Precontoured Locking Plate Fixation for Displaced Lateral Clavicle Fractures

SANG KI LEE, MD; JAE WON LEE, MD; DAE GEON SONG, MD; WON SIK CHOY, MD

abstract

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Displaced fractures of the lateral end of the clavicle are associated with an increased risk of nonunion with conservative treatment; therefore, operative treatment is recommended. Various operative treatments have been suggested, but no consensus exists regarding a gold standard for the surgical treatment of this type of fracture. The purpose of this study was to evaluate clinical and radiological outcomes using a precontoured locking compressive distal clavicular plate for Neer type II distal clavicle fractures.

Thirty-five patients with Neer type II distal clavicle fractures underwent surgery between March 2009 and January 2012. All patients were evaluated for function using the Constant-Murley Shoulder Outcome Score and University of California, Los Angeles shoulder rating scale, active shoulder range of motion, time to bone union, and coracoclavicular distance. Mean follow-up was 24.2 months (range, 12-35 months). No significant difference existed between the injured and contralateral sides in mean Constant-Murley scores (P=.13) or mean University of California, Los Angeles shoulder rating (P=.27). All patients obtained bony union over a mean of 4.1 months (range, 3.5-6.0 months).The coracoclavicular distance was not significantly different between the injured and contralateral shoulders in the immediate postoperative period (P=.28) or at final follow-up (P=.35). One superficial wound infection occurred, but no major complications, such as nonunion, plate failure, secondary fracture, or deep infection, occurred.

Precontoured locking compressive distal clavicular plate fixation for the treatment of displaced fractures of the lateral end of the clavicle is an acceptable surgical method with good results.

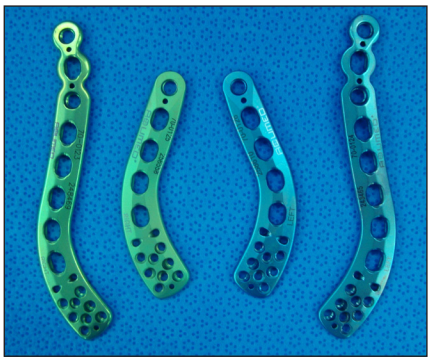

Figure: The precontoured locking compressive distal clavicle plate. The plate is anatomically precontoured and has fixed-angle, locking screw holes for increased plate stability and bone purchase. It is available in side-specific versions for optimal sizing and screw fixation.

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Clavicle fracture is a common traumatic injury of the shoulder girdle because of the subcutaneous position of the clavicle.[1] Distal clavicle fractures have been estimated to account for 12% to 15% of all clavicle fractures.[2] Neer[3] divided distal clavicle fractures into 3 types (types I, II, and III), of which type II fractures are divided into 2 subgroups according to disruption of the coracoclavicular ligaments. In type IIA, the conoid and the trapezoid ligaments are intact and attached to the distal fragments. In type IIB, the conoid ligament is ruptured but the trapezoid ligament remains attached to the distal segments.

Type I and III fractures can generally be treated conservatively; however, type II fractures are unstable because of loss of coracoclavicular ligamentous restraint on the medial fragment.[2,3] In addition, the weight of the arm distracts the distal fragment while the counter-pull of the trapezius on the long proximal fragment provides strong displacing forces.[1,3,4] Therefore, the nonunion rate in these fractures can be as high as 22% to 44%.[5-7] Persistent pain, restricted movement, and loss of strength and endurance of the shoulder may develop if the fracture fails to heal,[3,8] and reconstructing an established nonunion may be technically challenging.[9] Therefore, most authors recommend performing open reduction and internal fixation for type II distal clavicle fractures.[10,11]

