routinely performed according to the clinical course after confirming bone union.

Clinical and Radiological Evaluation

Clinical and radiological parameters were assessed independently after review by two orthopedic surgeons (KBK and YSL). Fracture union was assessed by CT imaging at 6 months postoperatively. Other outcome parameters were complications, including implant failure, infection, nonunion, and osteolysis. Meanwhile, factors related to osteolysis in all cases were analyzed by comparing the AP length and peripheral oblique angle of the manubrium measured on preoperative CT images (Fig. 3). For these, the last image in which the medial end of the clavicle was observed was selected among CT axial views.

The ROM of the shoulder was measured 6 months postoperatively and at the last follow-up. For assessment of shoulder functional outcome, visual analog scale (VAS) score, Quick Disabilities of the Arm, Shoulder and Hand (DASH) score, and American Shoulder and Elbow Society (ASES) score were evaluated at 6 months postoperatively and at the last follow-up.

Statistical Analysis

For continuous variables, data are presented as mean ± standard deviation (SD). For categorical variables, data are presented as absolute numbers (percentage). Unpaired *t*-test was used to evaluate the statistical significance between independent groups. Paired *t*-test was used to evaluate the statistical significance between preoperative and postoperative functional outcomes. SPSS software ver. 18.0 (SPSS Inc., Chicago, IL, USA) was used for all statistical analyses and *p*-values less than 0.05 were considered statistically significant.

RESULTS

Between 2016 and 2021, 18 patients were treated with a clavicle hook plate for a displaced medial-end clavicle fracture of Edinburgh type 1. There were 17 cases of acute fractures. One case was symptomatic nonunion in which conservative treatment was performed first. All fractures were classified as type 1B according to Edinburgh classification. For all fractures, the lateral segment was displaced anteriorly and the injury mechanism was found to be due to a high-energy trauma (6 motorcycle crashes, 3 direct hits, 3 falls from height, and 6 pedestrians traffic accidents). Associated thoracic trauma was the most common (Table 2).

The time from injury to surgery was 15.6 days (range, 3–120 days). The mean operation time of medial clavicle fractures was 43.8 minutes (range, 35–50 minutes). The mean duration of follow-up was 22.8 months (range, 12–42 months). Fracture union was assessed by CT imaging taken postoperatively. The mean union time confirmed by CT imaging was 6.2 months (range, 6–7 months) (Table 1). Bone union was confirmed in all cases. Implant removal was performed routinely according to the clinical course for 17 cases except for 1 case in which implant removal was rejected. The mean implant removal time was 10.0 months (range, 6–14 months). Regarding complications, there were 6 cases (33.3%) of osteolysis of the sternal manubrium. In 3 of these 6 cases, the hook portion was inserted into the manubrium. However, there was no infection, metal breakage, nonunion, or neurovascular injury. On the other hand, in 8 cases, swelling due to the formation of thick scar tissue was observed in the medial clavicle area even after hardware removal, although no pain or other discomfort was observed in this region.

Mean shoulder movements at 6 months postoperatively were as follows: forward flexion, 159° ± 21.6°; abduction, 154.6° ± 24.5°; internal rotation, 62.1° ± 15.4°; and external rotation, 63.1° ± 10.1°. Mean shoulder movements at the last follow-up were as follows: forward flexion, 174° ± 7.1°; abduction, 169.3° ± 9.4°; internal rotation, 68.1° ± 13.0°; and external rotation, 69.3° ± 11.2°. A sig-

Table 2. Injuries Associated with Medial Clavicle Fractures

Associated injury	No. of patients (n = 18)
Pneumothorax, hemothorax, or flail chest	10
Multiple rib fractures (> 5)	9
Abdominal organ injury (liver, spleen)	2
Head injury (brain hemorrhage, fracture)	2
Facial fracture	1
Thoracic spine fracture	3
Upper extremity fracture	4
Lower extremity fracture	2

