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CLINICAL ARTICLE

# Comparing the Efficacy of Anatomical Locked Plate Fixation with Coracoclavicular Ligament Augmentation to Hook Plate Fixation in Treating Distal Clavicle Fractures

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**Objective:** Hook plate fixation is the traditional method for treating distal clavicle fractures. However, in recent years, locked plate applications have emerged as a promising treatment method. This study aimed to compare the short- and mid-term clinical efficacy of anatomical locked plate fixation with coracoclavicular ligament augmentation using anchor nails to that of hook plate fixation in treating distal clavicle fractures.

**Methods:** This was a retrospective single-center cohort study investigating patients with distal clavicle fractures treated between January 2016 and February 2019 in Zhongnan Hospital of Wuhan University. Fifty-nine eligible patients who underwent either anatomical locked plate fixation with coracoclavicular ligament augmentation using anchor nails (LPF&CLA group; 20 patients) or clavicle hook plate fixation (CHPF group; 39 patients) were included. The visual analog scale (VAS) and Constant–Murley shoulder scores were used to assess shoulder function. In addition, the coracoclavicular distance between the affected and unaffected shoulders (ΔCC distance) was measured to assess the reduction. Patients were followed up at 3 months, 6 months, and 1 year postoperatively. The comparisons between the two groups were made using Student's *t*-test, chi-square test, or Fisher's exact test, if appropriate.

**Results:** Preoperative VAS scores were similar in both groups. At 3- and 6-month follow-up, the VAS score was significantly higher in the CHPF group than in the LPF&CLA group. In contrast, the Constant–Murley shoulder score was significantly lower in the CHPF group than in the LPF&CLA group. When the hook plates were removed, there was no statistical difference in both VAS ($0.2 \pm 0.4$ in LPF&CLA group vs. $0.5 \pm 0.5$ in CHPF group, $p = 0.05$) and Constant–Murley shoulder ($96.1 \pm 3.1$ in LPF&CLA group vs. $93.8 \pm 5.2$ in CHPF group, $p = 0.08$) scores at the last follow-up. Postoperatively, the ΔCC distance was $2.37 \pm 1.93$ mm in the LPF&CLA group and $-1.56 \pm 1.34$ mm in the CHPF group. One year after surgery, ΔCC distance increased to $3.96 \pm 1.17$ mm in the LPF&CLA group and to $-0.89 \pm 1.39$ mm in the CHPF group.

**Conclusion:** For distal clavicle fractures in which the coracoclavicular ligament is disrupted, anatomical locked plate fixation with coracoclavicular ligament augmentation achieved better functional recovery and less pain than hook plate fixation at the 6-month follow-up. However, the hook plate provided better reduction throughout the follow-up period and shoulder pain could be relieved using removal surgery. Therefore, locked plates with coracoclavicular ligament augmentation favors post-surgery pain relief while harvesting similar functional outcomes to hook plate fixation

**Key words:** Anatomical Locked Plate; Coracoclavicular Ligament Augmentation; Distal Clavicle Fracture; Hook Plate

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## Introduction

Distal clavicle fractures, which account for 21%–28% of all clavicle fractures,[1] were considered by most surgeons to require surgical management.[2] According to the AO/ATO system,[3] 15.3A b or c fractures refer to extraarticular distal clavicle fractures with coracoclavicular ligament complex partial disruption or complete disruption, respectively. These fractures have a high rate of nonunion after nonoperative treatment due to the progression of dislocation induced by trapezius traction forces and the weight of the upper extremity.[4] Various surgical procedures have been developed to treat distal clavicle fractures, including K-wire fixation,[5] tension band wires,[6] screw fixation,[7] suture anchors,[8,9,10] suture tension bands,[11] double plate fixation,[12] TightRope,[13] and hook plate fixation,[14] each of which has advantages and disadvantages.

The clavicular hook plate is one of the most widely accepted surgical treatments for achieving a high healing rate and satisfactory functional recovery.[14] However, it also results in many complications, including acromial osteolysis, rotator cuff tears, rotator cuff impingement, peri-implant fracture, and serious shoulder pain. In addition, many researchers have reported a high secondary surgery rate for implant removal.[15] In the last few decades, locking plates have been advocated for managing distal clavicular fractures. The polyaxial screws of these plates can provide adequate support to stabilize small and comminuted fragments. With a low profile, these plates often do not require removal. However, locking plates do not offer vertical or horizontal stability to the coracoclavicular ligament injuries.[16] Therefore, augmentation of the coracoclavicular ligament has been recommended to improve stability. Previous studies that combined anatomical locked plate fixation with coracoclavicular ligament augmentation to treat distal clavicle fractures have yielded satisfactory clinical outcomes.[17,18] However, whether this method is superior to the hook plate in treating distal clavicle fractures warrants further research since data are still scarce.