Although various fixation techniques, such as transarticular or extra-articular Kirschner wire fixation,[3] Knowles pin fixation,[11] coracoclavicular screw fixation,[10,12] and tension-band wire fixation,[13] have been recommended, such fixation methods are associated with a considerable risk of complications, such as loss of reduction, pin migration, skin ulceration due to pin irritation, screw penetration of the clavicle, and acromioclavicular (AC) joint degeneration.[11-14] Furthermore, it is difficult to obtain rigid fixation and early mobilization with the abovementioned methods, partly due to the small comminuted, soft metaphysis bone of the distal fragment, which does not hold strong fixation constructs well.[15]

Therefore, some authors have suggested using a hooked plate with an extension under the acromion to provide more stable fixation.[16,17] The locking compressive clavicular hook plate provides angular stable fixation of the fragments regardless of bone quality.[15] However, some studies have reported issues associated with this technique, such as subacromial impingement or bursitis, rotator cuff injury, and clavicle fracture at the medial end of the plate.[17-19] Furthermore, clavicular hook plates must be removed because long-term hook plate fixation has a considerable risk for these complications.[15,18,19]

A recently introduced precontoured locking compressive distal clavicular plate (LCDCP) (Acumed, Hillsboro, Oregon) enables stable angular fixation of fragments regardless of bone quality, with minimal bending of the plate and reduced risk of loss of reduction. This plate preserves the AC joint and restores its normal biomechanics. In addition, it does not lead to iatrogenic subacromial impingement or rotator cuff damage. The purpose of this study was to retrospectively evaluate the clinical and radiological outcomes of use of a precontoured LCDCP for the treatment of displaced fractures of the lateral end of the clavicle.

Materials and Methods

This study was approved by the institutional review board, and all patients who underwent the procedure under study were available for review.

Thirty-five consecutive patients with unstable fractures of the lateral end of the clavicle were treated surgically using a precontoured LCDCP between March 2009 and January 2012. Inclusion criteria were Neer type II fractures, unilateral fractures, more than 1 year of follow-up, and normal shoulder function before injury. Exclusion criteria were AC joint dislocation, pathological fractures, previous surgery on the injured clavicle or shoulder, and hemiparesis. All procedures were performed by the same surgeon (S.K.L.).

Implant Design Specifics

The precontoured LCDCP is an anatomically precontoured plate that facilitates optimal implant placement and provides outcome. It is available in 2 lengths (68 and 101 mm) and has 2 locking screw hole sizes (3.5 mm on the shaft portion and 2.3 mm on the distal portion), and left and right versions exist for optimal sizing (Figure 1). The lateral end of the plate has multiple locking screw holes that offer good fragment fixation and stability and allow early mobilization. Unlike conventional plates, the LCDCP has a diverging distal screw configuration that maximizes bone purchase and increases resistance to pullout forces compared with screws placed perpendicular to the plate. The distal screw holes are angled to maximize pullout strength and improve overall plate stability regardless of bone quality, especially in osteoporotic bone and the soft metaphyseal bone of the distal clavicle.

Surgical Technique

Under general or interscalene anesthesia, the patient was placed in the beach-chair position on a radiolucent operating table. A curved incision was made in the skin over the lateral one-third of the clavicle. The deltoid insertion over the clavicle was detached partially with a periosteal elevator. The AC joint capsule was left intact. The fracture site was exposed and reduced with temporary Kirschner wire fixation across the AC joint, and the status of the reduction was confirmed by fluoroscopy. The plate was selected based on the fracture length and the curvature of the clavicle. After provisional stabilization with a Kirschner wire, the first 2 screws were placed medial (3.5-mm cortical screw) and lateral (2.3-mm locking screw) to the fracture site. The plate was then fixed to the distal fragment using 2.3-mm lock-

ing screws through the lateral plate holes. While fixing screws on the lateral part, the near and far cortices were predrilled in all patients for stable fixation because of the softness of the distal metaphyseal bone. A locking screw with a length identical to that of both cortices was then inserted. For the holes in the shaft portion, 3.5-mm locking and cortical screws were placed. Depending on the type of fracture, an additional interfragmentary screw was also used if necessary. However, no wiring or Kirschner wires were used. Intraoperative radiographs confirmed the final fracture reduction and proper hardware placement and that the plate did not cross the AC joint and that all screws remained extra-articular (Figure 2).

