

# Treatment of Unstable Distal Clavicle Fractures (Neer type IIb): A Modified System using a Miniature Locking Plate with a Single Button

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## Research article

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# Abstract

**Background:** Distal clavicle fractures were common in shoulder injuries. This study described the novel fixation technique using a miniature locking plate with a single button and reported its clinical outcomes obtained in patients with distal clavicle fractures associated with coracoclavicular ligaments disruption.

**Methods:** Seven patients with distal clavicle fractures were included with a follow-up period of 12 months. All patients were diagnosed type IIb fractures according to the Neer classification. Distal clavicle fracture was fixed with a miniature locking plate and coracoclavicular ligaments were reconstructed using a single button. Functional outcomes were assessed at the final follow-up visit.

**Results:** At 1-year follow-up, all patients had achieved radiographic union. There were no cases of nonunion or osteolysis. Mean Constant score at final follow-up was  $88 \pm 5.13$  (range, 78-93). Mean DASH score was  $19.17 \pm 7.70$  (range, 11.67-25). Mean UCLA score was  $30 \pm 2.52$  (range, 25-33).

**Conclusions:** Internal fixation using a miniature locking plate and coracoclavicular reconstruction with a single button were reliable surgical techniques for restoring stability in patients with Neer type IIb distal clavicle fractures.

## 1. Background

Because of its subcutaneous position, fractures of the clavicle are common in shoulder injuries. Approximately 16.6% of all clavicle fractures occur in the lateral third, distal to the conoid tubercle, and 52.8% of them are displaced. <sup>[1]</sup> Neer and Craig classified distal clavicle fractures into five types. According to the definition, in type IIb fractures, the proximal fragment is detached from the coracoclavicular (CC) ligaments, whereas the lateral fragment remains attached to the scapula via the acromioclavicular (AC) joint capsule. <sup>[2, 3]</sup> The distal fragment is pulled by the weight of the arm and the strong pectoral and latissimus dorsi muscles, whereas the proximal fragment is pulled by the trapezius muscle posteriorly, causing instability in type IIb fractures. <sup>[4]</sup> The nonunion rate after nonsurgical treatment of Neer type IIb distal clavicle fractures is reported as 30–45%. <sup>[2, 4]</sup> Risk factors for nonunion include advancing age and displacement of the fracture. <sup>[5]</sup> Surgical management is recommended for type IIb distal clavicle fractures.

A variety of methods have been developed for fixation of type IIb distal clavicle fractures. Early fixation techniques were mainly transacromial Kirschner wire (K-wire) and Knowles pin fixation. <sup>[2, 6–9]</sup> Alternatively, K-wire fixation with a tension band has been reported. <sup>[10, 11]</sup> Fixation with a CC screw has also been suggested. This type of fixation has a remarkable healing rate but causes more immobilization. <sup>[12, 13]</sup> CC ligament with a polyethylene terephthalate tape loop and direct suture fixation of the fragments has been reported. <sup>[14, 15]</sup> A distal clavicle locking plate or a hook plate also can be used to capture the lateral fragment. <sup>[16, 17]</sup> However, all of these fixation methods have drawbacks, including delayed union, nonunion, and implant failure.

In type IIb distal clavicle fractures, the lateral fragment is often too small and comminuted to allow implantation of enough screws for fixation with an anatomic plate, resulting in relatively high failure rates with this technique. The use of an anatomic locking plate in combination with CC ligament reconstruction remarkably improves the reliability of internal fixation, but it may be difficult to place both implants at satisfactory sites. In addition, this method leads to increased cost. In the current study, we developed a modified fixation system for treating patients with Neer type

IIb distal clavicle fractures with a miniature locking plate and a single button. This study described the novel fixation technique and reported its clinical outcomes.