Therefore, we conducted a retrospective study to compare the efficacy of anatomical locked plate fixation with coracoclavicular ligament augmentation using anchor nails to that of hook plate fixation in treating distal clavicle fractures, with the following specific aims: (i) highlight the necessity and details involved in coracoclavicular ligament augmentation using a suture anchor; (ii) compare postoperative pain relief between the two operative techniques; and (iii) evaluate coracoclavicular reduction by the locked plate with suture anchor augmentation.

## Materials and Methods

### *Study Population*

This retrospective cohort study was conducted in Zhongnan Hospital of Wuhan University. All distal clavicle fracture (15.3A b or c) patients who underwent either anatomical locked plate fixation (Zhengtian, Tianjin, China) combined with coracoclavicular ligament augmentation using suture anchor (Stryker, Kalamazoo, MI) (LPF&CLA group) or clavicular hook plate (Dabo, Fujian, China) fixation (CHPF group) between January 2016 and February 2019 were reviewed for eligibility. The indication for surgery was a displacement of the lateral clavicle >1 cm identified on radiography. Surgical operations were performed by two groups of experienced orthopaedists with similar professional backgrounds. Individual patients were well informed by the orthopaedists about the specific surgical procedures, risks, and benefits of the two operative techniques and ultimately chose one technique from the two and signed informed consent forms. This study was reviewed and approved by the Ethics Committee of our institution (2020050).

### *Inclusion and Exclusion Criteria*

The inclusion criteria were: (i) patients with acute distal clavicle fracture (15.3A b or c) who underwent either anatomical locked plate fixation combined with coracoclavicular ligament augmentation using suture anchor or clavicular hook plate fixation; and (ii) who had complete medical records and follow-up. The exclusion criteria were: (i) patients who had concomitant fractures or diseases around the injured shoulder; (ii) open fractures; (iii) rheumatoid arthritis; (iv) polytrauma; and (v) those with incomplete medical records. Finally, 59 patients (20 in the LPF&CLA group and 39 in the CHPF group) were eligible for this study, and they were followed-up for at least 12 months.

### *Operative Technique and Postoperative Management*

In the LPF&CLA group, surgeries were performed under general anesthesia in the supine position. The fracture fragments and coracoid process were exposed using a direct curved incision along the clavicular axis. A suture anchor was inserted at the base of the coracoid process. After reduction, a distal clavicular anatomical locked plate was applied on the superior surface of the clavicle. Furthermore, 2.7-mm multidirectional locking screws were used to fix the distal fragment. Two strands of anchor suture were pulled between the clavicle and plate, where the medial and lateral coracoclavicular ligaments were attached and tied. The displacement of the knots was limited by the plates and screws. The surgical procedure is illustrated in Figure 1. An intraoperative radiographic assessment was performed to ensure the reduction of the clavicle and fixation position (Figure 2).

In the CHPF group, surgeries were performed under general anesthesia in the supine position. An incision was made to expose the distal clavicle and acromioclavicular joint. The reduction process was previewed, and a suitable clavicular hook plate was chosen. The reduction was easily realized by placing the cortical screw through the plate. After sufficient screws were inserted, an intraoperative radiographic assessment was performed (Figure 3).

All patients were instructed to suspend the upper limb immediately after the operation for at least 1 month. The