Postoperative Management

In the immediate postoperative period, a sling was used for comfort. Active range of motion (ROM) exercises of the elbow, wrist, and hand were initiated immediately postoperatively. Pendulum exercises of the shoulder joint with the arm in a sling were encouraged for 2 or 3 days postoperatively when the pain had subsided. The ROM of the pendulum swings increased gradually up to 90° by 4 weeks. After 4 weeks, the sling was removed and the patient was required to exercise the shoulder joint by active ROM of more than 90°; full ROM was usually achieved after 6 weeks. Patients were allowed to return to light office work and activities of daily living as tolerated, but heavy manual work was not permitted until solid union of the fracture was observed.

Patients and Evaluations

Thirty-five patients (19 men and 16 women; 17 right and 18 left shoulders) with a mean age of 46.8 years (range, 21-74 years) were included. The injury mechanisms were a simple fall (n=19), traffic accident (n=11), bicycle accident (n=3), and fall from a height (n=2). All patients underwent surgery using a precontoured LCDCP within 7 days of injury. Patients' functions were evaluated with the Constant-Murley Shoulder Outcome Score[20] and University of California, Los Angeles (UCLA) shoulder rating scale,[21] active shoulder ROM, time to bone union, and coracoclavicular distance. Mean follow-up was 24.2 months (range, 12-35 months).

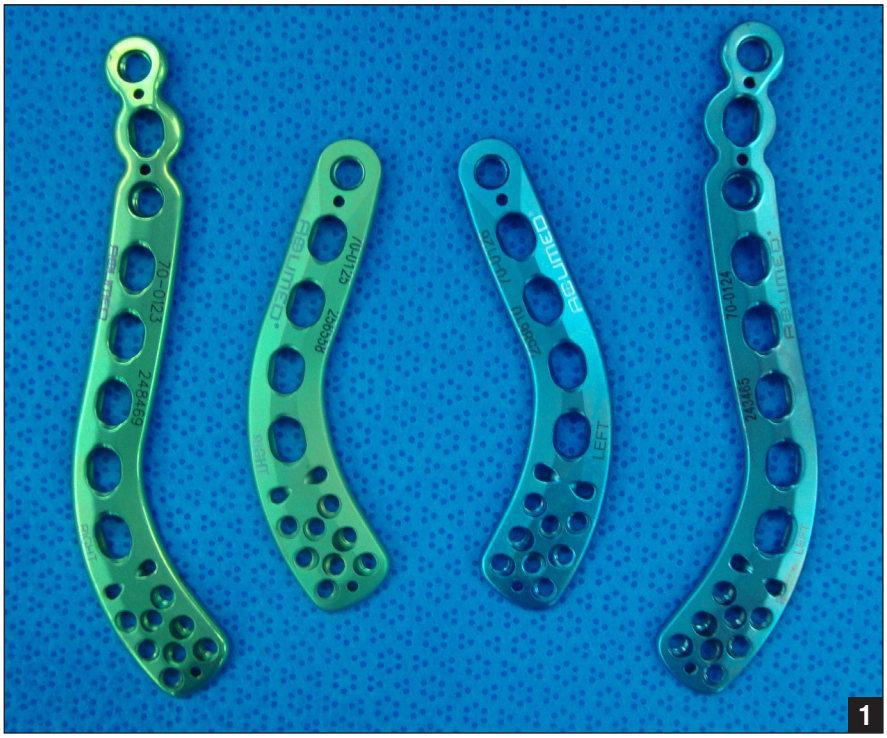

Figure 1: The precontoured locking compressive distal clavicle plate. The plate is anatomically precontoured and has fixed-angle, locking screw holes for increased plate stability and bone purchase. It is available in side-specific versions for optimal sizing and screw fixation.