## 2. Methods

The study was approved by our institutional ethics committee. We conducted a retrospective study of 7 patients who underwent surgery in our department from 2015 to 2017. After review of the radiographic appearance, all of the study patients were diagnosed and classified as having Neer type IIb distal clavicle fracture and were treated with miniature locking plate fixation in combination with a single button.

All procedures were performed by the same surgeon (Chao Yu). Surgery was performed under general anesthesia with the patient in the beach chair position. An 8-cm curved incision was made at the distal end of the clavicle, and the periosteum was cut layer by layer along the surface of the clavicle to expose the fracture site (Fig. 1A). The attachment of the deltoid to the anterior surface of the clavicle was dissected to expose the base of the coracoid process. During the procedure, care is taken to maintain the integrity of the AC joint without damaging the AC ligament. The fracture ends were debrided of fibrous tissue, and the CC ligament was explored to confirm rupture of the conoid ligament. The width of the coracoid process was displayed by clamping both sides of the coracoid process with an avascular clamp (Fig. 1B). After reduction of the fracture, a guide pin was inserted into the center of the cross point between the coracoid process and the clavicle (Fig. 1C). The drill (4.0 mm) penetrated four layers of the cortex of the clavicle and the coracoid process along the guide needle (Fig. 1D). Loop length was determined by measuring the channel length from the superior surface of the clavicle to the inferior surface of the coracoid with a depth gauge. A button (Endobutton; Smith & Nephew Inc., London, UK) of suitable Loop length was pushed through the drill holes and deployed under the inferior surface of the coracoids (Fig. 1E). With the fracture held reduced, the loop stitch was pulled up until only the tip protruded from the clavicular hole and a miniature locking plate (F3 Fragment Plating System; Zimmer Biomet, IN, USA) was slid into the loop and applied on the superior surface of the distal clavicle (Fig. 1F). Note that the plate should not cross the AC joint. The medial fragment was fixed by three locking or nonlocking screws, and the lateral fragment was fixed with three 2.5-mm locking screws. The loop was fixed in the groove between the two screw holes on the plate, and no screw was inserted into the adjacent two holes to avoid cutting the loop. Reduction and the position of internal fixation were again assessed with intraoperative fluoroscopy. Routine irrigation of the wound was performed, and the incision was closed layer by layer.

Postoperative management was identical for all patients. The shoulder was protected with an arm sling for 1 to 2 weeks. Pendulum exercises of the shoulder in the arm sling were allowed as soon as pain permitted. Active shoulder exercises were allowed 3 to 4 weeks after surgery, depending on the patient situation.

All patients were followed up at 2 weeks, 6 weeks, 12 weeks, 6 months, and 12 months. At each outpatient visit, patients were assessed clinically with physical examination and radiographically with an anterior-posterior plain film of the shoulder joint. Successful union was defined by obliteration of the fracture gap on plain film and no tenderness or pain at the fracture site during shoulder exercises. For assessment of shoulder functional outcomes, Constant scores, University of California, Los Angeles (UCLA) shoulder scores, and Disabilities of the Arm, Shoulder and Hand (DASH) scores were recorded at the last follow-up by a surgeon (Hua Ying) who was not involved in treatment. [18–20]

## 3. Results

We retrospectively reviewed 7 patients (5 men and 2 women) with an average age of  $48.57 \pm 16.18$  years (range, 28–76 years). The mechanism of injury was traumatic in all cases and included falling from a standing height in 3 patients, traffic accident in 3 patients, and sports injury in 1 patient. The left shoulder was fractured in 3 patients and the right shoulder was fractured in 4. On initial assessment, no patient had neurologic compromise. Interval to operation, operative time, and intraoperative blood loss (blood volume from the suction apparatus) are documented in Table 1. Follow-up was obtained for all 7 patients at 1 year. Overall, patient satisfaction was high in all cases. Individual functional outcomes cores are reported in Table 1. Mean Constant score at final follow-up was  $88 \pm 5.13$  (range, 78–93). Mean DASH score was  $19.17 \pm 7.70$  (range, 11.67-25). Mean UCLA score was  $30 \pm 2.52$  (range, 25–33). At 1-year follow-up, all patients had achieved radiographic union. There were no cases of nonunion or osteolysis. There were no hardware-associated complications, including breakage or fracture. No surgical site infections or perioperative fractures were observed. No patients had hardware irritation or prominence.