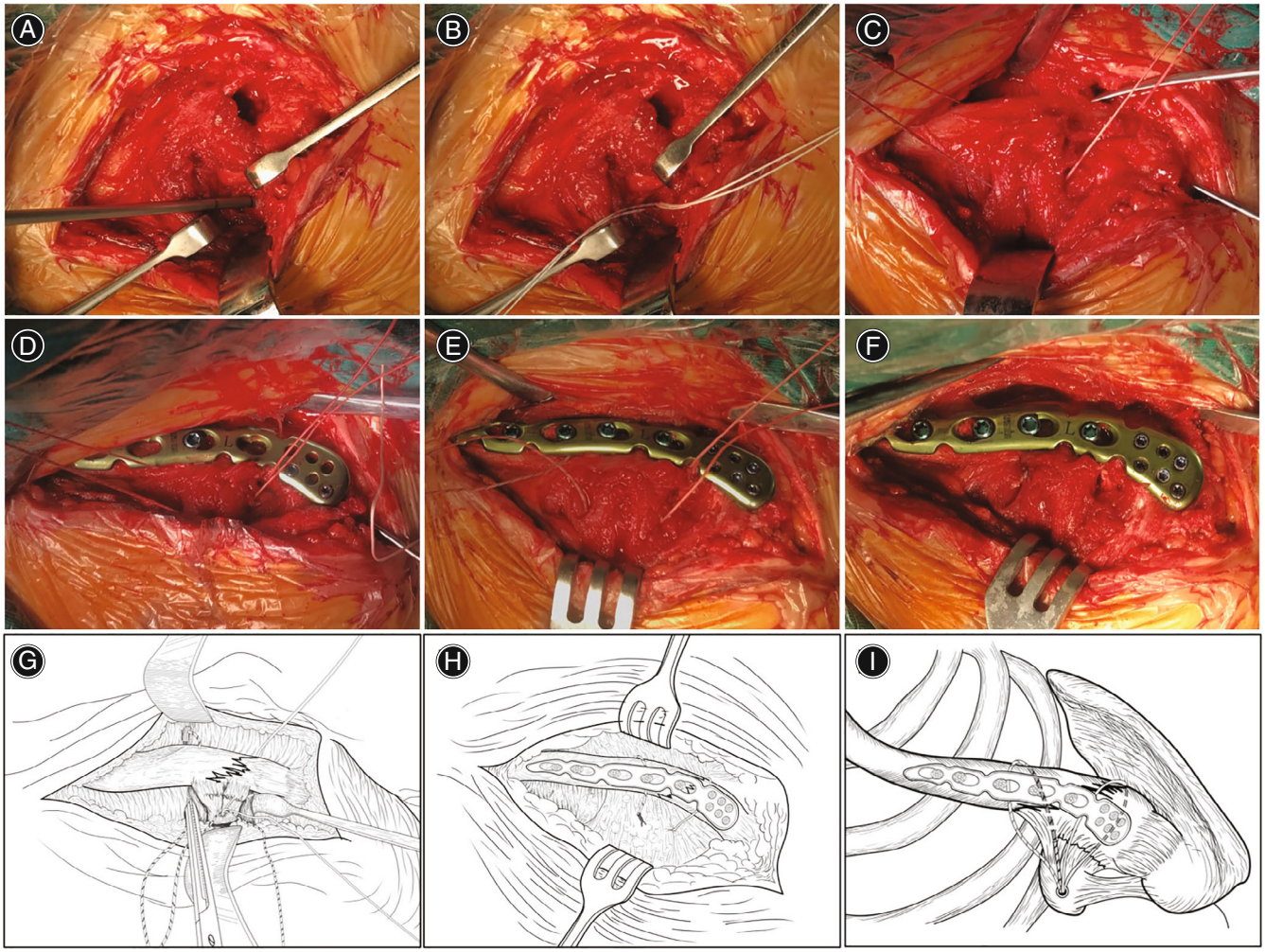


**FIGURE 1** Surgical procedures in the locked plate fixation with coracoclavicular ligament (LPF&CLA) group. (A) Expose of the base of coracoid process; (B) placement of suture anchor; (C) placement of the two stands of sutures; (D) placement of the plate; (E) placement of the nails; (F) reduction of acromioclavicular (AC) joint and tie of sutures. (G) Schematic diagram of placement suture anchor. (H) Schematic diagram of placement of locking plate. (I) Schematic diagram of the location of two suture strands

ipsilateral elbow, wrist, and hand movements were encouraged from the first day after surgery. Two weeks later, a pendulum exercise was performed. One month after surgery, the patients were guided to practice active function exercises and were gradually strengthened until their shoulder function was fully recovered. In the CHPF group, the hook plate was removed routinely 1 year after surgery.

### *Clinical Outcome Assessment*

Shoulder function was evaluated at 3 months, 6 months, and 1 year postoperatively with Constant–Murley shoulder scores[19] and visual analog scale (VAS) scores,[20] with a minimal clinically important difference of 6.3 [21] and 1.4,[22] respectively. Preoperative VAS scores were extracted from the medical documents. In addition, an anteroposterior (AP) view of the clavicle was performed preoperatively and postoperatively to identify the distal clavicle fracture or the reduction (Figure 2). The coracoclavicular (CC) distance was defined as the shortest distance between the superior cortex of the coracoid process and the clavicle's undersurface on the clavicle's AP view.[23] The fragment size was defined by the distance between the medial border of the fracture line and the distal border of the clavicle.[24]