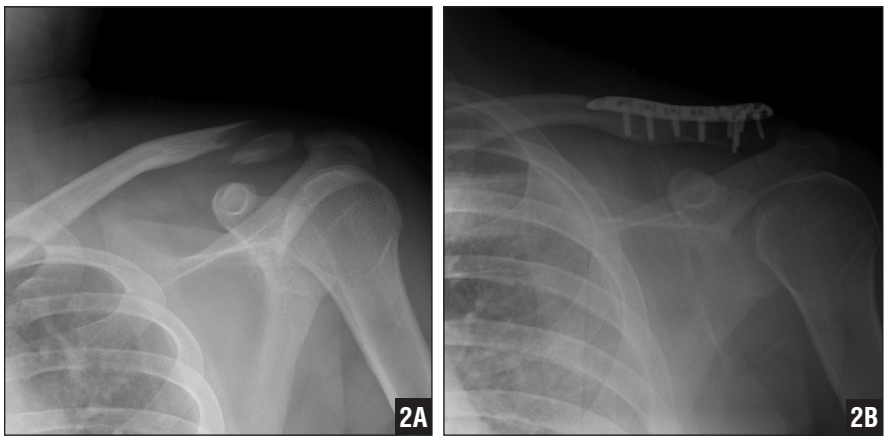

Figure 2: A 28-year-old man sustained a left distal clavicle fracture in a traffic accident. Preoperative anteroposterior radiograph showing a Neer type II fracture of the left distal clavicle (A). Immediate postoperative anteroposterior radiograph showing satisfactory reduction of the fracture (B).

Functional scores were evaluated for the injured and contralateral shoulders at final follow-up. In the Constant-Murley system, which has a maximum score of 100 points, subjective and objective clinical data were included: pain (15 points maximum), activities of daily living (20