Table 1  
Patient information and clinical outcomes

Case	Sex	Age (years)	Side	Mechanism of injury	Interval to operation (day)	Operative Time (minute)	Blood loss (mL)	Constant score	DASH score	UCLA score
1	F	44	Left	Fall	5	58	62	88	15	31
2	M	39	Left	Sport	11	83	80	93	11.67	33
3	M	60	Left	Bike accident	3	70	58	85	25	29
4	M	38	Right	Motorcycle accident	4	67	50	90	17.5	31
5	F	28	Right	Bike accident	3	55	75	92	12.5	31
6	M	76	Right	Fall	8	74	68	78	33.33	25
7	M	55	Right	Fall	17	62	50	90	19.17	30

Case presentation. A 61-year-old male fell on his left shoulder two days before hospitalization and had a history of scapulohumeral periarthritis. The plain film and CT scan showed Neer type IIb distal clavicle fracture (Fig. 2A, B, C). Distal clavicle fracture was fixed with a miniature locking plate and coracoclavicular ligaments were reconstructed using a single button (Fig. 2D). Twelve months after the injury, the patient had a pain-free, stable shoulder with flexion of 0 to 135 degrees and abduction of 0 to 120 degrees (Fig. 2E, F). External and internal rotation on the injured side was slightly limited compared with the contralateral arm (Fig. 2G, H), which was possibly due to the history of scapulohumeral periarthritis.

## 4. Discussion

The surgical treatment of Neer type IIb distal clavicle fracture includes three categories: internal fixation of the distal clavicle, CC ligament reconstruction, and a combination of both. Although all of these methods have been reported to achieve positive clinical results, none has been shown to be superior to the others.

Commonly used operative techniques for internal fixation of distal clavicle fractures include transacromial K-wire or Knowles pin fixation, distal clavicle anatomic locking plate, and hook plate.<sup>[21]</sup> Until now, many orthopedic surgeons have recommended anatomic locking plates to treat type IIb fracture, and satisfactory clinical results and high union rates have been obtained. However, some argue that in Neer type IIb fractures the lateral fragment is often too small and comminuted to accommodate enough screws and the fixation may not provide sufficient mechanical strength. The biomechanical studies of Madsen *et al.*<sup>[22]</sup> showed that the distal fragment of type IIb distal clavicle fractures needs at least five-screw fixation to effectively withstand the moderate force required for rehabilitation training (40 to 80 N) after surgery. Therefore, the authors implied that the plate-and-screw construct alone was not sufficient when it was not possible to obtain fixation with 5 screws in the small or comminuted distal fragment.<sup>[22, 23]</sup> An alternative option is a hook plate mounted on the medial fragment of the fracture that serves as a lever below the acromion. Screws can be implanted on the distal end of the plate to enhance fixation. Unfortunately, this frequently used method is associated with a higher complication rate than other methods. Complications include AC joint arthritis, shoulder dysfunction, acromion impingement, rotator cuff injury, and stress fracture.<sup>[24–26]</sup> Therefore, consensus has been reached on the need to remove the implant approximately 8 to 12 weeks postoperatively.<sup>[27]</sup>