### *Statistical Analysis*

All statistical analyses were performed using the Stata 15.0 software (StataCorp LLC, TX, USA). Quantitative data were presented as mean ± standard deviation. The Student's *t*-test was used to compare the means of continuous data between the two groups. Categorical variables were compared using the chi-square test or Fisher's exact test, if appropriate. Regression analysis was used to evaluate the correlation between the data, and the model was built

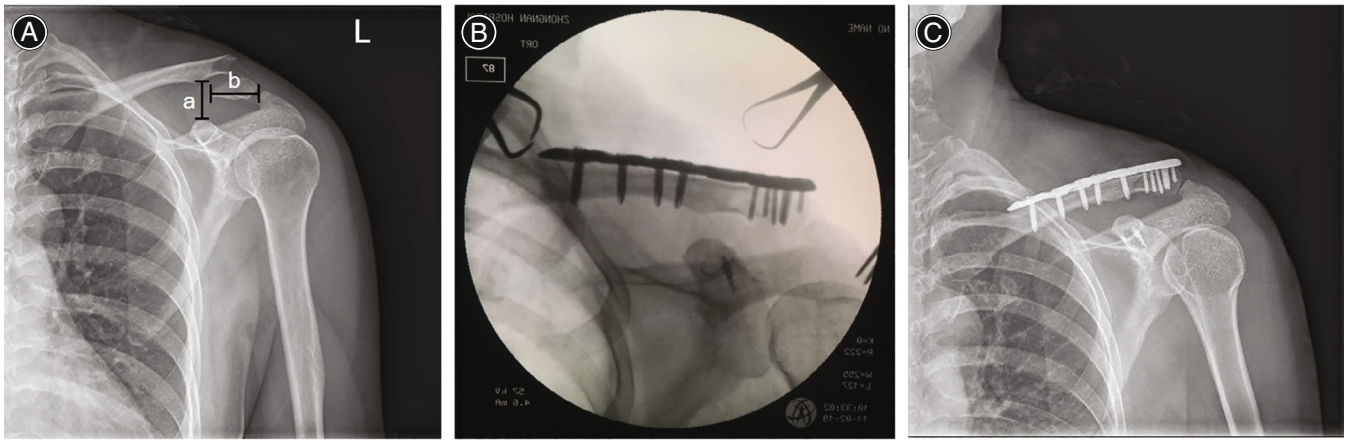


**FIGURE 2** X-ray pre- (A), intro- (B), and post-operation of the locked plate fixation with coracoclavicular ligament (LPF&CLA) group (C); (a) Coracoclavicular (CC) distance, defined as the distance between the superior cortex of the coracoid process and the undersurface of the clavicle on the AP view of the clavicle. (b) Fracture distance, defined as the distance between the medial border of the fracture line and the distal border of the clavicle

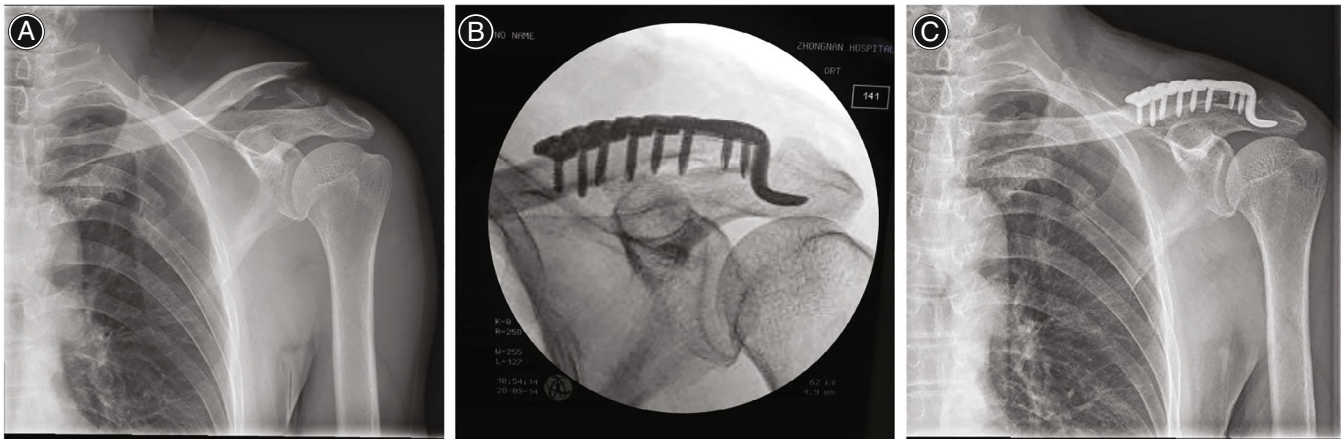


**FIGURE 3** X-ray pre- (A), intro- (B), and post-operation of the Clavicle hook plate fixation (CHPF) group (C)

using backward elimination. A two-tailed $p < 0.05$ was considered statistically significant.