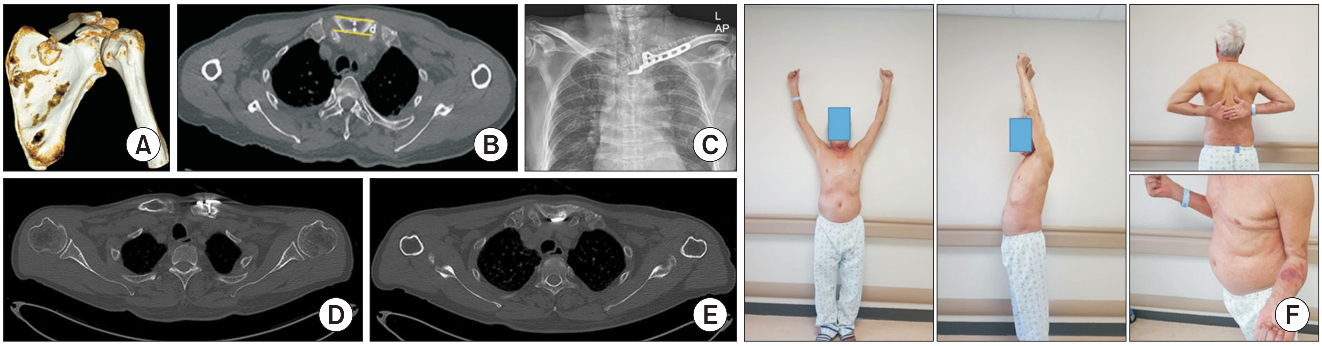

Fig. 5. (A) Three-dimensional computed tomography (3D-CT) image of a 68-year-old man who presented with a medial-end fracture of the left clavicle. (B) A hook depth of 15 mm was selected based on the anteroposterior length (d) of the sternal manubrium in the last image where the medial clavicle was observed among the axial images of the preoperative CT scan. (C) Fixation was performed using a hook plate with six holes. (D, E) At 6 months postoperative CT follow-up, the union of fracture site was shown. In the hook portion, osteolysis was observed. (F) There was no pain and full range of motion was observed 6 months after surgery.

Table 3. Clinical and Functional Outcomes Measured 6 Months Postoperatively and at the Last Follow-up

Variable	Postoperative 6 mo	Last follow-up	*p*-value*
Forward flexion (°)	159.0 ± 21.6	174.0 ± 7.1	0.006
Abduction (°)	154.6 ± 24.5	169.3 ± 9.4	0.009
Internal rotation (°)	62.1 ± 15.4	68.1 ± 13.0	0.016
External rotation (°)	63.1 ± 10.1	69.3 ± 11.2	0.028
VAS score	2.30 ± 1.7	0.37 ± 0.6	0.001
Quick DASH score	17.3 ± 15.7	5.1 ± 4.2	0.005
ASES score	66.9 ± 18.5	88.8 ± 8.4	0.000

Values are presented as mean ± standard deviation.
VAS: visual analog scale, DASH: Disabilities of the Arm, Shoulder and Hand, ASES: American Shoulder and Elbow Society.
*Paired *t*-test.

nificant improvement in the ROM was observed at the last follow-up compared to that at 6 months postoperatively (Fig. 5). Mean functional outcomes at 6 months postoperatively were as follows: VAS, 2.3 ± 1.7; Quick DASH, 17.3 ± 15.7; and ASES, 66.9 ± 18.5. At the last follow-up, mean functional outcomes were as follows: VAS, 0.37 ± 0.6; Quick DASH, 5.1 ± 4.2; and ASES, 88.8 ± 8.4. Significant improvements in functional outcomes were also observed at the last follow-up compared to those at 6 months postoperatively (Table 3).

Meanwhile, in two subgroups divided according to the presence or absence of osteolysis, radiologic measurements and functional outcomes were compared. On radiologic measurements using preoperative CT images, the AP length of the manubrium and hook depth showed significant differences between the non-osteolysis group and the osteolysis group ($p = 0.024$) (Table 4). However, clinical and functional outcomes were not significantly different at 6 months postoperatively or at the last follow-up between the two groups (Table 4).