Some Neer type IIb distal clavicle fractures are treated with CC ligament reconstruction without supplemental fixation. Commonly used techniques include cerclage wire, coracoid loop, suture anchors, double Endobutton plates, and tendon grafts.<sup>[28]</sup> Motamedi *et al.*<sup>[29]</sup> suggested that there was no significant difference in mean failure load and mean stiffness between the intact CC ligament complex and commonly used augmentations, such as braided polydioxanone and polyethylene. However, Shin *et al.*<sup>[30]</sup> reported one case of nonunion and two cases of delayed union in a series of 19 patients who had distal clavicle fractures associated with CC ligament disruption treated surgically with two suture anchors combined with two nonabsorbable suture tension bands. The use of CC ligament reconstruction alone cannot provide the rigid fixation that is required for fracture healing and early joint mobilization. The potential risk of fixing type IIb distal clavicle fractures merely with CC ligament reconstruction includes insufficient fixation strength, loss of fracture reduction, and fracture displacement. Especially in cases where the lateral fragments are highly displaced and the surrounding soft tissues, such as the fascia of the deltoid and trapezius muscle, are compromised, CC ligament reconstruction alone is likely to lead to nonunion or delayed union.

From a biomechanical perspective, the importance of the CC ligaments in controlling superior and horizontal translation of the AC joint has been elucidated.<sup>[31]</sup> Given the unstable characteristics of the Neer type IIb distal clavicle fracture, the mainstream therapy has shifted to use locking plates with additional CC fixation.<sup>[21]</sup> In Neer type IIb fractures, CC ligament injuries result in significant displacement of the fracture fragments. Previous biomechanical studies have shown that the reconstruction of CC ligament could reduce the forces on the internal fixation, and the use of a locking plate with CC fixation could provide better fracture stability than the use of either alone.<sup>[22, 31, 32]</sup> The combination of an anatomic plate with CC fixation could lead to increased fracture healing rates and reduced failure rates.<sup>[33]</sup>

In our institution, we previously treated Neer type IIb distal clavicle fractures with an anatomic locking plate and double buttons. Although this approach provided satisfactory clinical results, there were drawbacks. Because the locking plate was wide and occupied most of the space, the button was usually placed above or beneath the locking plate (Fig. 3), which could cause galvanic effect. Alternatively, the button could be placed anterior or posterior to the

locking plate, but iatrogenic clavicle fractures were likely to occur. Moreover, if the position of the button deviated from the middle line of the clavicle, it was likely to cause cutting of the loop.

In this study, we used a miniature locking plate and a single Endobutton as a system to treat Neer type IIb distal clavicle fractures. This approach provides the following benefits: (1) A modified fixation system that includes a miniature locking plate and a single button can fix the fracture and reconstruct the CC ligament simultaneously. (2) The miniature locking plate provides 2.5-mm locking screw holes on the distal end, smaller in diameter than the 2.7-mm holes on most anatomic locking plates. The smaller diameter allows more screw implantation to increase purchase in the bone and obtain adequate fixation. (3) Because the miniature plate is thin and narrow, the loop stitch can be tied around the miniature locking plate, which avoids the conflict of plate setup and reduces the expense of the implant. (4) The button provides more rigid fixation than a suture anchor, reducing the risk of loosening. We treated 7 patients with this system, and no loosening or implant failure was observed during follow-up.

Our study was not without limitations. Because the study was retrospective with prospective follow-up, it was affected by selection bias. Although the results were promising, the sample size was small and there was no control group. Final follow-up was obtained in all cases, but outcomes at long-term follow-up remain to be seen.

## 5. Conclusions

A novel internal fixation system to treat Neer type IIb distal clavicle fractures includes a miniature locking plate and a single button. This system stabilized the fracture site and reconstructed the CC ligament and obtained reasonable efficacy in clinical practice.

## Abbreviations

CC: coracoclavicular; AC: acromioclavicular; DASH: Disabilities of the Arm, Shoulder and Hand; UCLA: University of California, Los Angeles

## Declarations

## Ethics approval and consent to participate

This study was conducted in accordance with the Declaration of Helsinki (World Medical Association). Ethics Committee of Shanghai Ninth People's Hospital approved the study protocol of this research [SH9H-2019-T28-1], and informed consent has been obtained from the participants involved in this study.