## Results

### *Baseline Information and Follow-up Results*

Patient general characteristics, including age, sex, injury side, mechanism of injury, and the interval between injury and surgery, are summarized in Table 1. The two groups did not differ in sex, age, injury side, mechanism of injury, and time interval to injury; however, the LPF&CLA group showed a significantly longer surgery time. The distal fragment, which is the attachment area of the CC ligaments,[25] had a size of 17.8 ± 7.3 mm. The mean follow-up time was 13.6 ± 3.3 and 13.5 ± 1.9 months for the LPF&CLA and CHPF groups ($p = 0.84$), respectively. Based on clinical and radiographic examinations, a bony union was achieved in all patients within 3 months.

### *Clinical Improvement*

Preoperatively, there was no significant difference in the VAS overall pain score between the LPF&CLA (7.3 ± 0.7) and CHPF group (7.3 ± 0.8) groups ($p = 0.85$). However, at 3-month and 6-month follow-ups, VAS scores were significantly higher in the CHPF group (0.8 ± 0.8 in LPF&CLA group vs. 2.9 ± 1.2 in CHPF group at 3-month, $p < 0.05$; 0.1 ± 0.3 in LPF&CLA group *vs.* 1.2 ± 1.1 in CHPF group at 6-month, $p < 0.05$). Twenty-seven patients (69.2%) in the CHPF group experienced noticeable shoulder pain during rehabilitation before the removal surgery. At the last follow-

**TABLE 1 The general characteristics**

| Patient characteristics | LPF&CLA group | CHPF group | Total | *t* value | $\chi^2$ | *p* value |
|---|---|---|---|---|---|---|
| Sex (male/female) | 12/8 | 21/18 | 33/26 | - | 0.20 | 0.66 |
| Age at the time of surgery (year) | 52.5 ± 12.8 | 53.9 ± 16.1 | 53.4 ± 15.0 | 0.36 | - | 0.72 |
| Injury side (left/right) | 12/8 | 30/9 | 42/17 | - | 1.85 | 0.18 |
| Mechanism of injury (fall/accident) | 12/8 | 27/12 | 39/20 | - | 0.50 | 0.49 |
| Time interval to operation (day) | 3.2 ± 2.7 | 5.1 ± 3.8 | 4.4 ± 3.6 | 1.96 | - | 0.06 |
| Operating time (minute) | 90 ± 5.6 | 63.5 ± 5.8 | 72.5 ± 13.9 | 16.9 | - | <0.05 |
| Last follow-up (month) | 13.6 ± 3.3 | 13.5 ± 1.9 | 13.5 ± 2.5 | 0.20 | - | 0.84 |

Abbreviations: CHPF group, Clavicle hook plate fixation group; LPF&CLA group, Locked plate fixation with coracoclavicular ligament augmentation by anchor nail group.

**TABLE 2 Visual analog scale before and after surgery**

| Visual analogue scale | LPF&CLA group | CHPF group | *t* value | *p* value |
|---|---|---|---|---|
| Preoperative | 7.3 ± 0.7 | 7.3 ± 0.8 | 0.20 | 0.85 |
| Postoperative (3 months) | 0.8 ± 0.8 | 2.9 ± 1.2 | 6.66 | <0.05 |
| Postoperative (6 months) | 0.1 ± 0.3 | 1.2 ± 1.1 | 4.64 | <0.05 |
| Postoperative (last follow-up) | 0.2 ± 0.4 | 0.5 ± 0.5 | 2.00 | 0.05 |

Abbreviations: CHPF group, Clavicle hook plate fixation group; LPF&CLA group, Locked plate fixation with coracoclavicular ligament augmentation by anchor nail group.