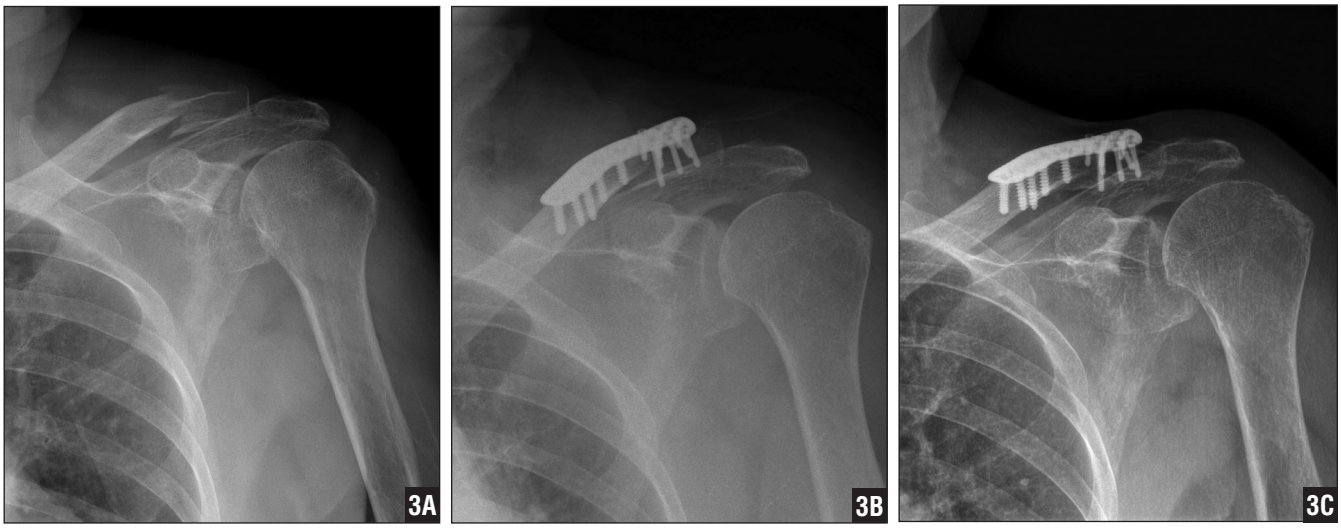

Figure 3: A 64-year-old woman sustained a displaced distal clavicle fracture in a simple fall. Preoperative anteroposterior radiograph showing a Neer type II fracture of the left distal clavicle with osteoporotic bone quality (A). Immediate postoperative anteroposterior radiograph showing satisfactory reduction of the fracture (B). Anteroposterior radiograph taken 16 months postoperatively showing the obliteration of fracture lines and well-maintained reduction without screw pullout (C).

points maximum), shoulder ROM (40 points maximum), and muscle power (25 points maximum). The UCLA shoulder rating scale, which rates pain, shoulder function, and patient satisfaction, has a maximum score of 35 points. According to this schema, pain and function are each rated on a scale of 1 to 10 points, with 1 point being the worst score and 10 points being the best score. Muscle power (active forward flexion), shoulder ROM (active forward flexion), and patient satisfaction each have a maximum score of 5 points. Shoulder ROM was evaluated by 1 surgeon (J.W.L.) using a goniometer.

Postoperatively, anteroposterior and axial radiographs of the shoulder were obtained once every 4 weeks for all patients at follow-up examinations. The radiographs were examined for evidence of fracture healing or implant failure. Fracture healing was defined as any bridging callus across the fracture site or obliteration of fracture lines on radiographs (Figure 3). Coracoclavicular distance (the height between the upper border of the coracoid process and the inferior cortex of the clavicle) was measured on radiographs immediately postoperatively and at final follow-up. To reduce measurement errors, measurements were obtained twice by each author (S.K.L., J.W.L.) and average values were calculated. Intraobserver reliability was considered the criteria of Winer (degree of bias and mean squared error).[22] Reliability was classified according to the intraclass correlation coefficient as absent to poor (0-0.24), low (0.25-0.49), fair to moderate (0.50-0.69), good (0.70-0.89), or excellent (0.90-1.0). The authors achieved an interobserver reliability of 0.93.

Statistical Analysis

Comparison of the functional Constant-Murley score, UCLA shoulder rating scale, and the coracoclavicular distance between injured and contralateral shoulders was performed using the Wilcoxon signed-rank test. Statistical analysis was performed with SPSS version 20.0 software (IBM SPSS, Inc, Chicago, Illinois). A P value less than .05 was considered statistically significant.

Results

At final follow-up, the mean Constant-Murley score was 91.0 points (range, 80-98 points) for the injured shoulder and 95.2 points (range, 89-100 points) for the contralateral shoulder. No significant difference existed in the functional score between the injured and contralateral shoulders ($P=.13$). Mean UCLA shoulder rating scale score was 31.5 points (range, 28-34 points) for the injured shoulder and 33.2 points (range, 30-35 points) for the contralateral shoulder. No differences existed in UCLA scores between the injured and contralateral shoulders ($P=.27$). Mean active shoulder ROMs at final follow-up were as follows: abduction, 160° (range, 130°-170°); forward flexion, 162° (range, 135°-170°); external rotation, 45° (range, 35°-55°); and internal rotation, 72° (range, 50°-85°).