DISCUSSION

Successful treatment of clavicle distal Neer II fractures has been confirmed with hook plate fixation techniques, which can effectively improve fixation stability and early mobilization of the shoulder joint.[13,14] However, to the best of our knowledge, fixation of a displaced medial-end clavicle fracture using a clavicle hook plate has not been reported yet. Thus, we evaluated clinical outcomes after clavicular hook plate fixation for displaced medial-end clavicular fractures. Although the injury mechanism of fractures was found to be due to a high-energy trauma, bone union was confirmed in all cases. Clinical outcomes measured at the last follow-up were good. ROM of the shoulder, VAS, Quick DASH, and ASES scores were not significantly different between the non-osteolysis group and the osteolysis group ($p > 0.05$).

Displaced fractures of the medial clavicle are uncommon. Because of intricate anatomy structures such as the pleura, lung, mediastinum, and trachea just behind this region and the risk of damage to neurovascular and airway structures with operative intervention, displaced medial-end fractures present a surgical challenge. Although they have been traditionally treated nonoperatively, a higher rate of nonunion and loss of upper limb function[4,17,18] can result from displaced medial-end fractures. A shift towards operative treatment has been suggested in

Table 4. Comparison of Radiologic Measurements and Functional Outcomes between Non-osteolysis Group and Osteolysis Group

Outcome	Evaluation period	Variable	Non-osteolysis (n = 12)	Osteolysis (n = 126)	*p*-value*
Radiologic measurement	CT taken before operation	MAPL (mm)	16.8 ±1.4	19.6 ± 4.4	0.193
		MOA (°)	57.1 ± 7.7	54.6 ± 7.2	0.582
		MAPL – HD (mm)	–0.64 ± 1.1	3.1 ± 2.9	0.024
Functional outcome	Postoperative 6 mo (before metal removal)	Forward flexion (°)	157.5 ± 16.6	161.6 ± 14.7	0.656
		Abduction (°)	150.8 ± 19.6	160.0 ± 16.7	0.404
		Internal rotation (°)	63.3 ± 9.8	60.0 ± 14.1	0.646
		External rotation (°)	57.5 ± 7.6	57.5 ± 7.5	0.99
		VAS score	2.6 ± 1.9	2.1 ± 1.6	0.640
		Quick DASH score	16.2 ± 9.2	19.0 ± 15.7	0.719
		ASES score	69.4 ± 16.3	62.8 ± 16.7	0.506
	Last follow-up	Forward flexion (°)	170.8 ± 9.1	175.0 ± 5.4	0.362
		Abduction (°)	165.8 ± 11	171.6 ± 7.5	0.313
		Internal rotation (°)	65.8 ± 7.3	69.1 ± 7.3	0.451
		External rotation (°)	65.8 ± 9.1	68.3 ± 11.2	0.682
		VAS score	0.2 ± 0.4	0.6 ± 0.8	0.209
		Quick DASH score	3.4 ± 3.1	7.1 ± 5.9	0.202
		ASES score	91.3 ± 7.8	86.1 ± 9.2	0.313

Values are presented as mean ± standard deviation.
CT: computed tomography; MAPL: manubrium anteroposterior length, MOA: manubrium oblique angle, HD: hook plate depth, VAS: visual analog scale, DASH: Disabilities of the Arm, Shoulder and Hand, ASES: American Shoulder and Elbow Society.
*Unpaired *t*-test.

recent research studies.[8)] Diverse surgical techniques for a medial-end clavicle fracture have been reported.[5-9)] K-wire and tension band are conducive to fracture healing and reliable fixation, which can facilitate early functional exercise of the shoulder and recovery of joint function. However, tension strength of the K-wire and tension band are unstable.[10,11)] They are prone to cause a re-fracture, dislocation, loosening, withdrawal, migration, vascular injury, and nerve compression.[10,11)] T-shaped locking plate fixation can be used for treating clavicle fractures, which are fixed by a single cortex to avoid damage to adjacent tissues. If the fixation is poor, early postoperative functional exercises might result in stress concentration and cause plate loosening or re-fractures.[12)] Although reconstruction plates are an alternative implant, care is needed to avoid damage to subclavian arteries, veins, and brachial plexus or penetration to the mediastinum and pleura to prevent serious complications.[19)]