**TABLE 3 Constant–Murley shoulder score 3 months after fixation surgery**

| Constant–Murley shoulder score | LPF&CLA group | CHPF group | *t* value | *p* value |
|---|---|---|---|---|
| Pain | 13.8 ± 3.9 | 9.5 ± 2.2 | 4.48 | <0.05 |
| Activity level | 9.0 ± 1.8 | 6.6 ± 2.3 | 4.15 | <0.05 |
| Positioning | 8.4 ± 0.8 | 6.5 ± 1.2 | 6.63 | <0.05 |
| Range of motion | 38.0 ± 1.6 | 36.3 ± 1.7 | 3.57 | <0.05 |
| Power | 19.9 ± 1.3 | 17.8 ± 2.9 | 3.09 | <0.05 |
| Total | 89.0 ± 5.1 | 76.6 ± 9.8 | 5.28 | <0.05 |

Abbreviations: CHPF group, Clavicle hook plate fixation group; LPF&CLA group, Locked plate fixation with coracoclavicular ligament augmentation by anchor nail group.

up, no significant difference was observed in the VAS scores between the two groups (Table 2). However, in the CHPF group, at the last follow-up, the patients' VAS scores were significantly improved at the last follow-up than at the 6-month follow-up.

At the 3- and 6-month follow-up, better pain relief, activities of daily living, and shoulder power were observed in the LPF&CLA group than in the CHPF group (Tables 3 and 4). At the last follow-up, there was no difference in the constant score between the two groups ($p = 0.08$) (Table 5). However, in the CHPF group, the patients' constant scores were significantly improved at the last follow-up than at the 6-month follow-up.

### *Radiographic Improvement*

As shown in Table 6, both LPF&CLA and CHPF reduced the CC distance significantly. Two days after surgery, in the LPF&CLA group, the difference in CC distance between affected and unaffected shoulders (ΔCC distance) was 2.37 ± 1.93 mm, while it was −1.56 ± 1.34 mm in the CHPF group. Regression analysis was performed to identify the factors influencing CC distance immediately after surgery. The results showed that the operative method was strongly associated with CC distance after surgery (adjusted

**TABLE 4 Constant–Murley shoulder score 6 months after fixation surgery**

| Constant–Murley shoulder score | LPF&CLA group | CHPF group | *t* value | *p* value |
|---|---|---|---|---|
| Pain | 14.5 ± 1.5 | 11.2 ± 2.9 | 4.79 | <0.05 |
| Activity level | 9.2 ± 1.6 | 6.8 ± 1.7 | 4.91 | <0.05 |
| Positioning | 8.6 ± 0.9 | 6.6 ± 0.9 | 7.70 | <0.05 |
| Range of motion | 39.4 ± 0.9 | 38.0 ± 1.6 | 3.62 | <0.05 |
| Power | 21.3 ± 1.3 | 18.7 ± 1.9 | 5.52 | <0.05 |
| Total | 93.0 ± 4.6 | 81.3 ± 6.6 | 7.10 | <0.05 |

Abbreviations: CHPF group, Clavicle hook plate fixation group; LPF&CLA group, Locked plate fixation with coracoclavicular ligament augmentation by anchor nail group.

*R*-squared = 0.48, root mean-squared error = 2.88), after adjusting for patient age, time from injury to surgery, CC distance before surgery, and fracture distance. At the 12-month follow-up, the ΔCC distance still exhibited significant improvement than the preoperative ΔCC distance in both groups ($p < 0.05$, both groups). A slight loss of reduction was observed in both groups during follow-up. While

**TABLE 5 Constant–Murley shoulder score at last follow-up**

| Constant–Murley shoulder score | LPF&CLA group | CHPF group | *t* value | *p* value |
|---|---|---|---|---|
| Pain | 14.5 ± 1.5 | 13.8 ± 2.1 | 1.22 | 0.23 |
| Activity level | 9.2 ± 1.6 | 8.5 ± 2.0 | 1.44 | 0.16 |
| Positioning | 9.2 ± 1.0 | 9.1 ± 1.0 | 0.44 | 0.66 |
| Range of motion | 39.4 ± 0.9 | 38.8 ± 1.3 | 1.87 | 0.05 |
| Power | 23.8 ± 1.3 | 23.7 ± 1.3 | 0.28 | 0.78 |
| Total | 96.1 ± 3.1 | 93.8 ± 5.2 | 1.78 | 0.08 |

Abbreviations: CHPF group, Clavicle hook plate fixation group; LPF&CLA group, Locked plate fixation with coracoclavicular ligament augmentation by anchor nail group.