Bony union was obtained in all patients, and the mean period required for healing was 4.1 months (range, 3.5-6.0 months). Immediate postoperative radiographs showed a mean coracoclavicular distance of 10.5 mm (range, 9.7-11.6 mm) for the injured shoulder and 10.2 mm (range, 9.6-11.2 mm) for the contralateral shoulder. Mean coracoclavicular distance at final follow-up was 10.7 mm (range, 9.7-11.8 mm) in the injured shoulder and 10.3 mm

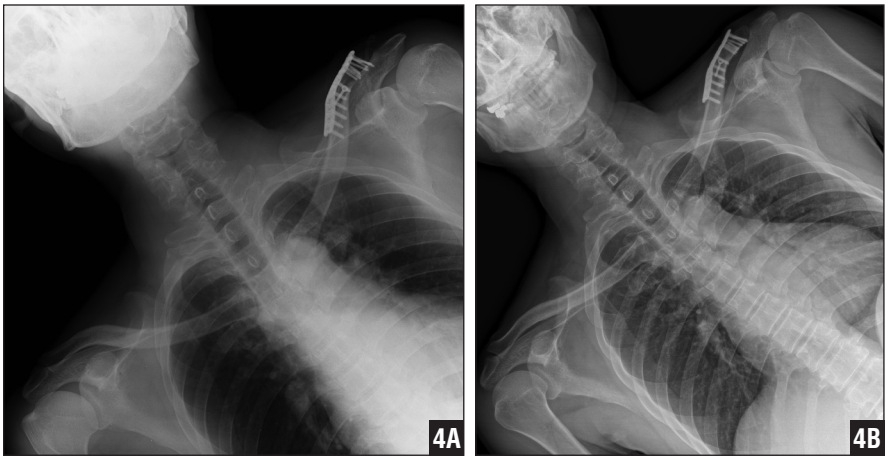

Figure 4: Radiograph of a 49-year-old man with a left distal clavicle fracture shows coracoclavicular distance similar to that of the right shoulder (A) in the immediate postoperative period (B) at final follow-up.

(range, 9.7-11.2 mm) in the contralateral shoulder (Figure 4). No statistically significant difference existed between the injured and contralateral shoulders immediately postoperatively ($P=.28$) or at final follow-up ($P=.35$).

No intraoperative complications necessitated a change in operative technique. One minor postoperative complication, a superficial wound infection, occurred and was treated with oral antibiotics and local wound care. No major complications, including nonunion, plate failure, secondary fracture, and deep infection, occurred. Three plates were removed at the patients' requests. Mean time from surgery to removal was 14.2 months.

All patients had returned to their previous work by 6 months postoperatively. Thirty-two (91.4%) patients could perform the same athletic activities and movements involving strenuous arm use 6 months postoperatively.

DISCUSSION

This study demonstrates that promising treatment outcomes can be achieved for displaced fractures of the lateral end of the clavicle using precontoured LCDCPs.

Neer type II fractures of the distal clavicle are associated with a nonunion rate of 22% to 44% with nonoperative treatment.[5-7] This high incidence of nonunion may be due to the loss of coracoclavicular ligamentous restraint on the medial fragment, muscle forces, and soft tissue interposition between the fracture fragments.[1-4,6] Therefore, most authors recommend surgical treatment for unstable distal clavicle fractures,[10,11] and several surgical methods have been introduced.[3,10-13]

Distal clavicle fracture is caused mainly by direct trauma during a fall; the superior cortex of the distal clavicle is damaged and occasionally comminuted, whereas the inferior cortex is often relatively intact. Because the distal clavicle is composed of soft metaphyseal bone and the distal fragment is usually small, it is difficult to achieve stable fixation and early mobilization.[23] Previously proposed operative treatments are associated with problems such as loss of reduction, pin migration, and AC joint degeneration.[11-13,18] No consensus exists on a gold standard of operative treatment with respect to optimal clinical results.

The precontoured LCDCP was anatomically designed to fit distal clavicle fractures, optimizing their internal fixation with multiple screw placements in the lateral fragment and a locking configuration. Firm and stable fixation can be achieved regardless of bone quality without involving the subacromial space or AC joint, and complications, such as fixation failure, AC joint osteoarthritis, subacromial bursitis, and iatrogenic damage to the acromial undersurface or rotator cuff, may be reduced. Early postoperative ROM may be possible, even in elderly patients with osteoporotic bone quality (Figure 3); without the forceful levering of a hook plate, no stress fracture occurs at the medial edge of a clavicular plate because of the concentration of stress. In addition, it is not necessary to remove these plates, which have low-profile configurations, unless patients request removal. In the current study, 3 implant removals were performed at the patients' requests.