## Consent for publication

Informed consent regarding publishing the patients' data and photographs have been obtained.

## Availability of data and materials

All the data will be available upon motivated request to the corresponding author of the present paper.

# Competing interests

The authors declare that they have no competing interests.

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# Authors' contributions

Chao Yu performed the operation. Hua Ying and Jihuan Wang participated in the design of the study and performed the statistical analysis. Fei Yang was the major contributor in writing the manuscript. Yuehua Sun and Kerong Dai read and revised this manuscript. All authors read and approved the final manuscript.

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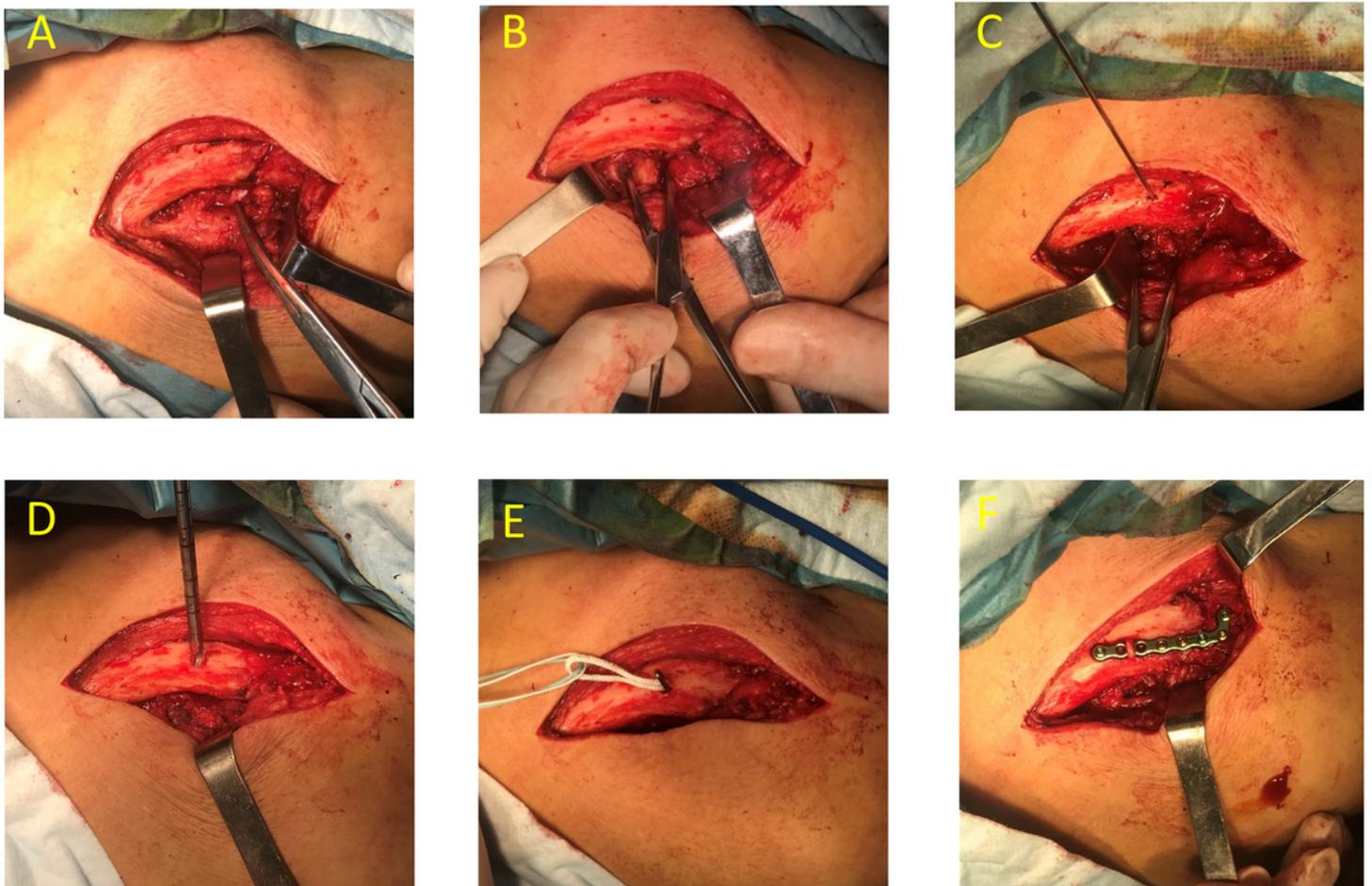
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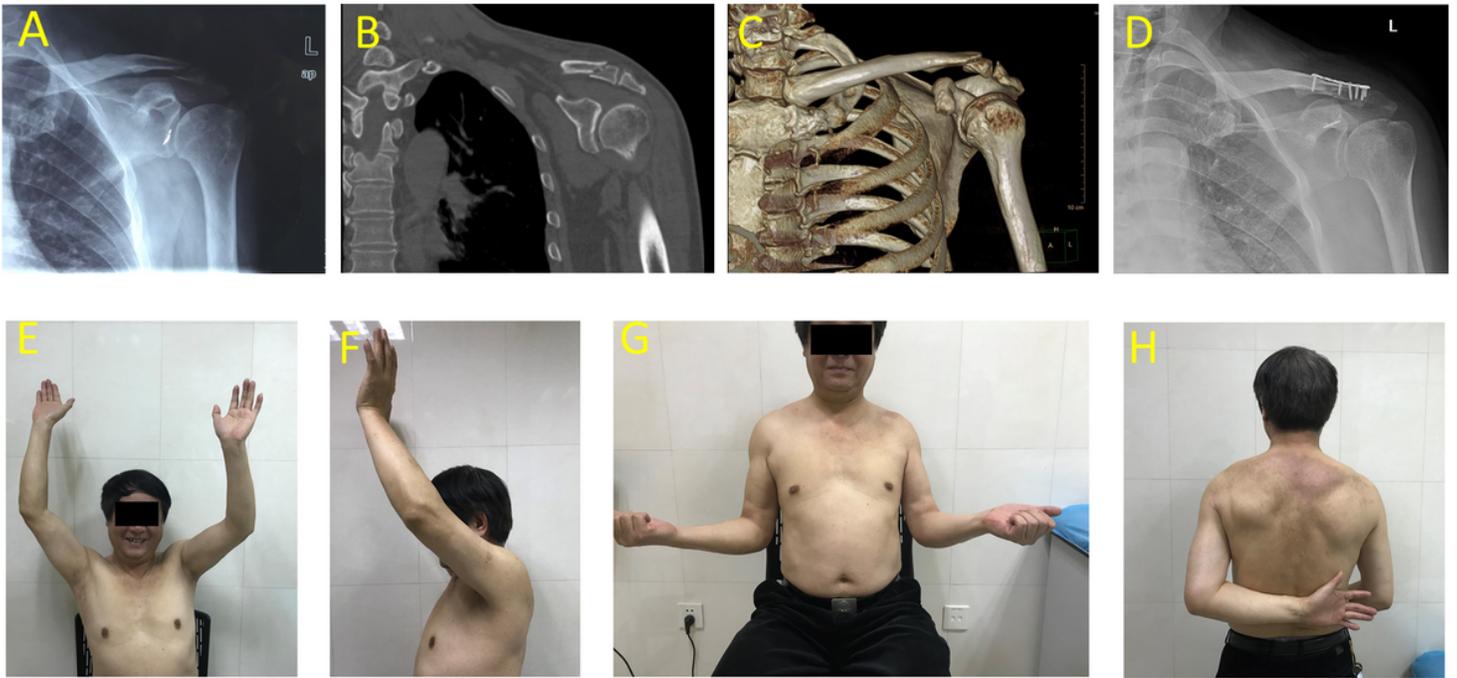
## Figures