**TABLE 6 Coracoclavicular distance pre- and post-fixation surgery**

| ΔCC distance (mm) | LPF&CLA group | CHPF group | *t* value | *p* value |
|---|---|---|---|---|
| Preoperative | 10.3 ± 3.90 | 7.65 ± 5.38 | 1.96 | 0.06 |
| Postoperative (2 days) | 2.37 ± 1.93 | -1.56 ± 1.34 | 9.15 | <0.05 |
| Postoperative (3 months) | 3.11 ± 1.26 | −1.20 ± 1.38 | 11.69 | <0.05 |
| Postoperative (6 months) | 3.40 ± 1.33 | −1.01 ± 1.33 | 12.39 | <0.05 |
| Postoperative (12 months) | 3.96 ± 1.17 | −0.80 ± 1.39 | 13.19 | <0.05 |
| Post-removal | - | −0.62 ± 1.25 | - | - |

Abbreviations: ΔCC distance, the coracoclavicular distance difference between affected and unaffected shoulder; CHPF group, Clavicle hook plate fixation group; LPF&CLA group, Locked plate fixation with coracoclavicular ligament augmentation by anchor nail group.

no statistical significance was found at 2 days after surgery, ΔCC distance increased to 3.40 ± 1.33 in the LPF&CLA group ($p = 0.05$) and −1.01 ± 1.33 in the CHPF group ($p = 0.08$) 6 months after surgery, respectively. Twelve months after surgery, ΔCC distance significantly augmented in both groups comparing 2 days after surgery ($p < 0.05$, both groups). In the CHPF group, the ΔCC distance was similar before and after removal surgery ($p = 0.38$, $t = 0.79$). No correlation was found between ΔCC distance and the Constant score.

### *Complications*

No deep infections, neurovascular injury, peri-implant fracture, implant malposition or failure, or other severe complications were observed. One case of CC interspace ossification without any symptoms was observed in each group. Patients in the CHPF group had the plate removed at 11.7 ± 2.1 months. Persistent postoperative pain was observed in three patients in the CHPF group. Conservative treatment could not relieve the pain, so their implants were removed approximately 6 months after surgery. All patients in the CHPF group experienced pain relief after hook plate removal. In the LPF&CLA group, three patients requested plate removal for cosmetic reasons.

## Discussion

This study compared the clinical outcomes between anatomical locked plate fixation with coracoclavicular ligament augmentation and hook plate fixation for distal clavicle fractures. Both fixation methods yielded satisfactory outcomes. However, the hook plate fixation required less operation time, whereas locked plate fixation induced less shoulder pain during rehabilitation. Desirable shoulder function was obtained in both groups, as indicated by the Constant scores. A slightly better function was observed in the LPF&CLA group 6 months after surgery than the CHPF group. The coracoclavicular distance significantly decreased after surgery using both methods; however, it seemed better in the hook plate group. No intraoperative complications were observed in this study.

### *Analysis of Hook Plates in Treating Distal Clavicle Fractures*

For distal clavicle fracture (15.3A b or c), traditional plate fixation cannot achieve sufficient purchase using small lateral fragments. Therefore, hook plates have been designed and widely used to treat displaced distal clavicle fractures.[26] A high healing rate and satisfactory functional recovery can be achieved using hook plate fixation. However, the hook plate can also result in many complications, such as acromial osteolysis or erosion, peri-prosthetic fracture, shoulder stiffness, and subacromial impingement.[15,27] In the latest systematic analysis, acromial osteolysis or erosion and peri-prosthetic fracture were considered to be the most common complications.[15] Shoulder pain, the most reported complaint after hook plate fixation, could be caused by almost all the complications of hook plate fixation. Furthermore, most patients could not obtain pain relief after intra-articular steroid injection.[28] In our study, the hook plate was routinely removed 12 months after surgery; however, three patients in the CHPF group had severely aggravated night-time or resting shoulder pain accompanied by stiffness; therefore, their plates were removed early. While a high incidence of acromial osteolysis or erosion has been observed in many studies,[28–30] whether it causes shoulder pain remains unclear. In our study, various degrees of acromial erosion were observed in all patients in the CHPF group; however, it seems to be correlated to the slight loss of reduction instead of shoulder pain. Therefore, we categorized it as a sequela and not a complication.

### *Necessity of CC Ligament Augmentation in Treating Distal Clavicle Fractures*

Locked plates have been applied to distal clavicle fractures since the 2000s, Kalamaras and Yu reported a technique