With the locking compressive plate, the screws lock into the plate; therefore, the stability does not solely depend on the friction between the bone and plate. In addition, the angular stability of the locking plates and screws provides better resistance against bending and torsion forces than does traditional compression plating, which relies on the holding power of the screws.[24] Thus, locking compression plates are acceptable regardless of bone quality. Because locking compression plates do not rely on screw threads to create compression or friction between the plate and the bone, the screws have a shallow thread profile.[24,25] Therefore, the pullout strength is lower for a locking screw than a standard screw because of the decreased thread-bone interface. Consequently, a locking compressive plate is most susceptible to failure when the screws are loaded in a purely axial direction.[26] One study reported 4 patients in which superiorly placed locking plates and screws applied to fractures or nonunions of the clavicle had failed because of axial pullout of the locking screws from the lateral clavicular fragments.[27] In contrast, the diverging distal screw configuration of the precontoured LCDCP used in the current study increases resistance to the pullout force of an axial load. Distal locking screws were inserted into holes

predrilled in the near and far cortices so that the fixation was more stable. No plate failure occurred, and bony union was achieved in all patients.

Displaced distal clavicle fractures may involve double disruptions of the superior shoulder suspensory complex when the fractures occur in association with disruption of the coracoclavicular ligaments.[28] Therefore, some authors have advocated using a coracoclavicular loop-and-sling technique using autograft, allograft, or prosthetic ligaments to reconstruct these ligaments.[29] However, recent studies have reported that as long as the biomechanics of the AC joint are maintained, reconstruction of the coracoclavicular ligaments is not necessary and healing of the lateral-end fracture will usually restore stability to the complex.[15] In addition, Robinson et al[9] reported that the coracoclavicular ligaments are frequently only partially disrupted (Neer type IIB injury) or intact, with the majority of the ligamentous complex remaining attached to the lateral fragment (Neer type IIA injury). Furthermore, other studies have reported that even when coracoclavicular ligaments were not repaired, they healed without complications, such as nonunion, ROM limitation, or residual pain.[9,15,30]

On the basis of the findings of other studies, the current authors consider primary ligamentous reconstruction to be unnecessary in most patients. They only performed open reduction and internal fixation of distal clavicle fractures, without repair of coracoclavicular ligaments. However, no complications such as fixation failure, nonunion, or separation of the AC or coracoclavicular joints occurred.

This study had some limitations. First, it was a retrospective study without a control group. It was difficult to obtain a sufficient number of patients because distal clavicle fracture was not a common injury and Neer type II fractures are less common. Future studies are warranted for detailed comparisons with groups that use other treatment methods. Second, the follow-up period was sufficient for the evaluation of bony union because all patients achieved full union within 6 months. Nevertheless, implant-related complications, such as screw cut-out or breakage or AC joint osteoarthrosis, may occur later. Although the early results are promising, longer-term monitoring and larger study populations are required to verify the presented data.

Conclusion

The precontoured LCDCP is anatomically precontoured to fit the clavicle. The current results on the use of this plate are encouraging because this technique has the advantage of achieving a stable fracture fixation using multidirectional locking screws in a small distal clavicular fragment, which allows early mobilization of the shoulder joint. Because no interference occurs with the AC joint, the technique does not cause rotator cuff injury or subacromial impingement and, thus, does not require plate removal. Therefore, this precontoured LCDCP provides an acceptable alternative surgical method for the internal fixation of unstable distal clavicle fractures and will provide satisfactory results in these difficult-to-treat fractures.

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