**Figure 1**

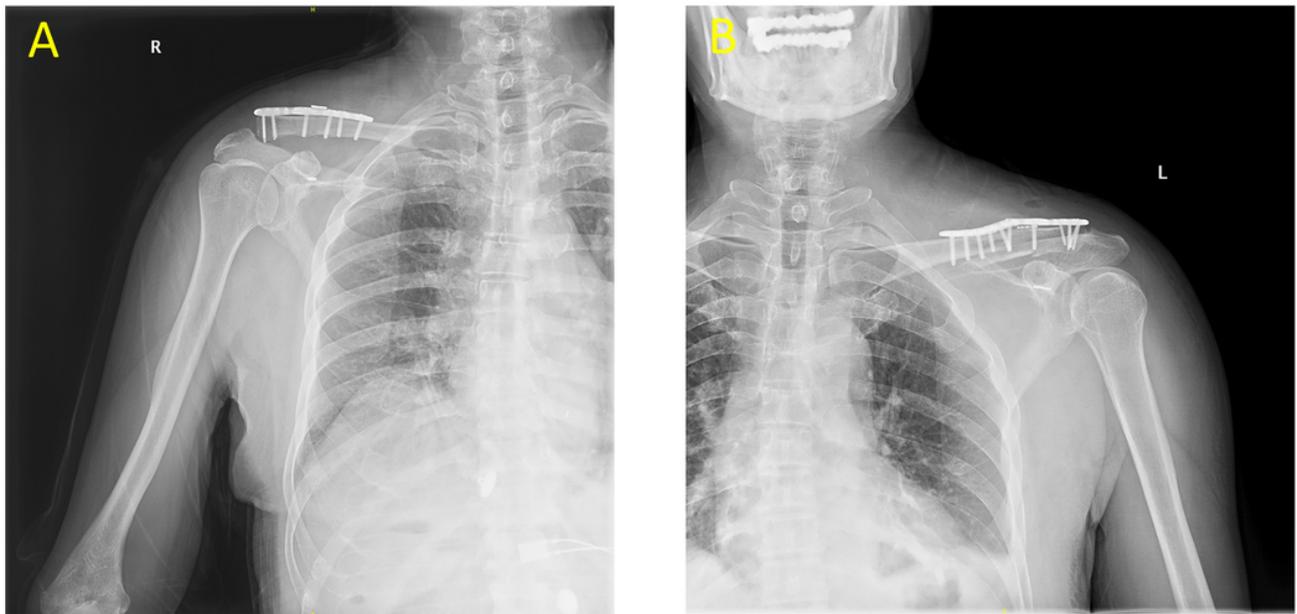
Illustration of the surgical technique using a miniature locking plate with a single button. (A) An 8-cm curved incision was made at the distal end of the clavicle and the rupture of CC ligament was confirmed. (B) The width of the coracoid process was displayed by clamping both sides of the coracoid process with an avascular clamp. (C) A guide pin was inserted into the center of the cross point between the coracoid process and the clavicle. (D) The drill penetrated four layers of the cortex of the clavicle and the coracoid process along the guide needle. (E) A button

was pushed through the drill holes and deployed under the inferior surface of the coracoid. (F) The button loop was tied around the miniature locking plate.



**Figure 2**

X-rays of Neer type IIb distal clavicle fracture pre- and post-operatively and photographs demonstrating range of motion. (A) Pre-operative anteroposterior shoulder x-ray. (B and C) CT scan reconstruction of the injured shoulder. (D) Post-operative anteroposterior shoulder x-ray. (E to H) Postoperative photographs obtained 12 months postoperatively demonstrating healing and return to preinjury level of function.



**Figure 3**

Postoperative X-rays demonstrating the placement of double buttons and an anatomic locking plate. The button was placed above (A) or beneath (B) the anatomic locking plate.