using T-shaped locked distal radius plates for distal clavicle fractures, which helped their patients regain good shoulder function.[31] Herrman et al. also treated Neer type II clavicle fractures using locked T plates with CC ligament augmentation using a suture anchor.[32] All seven cases in their study regained normal CC distance and excellent clavicular stability. Since then, the benefits of using additional CC ligament augmentation compared with locked plate fixation alone have been controversial. Despite biochemical research demonstrating that CC ligament augmentation provided more stability to Neer type IIB clavicle fractures fixed with a locked plate when loaded to failure,[33] a series of studies reported satisfactory results using locked plates alone on unstable distal clavicle fractures.[34–36] They considered that in most cases the trapezoid ligament was only partially ruptured, and multidirectional locking screws rigidly fixed the small distal fragment, offering sufficient stability. Furthermore, CC augmentation increased the surgery time, and the risk of knot-induced irritation, peri-anchor osteolysis, coracoid fracture, brachial plexus injury, and CC interspace ossification. Comparative studies evaluated outcomes after treatment of distal clavicle fractures using locked plate fixation with and without CC ligament augmentation. They found that both methods achieved satisfactory bone union rate and excellent shoulder function.[37–39] However, while there were no significant differences, LPF&CLA group had a lower complication rate, shorter union time, and better function at the early stage in all these studies. Wu et al. advised additional CC ligament augmentation for hook plate fixation and found that suture anchors could improve patient functional outcomes.[40] Except for the former reasons, we chose the additional CC ligament augmentation in our study to prevent the effect of potential CC ligament impairment when exposing the fracture during surgery and to help patients return to work early. In our LPF&CLA group, only CC interspace ossifications (which also exist in hook plate fixation) were observed, and no serious complications were caused by the anchor suture.

### *CC Distance Analysis*

The coracoclavicular ligament, including the lateral coracoclavicular ligaments (LCCLs; conoid and trapezoid) and medial coracoclavicular ligament (MCCL), provides vertical stability to the acromioclavicular joint.[41] Augmentation of the coracoclavicular ligament could further increase stiffness and maximum resistance to compression, and decrease displacement when locked plate fixation is performed for distal clavicle fractures.[33] Furthermore, several methods, such as screws, tapes, sutures, buttons, or anchors, have been introduced to augment the coracoclavicular ligament through the base of the coracoid process and the clavicular fragments.[42] However, little attention has been paid to the MCCL, which acts as the last container of the coracoclavicular space in both the cephalad and posterior directions, preventing additional displacement in the absence of LCCLs.[43] In our LPF&CLA group, two stands of sutures were tied where the MCCL and LCCLs were attached to disperse stress on the clavicle. Moreover, sutures were performed between the clavicle and plate to minimize tissue irritation. In our LPF&CLA group, no knot irritation, coracoid fracture, or peri-anchor osteolysis were observed. However, the LPF&CLA group seemed to have a higher CC distance after surgery, even after adjusting for age, fracture distance, and CC distance preoperatively. This showed that the hook plate provided better reduction using its leverage. The suture anchor could not maintain a constant CC distance during the follow-up period. Loss of reduction was observed in both the LPF&CLA and CHPF groups and was more obvious in the former. No peri-anchor osteolysis or anchor pull-out was observed in our study, and the loss of reduction may be due to the loss of knot or length of suture. While no correlation between CC distance and shoulder function was found in our study, other studies have shown that CC distance might be associated with coracoclavicular bursal changes.[44] In addition, CC distance change may influence appearance-bothered individuals, and have unpredictable long-term effects. Therefore, a more reliable method for CC ligament augmentation, such as titanium cable or TightRope, could be chosen to achieve better reduction.[13,45]

### *Strengths and Limitations*

In this study, we highlighted the details and key steps involved in the CC ligament augmentation with suture anchor providing a practical reference for orthopaedic surgeons. We also compared the Constant scores, VAS scores, and CC distance at different time points in the two surgical technique groups and demonstrated the dynamical rehabilitation of the patients. Our study had several limitations. First, this was a retrospective study with inherent limitations. A randomized controlled trial is required to address this issue. Second, the sample size of enrolled patients was small. However, the power analysis showed that our sample size was sufficient to ensure adequate power to detect statistical significance between functional outcomes of the shoulder. Third, while functional scores did not differ significantly between groups, we cannot exclude the possibility that these findings may result from type II errors. Thus, these limitations should be considered when interpreting our findings.

### *Conclusion*

For distal clavicle fractures in which the coracoclavicular ligament is disrupted (15.3A b or c), anatomical locked plate fixation with coracoclavicular ligament augmentation resulted in faster functional recovery and less pain than hook plate fixation during a short follow-up without requiring second surgery to remove the implant. However, the hook plate could offer better reduction, and the symptoms caused by the hook plate significantly improved after the plate was removed.

## Author Contributions

Xin Wang and Zhenyu Pan contributed to the conception of the study; Zhe Xie performed the data analysis

and wrote the manuscript; Weidong Xiao and Baiwen Qi helped perform the data analysis; Xue Fang performed the retrospective study and data collection. All authors discussed the results and contributed to the final manuscript.

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## Conflicts of Interest

The authors have no conflicts of interest to declare.

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