In a previous anatomical study of the SC joint anterior view, Lee et al.[16)] reported that the quantitative distance between the inferior clavicular cartilage and the most medial fibers of the costoclavicular ligament (the most cephalad line) is about 10.3 mm (the two inferior lines). The distance between the center of attachment of the costoclavicular ligament and the subclavius tendon on the first-rib cartilage or the inferior manubrial cartilage was 14.8 mm or 14.2 mm, respectively. The subclavian vein was found posterior and lateral to the lateral edge of the costoclavicular ligament (Fig. 4B). They also found that in the SC joint posterior view, the sternohyoid muscle was inserted on the posterior aspect of the SC joint capsule and the clavicle with the sternothyroid muscle inserted on the posterior aspect of the sternum and costal cartilage. Thus, anterior to this sternothyroid muscle bellies was a potential safe zone without vascular structures (Fig. 4C and D).[16)]

Therefore, we assumed that if the hook portion was inserted into the quadrangular space bounded by the lower edge of the clavicle upward, the first-rib cartilage downward, the anterior SC ligament medially, and the costoclavicular ligament laterally, gently entering along the dorsal bone surface of the sternal manubrium, the hook portion could be located anterior to sternothyroid muscle bellies without vascular structures as suggested by Lee et al.[16]

In the present study, we paid some attention to the surgical procedure based on the literature on hook plate fixation for lateral-end clavicle fractures to have a safe and effective hook plate fixation for medial-end clavicle fractures.[13,14] First, in the case of surgery using a hook plate, there is no need to perform a lot of subperiosteal dissections because less effort is needed for anatomical reduction than using a locking plate. Therefore, the use of a hook plate makes it possible to perform fixation while minimizing the chance of damaging blood flow to the cortical bone. In this respect, the use of hook plates might be helpful for fracture union. Second, for stable fixation of the medial bone fragment, the lower surface of the proximal part of the plate and the lower surface of the medial clavicle are positioned to coincide. By doing this, the medial bone fragment could be fixed with two locking holes in the widened portion of the proximal part of the hook plate and the hook portion has sufficient bone contact with the sternal manubrium. Third, for stable fixation of the lateral bone fragment, screws are fixed in at least three holes (three bicortical locking screws) on the lateral fracture fragment. Since the plate shaft is anatomically pre-contoured (12°), the outermost hole might need bending in some cases.

Finally, for the safety of hook plate fixation, anatomical variation below the expected position of hook insertion in the CT taken preoperatively was checked. A proper depth of the hook plate was also selected by measuring the AP length of the sternal manubrium at the expected position of hook insertion. While checking the C-arm fluoroscopy, the pointed end of the hook plate was inserted into the quadrangular space, gently entering along the dorsal bone surface of the sternal manubrium. When bicortical screw fixation of the medial bone fragment was attempted, posterior structures could be protected by carefully using a Darrach retractor.

In the current study, hook plate fixation in medial-end clavicle fractures has several advantages. First, the operation was completed in a relatively short time (mean, 43.8 minutes). Second, the hook plate is more effective than a T-plate or other plates to stabilize the small and mostly weak metaphyseal bone of the medial fragment. Third, bone union was obtained at an average of 6.2 months in all cases. Moreover, in one of these cases, successful union was achieved by hook plating and autogenous bone grafting after failed conservative treatment for symptomatic nonunion (Fig. 6). Finally, functional outcomes and complications at the last follow-up were similar to those of other papers examining outcomes of surgical fixation of displaced medial-end clavicle fractures

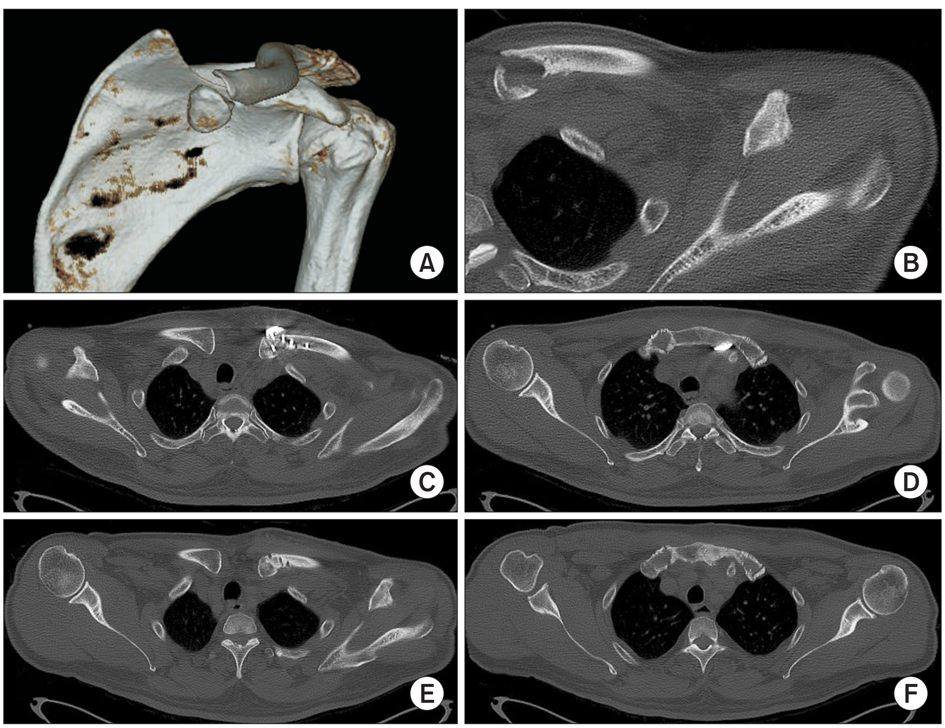

Fig. 6. (A, B) Three-dimensional computed tomography (3D-CT) images of a 56-year-old man who presented with nonunion of a medial-end clavicle fracture. (C, D) A clavicle hook plating was performed with an autologous bone graft. (D, F) At 6-month postoperative CT follow-up, the union of fracture site was shown without osteolysis.

(Table 3).[9,19] Therefore, hook plate fixation for a displaced medial-end clavicle fracture as a simple technique can be an alternative method with good outcomes. However, clavicle hook plating for a displaced medial-end clavicle fracture has some limitations, including limited available hook depths (12, 15, and 18 mm), necessity of CT scans to confirm bone union, and significant differences in clinical outcomes before and after implant removal.

In previous studies on hook plating for a distal clavicle Neer II fracture, bending of the hook portion or routine implant removal was recommended.[5,14,20] In the current study, there was no significant functional difference between the non-osteolysis group and the osteolysis group of the manubrium, similar to the study by Sun et al.[21] However, significant improvements in functional outcomes were observed at the last follow-up compared to 6 months postoperatively. This suggests that although hook plate fixating for medial-end clavicle fractures can preserve the SC joint and enable early mobilization, functional outcomes before implant removal might be poorer than those after implant removal due to irritation of the hook portion. Therefore, we have been performing hook portion bending recently to reduce pain and occurrence of osteolysis in case of size mismatch. We also recommend routine implant removal to improve pain and clinical outcomes.

The current study has some limitations. First, this is a retrospective study. Second, our cohort with 18 patients was relatively small, although the largest sample sizes of previously published studies were 15 and 20 patients.[7,22] Third, most patients were not available for long-term clinical follow-up. However, since displaced medial-end fractures are rare, a prospective study with a large sample is difficult.[23] Finally, despite the excellent results of our study, further anatomical studies evaluating the safety of this technique are needed in the future.

Clavicle hook plating can be a safe and effective method that can be easily applied with good outcomes if used with appropriate surgical planning and techniques for medial-end clavicle fractures. CT scans are useful for preoperative planning and postoperative evaluation of bone union or complications.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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